The Effect of Inclination Angle of The Solar Panel on The Resulting Output Voltage

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Abstract. Renewable energy is alternative energy for the future. One renewable energy that is easy to develop is solar power generation. In this study, we will discuss the effect of the tilt angle on the solar panel and the value of the intensity of sunlight on the resulting output voltage. The data collection process was carried out at the Mechanical and Electrical Power System Laboratory, Faculty of Engineering, Universitas Negeri Yogyakarta. The data collection stage was carried out at an angle of 0°, 30°, and 60°. The results showed that the smaller the value of the intensity of sunlight, the smaller the output voltage produced. The tilt angle of the solar panel at 30° has a maximum output voltage more significant than the angle of 60° and 0°.

1. Introduction

Most of the global energy comes from fossil fuels, of which these sources are finite and will run out in 50 to 75 years, as most studies show [1]. Renewable energy is alternative energy for the future [2]. The shift towards new and renewable, and environmentally friendly energy is an important issue today. The high dependence on fossil fuels converted into electrical energy or others causes environmental damage and human health [3]. New and renewable energy (EBT) has enormous potential to be applied in Indonesia in the next few years. Examples of renewable energy used in Indonesia are biomass energy, water energy, geothermal energy, wind energy, solar energy and biofuel energy. The energy produced from fossils cannot last long, and the world will run out of fossil energy reserves shortly. So there is a need for renewable energy whose availability is guaranteed for a long time [4]. One example of energy that is easily converted into electrical energy is solar energy.

The sun is a source of free and inexhaustible energy for planet Earth. Solar power plants are renewable energy-based plants that can contribute the second-largest power after wind power plants [5]. Earth receives energy released by the sun about 1366 kW/day. This is a source of energy that will never run out. The benefit of solar energy compared to other energies is that sunlight can be directly converted into electrical energy using photovoltaic (PV) technology. Solar energy also has another advantage, namely affordable installation costs compared to other power plants.

Based on the application and configuration, solar power plants are classified into three, namely systems where solar power plants are not connected to the network (off-grid solar power plants), solar power generation systems that are connected to the network (on-grid solar power plants), and Hybrid solar power
generation system is a solar power system which in its installation is combined with other types of power plants to supply consumer loads. Based on data from [7] [8], it is explained that the PLTS system, when viewed from the capacity of the electrical energy produced, is classified into 3, namely Small Scale 10 kW, Medium Scale 10–500 kW and Large Scale 500 kW.

As a tropical country, Indonesia should be able to optimize solar power plants as an alternative to power generation. Based on this background, it will be investigated about the effect of the tilt angle of the solar panel and the value of the intensity of sunlight on the resulting output voltage.

2. Method

Research on the effect of the inclination angle of the solar cell on the output voltage was carried out at the Mechanical and Electrical Power System Laboratory, Faculty of Engineering, Universitas Negeri Yogyakarta. The tools and components used include solar cell panels, battery control regulator (BCR), inverters, connecting cables, batteries and lux meters. Figure 1 shows the frame design of the solar cell unit. For any location on Earth, the PV cell has an angle of incidence that depends on the incidence of optical solar radiation [1]. This angle can be measured theoretically and experimentally and used to improve the array result. The angle of incidence of the sun varies according to time and season [9]. Experiments on the effect of the slope angle on the PV output voltage were carried out quickly to avoid the effect of time variations.

The solar panels used in this study were three solar panels with a power of 50 watts each. The maximum power produced by a series of solar cells in this study is 150 watts. The characteristic parameters of solar PV are shown in Table 1.

![Solar cell circuit design](image)

Table 1. Characteristics of Solar PV

| Product Name                  | Voltage Level         | Rated Current         |
|-------------------------------|-----------------------|-----------------------|
| Silicon Solar PV Module 50W   | Rated = 12 volt       | I max power = 2.78 A  |
|                               | V max power = 18 volt | I short circuit = 3 A  |
|                               | V open circuit = 22.19 volt |                 |
The solar cell used has a voltage rating of 12 V with a maximum power voltage of 18 V and current maximum power of 2.78 A. In this study, the solar cell module was connected in series to determine the maximum voltage that could be generated.

The inclination angle of the solar panels starts from the range of 0°, 30° and 60°. The data collection time for each slope angle is 45 minutes with a data collection interval of 5 minutes. The data generated from this research is the output voltage and the intensity of sunlight.

3. Results and Discussion
The data collection process can be seen in Figure 2. The measuring instrument used is an arc to adjust the slope angle, a voltmeter to measure voltage, and a lux meter to measure the amount of light intensity. The data collection process was carried out starting at 09.00 West Indonesian Time.

From the results of data retrieval, the size of the resulting voltage depends on the intensity of sunlight; if the lux is high, then the voltage is high and vice versa. In Figure 3, it can be seen that every time there is a decrease in light intensity, there will be a decrease in voltage at the 25th minute.
Figure 3. The results of data collection at an inclination angle of $0^\circ$

The same thing also happened when the data was taken at an angle of $30^\circ$ (Figure 4), where there was a decrease in the voltage from the previous 60 V to 54 V at 20 minutes. The decrease influenced the decrease in voltage in the value of the intensity of sunlight. At an angle of $30^\circ$ the maximum voltage that can be obtained is 60 V.

Figure 4. Results of data collection at an inclination angle of $30^\circ$
Furthermore, in the experiment, the angle of inclination is 60° (Figure 5). When there is a decrease in the intensity of sunlight, it is always offset by a decrease in the output voltage. There was a decrease in voltage from the previous 56 V to 48 V at 25 minutes. The decrease influenced the decrease in voltage in the intensity of sunlight.

Based on data collection, it can be seen that the intensity of sunlight will affect the magnitude of the output voltage. The higher the light intensity, the greater the voltage generated by the solar power plant. At 09:00 WIB, a slope angle of 30° can produce a higher maximum output voltage when compared to an angle of 0° or 60°. This is in line with [10], which explains that the higher the light intensity, the greater the output voltage produced by PLTS. The most appropriate angle setting for the solar panel module is facing the sun.

4. Conclusion

The results of this study indicate that the smaller the value of the intensity of sunlight, the smaller the output voltage produced. Changing the tilt angle of the PV panels is better than fixing the cells at a specified angle, and the slope of the cells has to be changed over time. One of the factors that decrease the value of the intensity of sunlight is influenced by the blocking of sunlight by clouds or due to the presence of dust. In this study, the more dominant influence is due to the influence of clouds. From this study, it can also be seen that the voltage drop due to a decrease in the value of light intensity is in the range of 2-6 V. At an angle of 30° it can produce the highest maximum voltage when compared to an angle of 0° and 60°.

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