E-ISSN : 2987 - 2685
page 159 - 166

Rooftop Solar Power Plant Design on Campus Cafe

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ABSTRACT

The Indonesian government has also signed the Paris Agreement to the United Nations Framework Convention on Climate Change on April 22, 2016. With the government's participation in the Agreement, the government has committed to developing new and renewable energy. Muhammadiyah University of Semarang is located in an area with abundant solar energy potential, but has not yet utilized this potential. This paper studies the design a potential plan for a solar power plant on one of the roofs of a building at the University of Muhammadiyah Semarang using computational simulations. Simulation using HelioScope software for design slope position of solar cell. The results show that the optimized slope position of solar cell can effectively improve electrical energy generated.

Keywords: Renewable Energy, Solar Energy, HelioScope, Slope Position of Solar Cell.

1. INTRODUCTION

The growth of electricity demand is projected to increase from time to time. The largest share of electricity demand is in the household sector, then industry, followed by commercial, transportation, and other sectors. Indonesia's new renewable energy potential is still quite large. With the average radiation level/day in Indonesia reaching 4.8 kWp/m2/day [1][2].

Sunlight is one of the renewable energy sources that is increasingly being used today. Sunlight into electrical energy by using solar panels as a means of conversion. A solar module consists of many solar cells connected in series and parallel with certain current and voltage characteristics. In addition to solar modules known as solar panels. Solar panels are used to represent a collection of several solar modules in a particular installation. Generally, the solar panel configuration consists of several solar modules with the same current and voltage characteristics. The output power generated by the solar panel system is influenced by several environmental factors such as the intensity of solar radiation, ambient temperature, the spectrum of sunlight, the angle of incidence of light, and others [3].

Energy sources from the sun are one of the alternative options because they are quite abundant and have a lower level of pollution than power plants sourced from fossil energy. This makes solar power generation one of the most desirable technologies in the world. Based on the technology used, solar power plants are divided into two systems, namely off-grid and on-grid [2][4].

E-ISSN : 2987 - 2685
page 159 - 166

The solar power plant that is being promoted by the government is a rooftop solar power plant. This system is one solution for the use of renewable energy in industrial, residential and office areas which are considered to have limited land [5]. The Indonesian government has also signed the Paris Agreement to the United Nations Framework Convention on Climate Change on April 22, 2016[1][6]. With the government's participation in the Agreement, the government has committed to developing new and renewable energy. Muhammadiyah University of Semarang is located in an area with abundant solar energy potential, but has not yet utilized this potential. This study aims to design a potential plan for a solar power plant on one of the roofs of a building at the University of Muhammadiyah Semarang using computational simulations.

2. LITERATURE REVIEW

2.1. Solar Cell

The solar cell is component that can convert sunlight energy into electrical energy. This convertion using the principle of the photovoltaic effect. The photovoltaic effect is a phenomenon where an electric voltage arises due to the connection or contact of two electrodes connected to a solid or liquid system when receiving light energy. Solar cells are often referred to as Photovoltaic (PV) cells. The electric current arises because the photon energy of sunlight it receives manages to free the electrons in the N-type and P-type semiconductor junctions to flow. A solar cell is a photodiode that has a very large surface. The large surface area of the solar cell makes this solar cell device more sensitive to incoming light and produces a voltage and current that is stronger than a photodiode in general. For example, a solar cell made of silicon semiconductor material is capable of producing a voltage as high as 0.5 V and a current as high as 0.1 A when exposed to sunlight [7].

This semiconductor region with free electrons is negative and acts as an electron donor, this semiconductor region is called an N-type semiconductor. The semiconductor region with positive holes that acts as an electron acceptor is called a P-type semiconductor. At the junction of the positive and negative regions, energy will cause the electrons and holes to move in opposite directions. Electrons will move away from the negative region while the holes will move away from the positive region when given a load in the form of a lamp or other electrical device at this positive and negative junction. This condision will generate an electric current [7].

2.2. Solar Cell Development

The development of solar cells is increasingly using various semiconductor materials and silicon which is individually widely used, including:

a. Mono-crystalline, made from single-crystal silicon obtained from silicon smelting in an oblong shape. Now, mono-crystalline can be made as thick as 200 microns, with an efficiency value of about 24%.
b. Polycrystalline/Multi-crystalline, made from melting silicon in a ceramic furnace, then cooling slowly to get a silicon mixture that will arise on top of the silicon layer. These cells are less effective than mono-crystalline cells (18% effectiveness) but cost less.

2.3. Solar Charge Controller

The solar charge controller regulates overcharging because the battery is full and overvoltage from the solar panel. Overvoltage and charging will reduce battery life. The solar charge controller applies Pulse width Modulation (PWM) technology to regulate the battery charging function and current release from the battery to the load. 12-volt solar panels generally have an output voltage of 16-21 volts. Without a solar charge controller, the battery will be damaged by over-charging and voltage instability. Batteries are generally charged at 14-14.7 volts. Some of the functions of the solar charge controller are regulating the current for charging to the battery, regulating the current to be released from the battery so that the battery is not overloaded, and monitoring battery temperature. When the battery is fully charged, the charging current from the solar panel automatically stops. The solar charge controller will charge the battery to a certain voltage level, then if the voltage level drops, the battery will be charged again [7].

2.4. Battery

Batteries for solar cells have an important purpose in solar cell systems. First, it provides electrical power to the system when power is not provided by the array of solar panels. Second, save the excess power generated by the panels whenever the power exceeds the load [8].

3. METHODS

All the stages in conducting this research can be seen in the flow chart in Figure 3.1. The stages of the research carried out are as follows:

a. Literature study to study solar power plant design planning. The study was conducted to find references that can assist in the implementation of research. Such as research journals that use solar power plants.
b. Create a design in advanced solar design software.
c. Testing whether the design can be applied in the field.
d. Analysis of the research results that have been carried out and the conclusions obtained in the study.

E-ISSN : 2987 - 2685
page 159 - 166

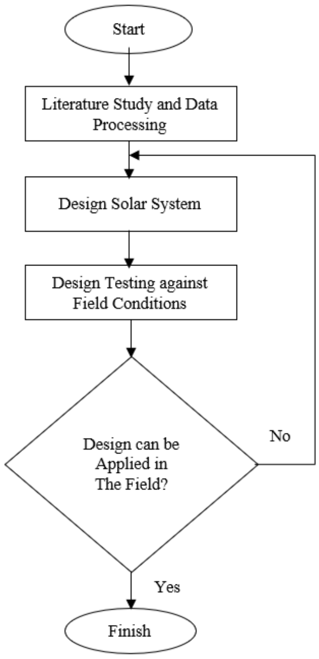

Figure 1. *The stages of the research*

Data processing and design using HelioScope software to optimize this result. The test field condition not only about electrical technique but also seen from the architectural aspect.

4. RESULTS AND DISCUSSION

The specifications of the solar cell module and the inverter used in this research can be seen in Table 1.

Table 1. Specification of Solar Power Plant Component

Component	Specification
Module	Trina Solar, TSM-PD14 320
Inverter	Sunny Tripower 24000TL-US

The difference in the slope of the solar panels results in varying energy production. The effect of the slope of the solar panel on the energy produced can be seen in the Table 2.

Table 2. Annual production with tilt variation

Tilt (°)	Annual Production (MWh)
10	28.55
20	29.75
30	32.59

The results of this research according to Table 2, it can be seen that the increase in the slope of the solar panels further increases the production of energy from solar panels. Energy production every month on a slope variation of 10o can be seen in Figure 2.

E-ISSN : 2987 - 2685
page 159 - 166

Figure 2*. Monthly production with tilt 10o*

Energy production every month on a slope variation of 20o can be seen in Figure 3.

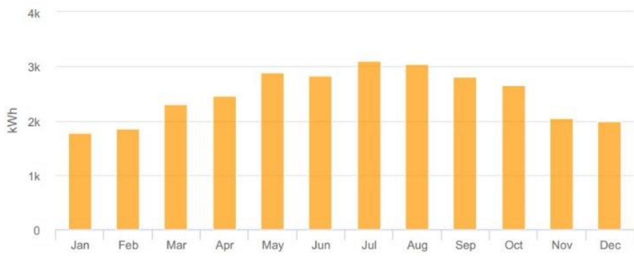

Figure 3*. Monthly production with tilt 20o*

Energy production every month on a slope variation of 30o can be seen in Figure 4.

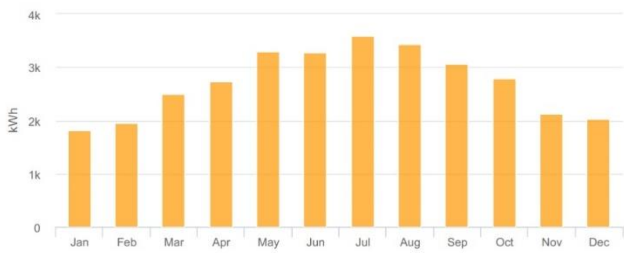

Figure 4*. Monthly production with tilt 30o*

The arrangement of the solar panels in this research when viewed from above will look like in Figure 5.

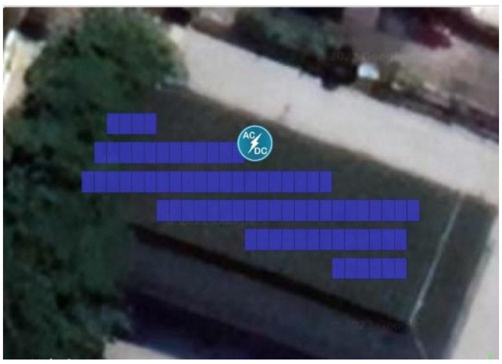

Figure 5*. The arrangement of the solar panels*

E-ISSN : 2987 - 2685
page 159 - 166

This research is limited to a slope of 30o because the slope of 30o is the most widely used as a roof slope. The solar panels in this research apply a flush mount method where the position of the solar panels sticks to the slope of the roof. This result is a solar panel design from an electrical engineering perspective.

If the results of this research are viewed from the architectural point of view, of the various targets that must be achieved in architectural works, two of them, the first is that architectural works must be able to meet the needs of comfort, the second is aesthetic value [9].

In fulfilling the need for comfort, including several aspects of comfort, namely spatial, visual, audial, and thermal. From several aspects of comfort in architecture, the discussion needed on solar panels is thermal comfort related to human needs for the thermal environment (a combination of humidity, radiation, temperature, and airflow) so that human work can run optimally [9].

In his research, he stated whether the function of solar panels can be maximized if the slope is 30° according to the slope of the roof in general, and then states that it is important to determine the orientation position of the solar panels according to the slope of the roof so that the placement and design on the building cover can be harmonious and in accordance with architectural rules, and still effectively generate electrical energy. At a 30° solar-cell slope, which corresponds to a typical roof slope, the solar cell effectively generates current for a north-facing orientation, then the next sequence is a west-facing orientation [10].

According to the angle of inclination of the solar panels to receive the highest solar radiation, they tend to be the same, which is between the angles of 0° to 20°, which has a different value is the average solar radiation received by the solar panels. The solar panel installation angle that affects the solar radiation that the panel can receive is the slope angle and the azimuth angle of the photovoltaic module (solar cell). An example is the most appropriate azimuth angle for the installation of one type of fixed array panel in the city of Semarang is 180° where the panel is faced to the north [11].

It can be concluded that the ideal solar panel slope is recommended according to the roof slope in general, which is 30°, but the reception of solar radiation occurs at an angle of 0° to 20°. In this case, the ideal conditions for the solar panels also look at the surrounding conditions such as the presence of trees and other buildings that can cast shadows near the buildings that are installed with solar panels. The combination of thermal comfort on one of the targets of architectural work such as humidity, radiation, temperature and air flow also affects the ideal work of solar panels, in this case the ideal orientation for maximum thermal conditions is facing north.

5. CONCLUSION

This paper studies the optimal slope design of photovoltaic in rooftop. The slope of the solar panel affects the electrical energy produced. At 10°, 20°, and 30° slope variations, the energy produced is the most optimal at 30 slopes. The Total energy that can produce at 30° slopes is 32.59 MWh with the most energy is produced in July. Important to determine the position of the orientation of the solar panels according to the slope of the

E-ISSN : 2987 - 2685
page 159 - 166

roof so that the placement and design on the building cover can be harmonious and in accordance with architectural rules, and remain effective in generating electrical energy.

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