Comparative study of electrical energy conversion on monocrystalline and polycrystalline solar panel types in fixed position with various weather conditions in mountain area

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Abstract. A solar panel is one alternative energy solution that is widely used today. Solar panels consist of two main types, namely polycrystalline and monocrystalline. The two solar panels have physical differences and the ability to produce electrical energy. Therefore, we compare two solar panels in order to conclude which type of solar panel is the most effective in producing electrical energy. The area used is plateau areas with a mountainous contour and has low humidity and temperature. Data is collected for three days. The solar panels used have a capacity of 200 Wp each. As a data logger, Arduino and several supporting components are used. Polycrystalline solar panels produce a greater voltage than monocrystalline types from the first day to the third day. However, the current produced by the two solar panels tends to be the same. The average total energy produced by polycrystalline solar panels is 665.46 watts and monocrystalline solar panels is 500.62 watts. It can be concluded that in mountainous areas it is more efficient to use a polycrystalline type of solar panels.

1. Introduction
Alternative energy becomes an answer to the limited energy produced by fossil materials. Various ways have been done by humans in developing and finding alternative energy that is environmentally friendly and available. The alternative energy is used as a producer of electrical energy to reduce the fossil energy that is not environmentally friendly [1].

The Solar panel is a very good breakthrough in producing environmentally friendly electrical energy. The Solar panel works only by utilizing solar energy as a source and then transforming it into electrical energy[2]. The Solar energy that is freely available in nature allows solar panels as alternative electrical energy generators to be widely used in the future. The ability of solar cells to generate electrical energy does not depend on the silicon field area and constantly generate energy about ± 600mV at 2A, with the power of solar radiation is 1000 W/m² and produce an electric current (I) of about 30mA/ cm² per solar cell[3].

There are two types of solar panels that are widely used namely polycrystalline and monocrystalline. The difference between these two solar panels can be seen in the shape of the cell arrangement. However, the functions of these two panels are same. The market price of monocrystalline solar panels is more expensive than polycrystalline types. It is caused by the manufacturing process of the two different solar panels. The Polycrystalline solar panel has a random arrangement of panels and is fabricated by a casting process. Meanwhile, the monocrystalline solar panels are done manually [4].
Both types of solar panels are often used in various areas. However, it has a different level of efficiency in a particular area. “We tested the two solar panels in mountainous areas to conclude the solar panel type with the more excellent electrical energy conversion. The sampling of the mountainous area is due to lower temperature and humidity conditions than low-lying areas. The area for sampling location was Bukittinggi. Bukittinggi City has a height of about 780 – 950 m above sea level [5]. Each solar panel in this study has a capacity of 200Wp. With this comparative study, it is expected that the use of the solar panel in mountainous areas can be selected best type of the two existing types.

2. Methods

Generally, the contours of the Bukittinggi have the same temperature of around 16.1°C - 24.9°C and the humidity ranges from 82.0% - 90.8% [6]. The solar panels used in this study had a capacity of 200Wp each [7]. The equipment used in taking the research results was Arduino Uno R3, current sensor, temperature sensor, voltage sensor, USB port shield, computer, connecting cable and other auxiliary equipment [8]. Data collection was carried out for 3 consecutive days with different weather. In this case the temperature used as a comparison guide was the temperature of the panel surface and not the ambient air temperature [9]. Diagram block of data retrieval can be seen as seen on Figure 1 below:

![Diagram of data retrieval of electrical energy conversion of polycrystalline and monocrystalline solar panel](image)

Figure 1. Block diagram of data retrieval of electrical energy conversion of polycrystalline and monocrystalline solar panel

The data was collected in the form of voltage, current, and temperature on both solar panels [10]. The limitations of equipment in recapitulating the total energy obtained from solar panels provide an alternative to manual energy calculations based on units of time. In order to be more accurate, the total energy data obtained by each solar panel, the data collection time was carried out every 15 minutes as formulated in the following equation:

\[ P = V \cdot I \] (1)

\[ W = V \cdot I \cdot t \] (2)

2.1. Hardware design

The kind setting of this electrical loads in order to obtain current, power and energy from two solar panels [11,12]. The loads used a resistive load. The total loads used can be seen based on the following calculations:

\[ P = V \cdot I \] (3)

\[ P = I^2 \cdot R \] (4)

\[ R = \frac{P}{I^2}, R = \frac{200}{6.33^2} = \frac{200}{40.2609} = 2.88 \Omega \] (5)

The amount of resistance used was adjusted to the resistive load and installed on both solar panels.
The design of electrical loads of the two solar panels can be seen from the Figure 2 (a) below, and the voltage sensor module was installed in parallel to the solar panel load[13] in Figure 2 (b):

![Figure 2](image)

Measurement of the energy conversion by the two solar panels using two tools, namely a voltage sensor and a current sensor. The voltage sensor used was a module that uses the principle of a voltage divider. This module can reduce the input voltage up to five times of the original voltage[12]. The maximum analog input voltage of the Arduino microcontroller was 5 volts, so that the input voltage module cannot exceed 5 x 5 volts or 25 volts. The voltage sensor module was installed in parallel to the solar panel load [13].

Basically the sensor reading was only changed in the form of numbers from 0 to 1023. Because the Arduino chip had 10 AD, the resolution of the solar module voltage reading is:

\[ V = \frac{0.00489 \times 5}{1023} \]  

(6)

The input voltage of this module must be more than:

\[ 0.00489V \times 5 = 0.02445\text{Volt} \]  

(7)

For other solar panel output voltage, it can be formulated as follows:

\[ V = [(V_{out} \times 0.00489) \times 5] \]  

(8)

To read the current, the ACS 712 module is used to detect the amount of current flowing through the terminal block. This sensor can measure positive and negative current in the range of -5A to 5A. This sensor requires a power supply of 5 Volts [14]. To read the median value (zero Ampere) the sensor voltage is set at 2.5 Volts, it is half of the VCC = 5V power source voltage. on negative polarity the current reading of -5A occurs at a voltage of 0.5V. the level of change in voltage is linearly correlated with the current magnitude of 400 mV/Ampere. Vout is a reading on the Arduino analog read. This voltage module is arranged in parallel with the load as shown in the following Figure 3:

![Figure 3](image)

The readings from the current sensor module need to be readjusted with the actual current value readings generated by the solar panel. The ACS712 module had a voltage sensitivity of 66-185 mV/A[15,16]. similar to the voltage sensor, the current sensor has a reading range from zero (at 0V
input) to 1023 (at 5V input) with a resolution of 0.0049V. current sensor readings, I on analog read is formulated as follows:

\[ I = \frac{0.0049 \times V_{out} - 2.5}{0.185} \]  

(9)

This sensor module is arranged in series with the load as shown in the following Figure 4 (a). Voltage sensors and current sensors were combined with Arduino and other components to make measurement results accurate[16]. Overall data can be seen in the following Figure 4 (b):

![Figure 4](image-url)

**Figure 4.** (a) Current censor circuit (b). Wiring diagram of the whole equipment planning

2.2. Software design

The PLX – DAQ program is used to display data from Arduino to Microsoft Excel directly. PLX – DAQ can display graphs, read measurements of three sensors at the same time and display measurement times from sensors. The following is the interface of the PLX – DAQ software in Figure 5.

![Figure 5](image-url)

**Figure 5.** User interface of PLX – DAQ Software

3. Results and Discussion

Data collection was carried out from 16-18 February 2019 with different weather conditions. There were three data obtained, namely voltage, current and power data.

![Voltage/Stream Polycrystalline](image-url)

![Voltage/Stream Monocrystalline](image-url)

![Temperature (°C)](image-url)

**Figure 6.** Curve Indicator
The data from the first day can been seen in the Figure 7 below:

**Figure 7.** (a). Comparison between voltage and temperature by time (day 1) (b) Comparison between current and temperature by time (day 1)

Figures 7 is the results of data collection on the first day where the voltage was obtained polycrystalline solar panels were higher than monocrystalline solar panels. However, the current obtained tends to be the same and stable. The total energy obtained by the polycrystalline type solar panels was 718.0 watts and the monocrystalline type was 443.9 watts. The second day Data collection can be seen from the Figures 8 below:

**Figure 8.** (a) Comparison between voltage and temperature by time (day 2), (b) Comparison between current and temperature by time (day 2)

The weather conditions on the second day (Figure 8) is often changed and sometimes the sunlight was covered by clouds so that the resulting voltage data is unstable. However, the voltage curve for polycrystalline solar panels was still higher than monocrystalline solar panel. Meanwhile, the current generated tends to be stable and almost the same between the two solar panel. The temperature on the curve tends to be unstable and the highest temperature was around 14.01 WIB. The total energy obtained by the polycrystalline type solar panels was 651.5 watts and the monocrystalline type was 505.8 watts. The third day data can been seen in Figure 9.

Similar to the weather on the second day, on the third day (figure 9) the weather data collection also changed frequently so that the voltage obtained was unstable. It can be seen in Figure 13. However, the voltage generated by polycrystalline solar panel was still higher than monocrystalline solar panels. The excess voltage obtained by polycrystalline solar panels only occurred between 13.00 - 15.00 WIB. The current generated on the third day of data collection showed the same thing as the data on the previous days that tend to be the same between polycrystalline and monocrystalline solar panels. The total energy
obtained by the polycrystalline type solar panel was 626.7 watts and the monocrystalline type was 552.0 watts.

Data collection for three days between polycrystalline and monocrystalline solar panels shows that polycrystalline solar panels are more suitable for use in mountainous areas than monocrystalline solar panels.

4. Conclusions
Data collection was carried from 16-18 February 2019 with changing weather conditions. The data collected for 12 hours/day starting from 06.00 - 18.00. The first day the electrical energy generated by the polycrystalline solar panel was 718.0 watts and the monocrystalline type was 443.9 watts. On the second day, the polycrystalline solar panel was 651.6 watts and the monocrystalline type was 505.8 watts. On the third day, the polycrystalline solar panel was 626.7 watts and the monocrystalline type was 552.0 watts.

The conclusion of this study is polycrystalline solar panel is better used in mountainous areas than monocrystalline solar panels In addition to the total energy data, it can be seen that the voltage data generated from the first day to the third day is dominated by polycrystalline solar panels. While the current data generated by the two solar panels from the first day to the third day tends to have the same value.

References
[1] Yandi 2020 J. Ecotipe (Electronic, Control. Telecommun. Information, Power Eng 755–60, 2020, doi: 10.33019/ecotipe.v7i1.1486.
[2] Syafii and Nazir Int. J. Power Electron. Drive Syst. 7 1348–1354, 2016 doi: 10.11591/ijpeds.v7i4.pp1348-1354.
[3] Puriza M Y, Arkan F, Yandi W, Tiandho Y and Siregar E M 2020 Forecasting electricity consumers and consumption in 2019–2050 to prevent electricity waste and reduce use of fossil fuels IOP Conf. Ser.: Earth Environ. 599 012015.
[4] Omar M A and Mahmoud M M 2018 Renew. Sustain. Energy Rev 82 2490–2497
[5] Angenendt, Zurmühlen, Axelsen and Sauer 2018 Appl. Energy 229 884–899 doi: 10.1016/j.apenergy.2018.08.058.
[6] Amatraj and Michael 2019 Results Phys. 15 102797 doi: 10.1016/j.rinp.2019.102797.
[7] Yandi, Syafii and Pulungan 2017 J. Nas. Tek. Elektro 6 159 doi: 10.25077/jnte.v6n3.468.2017.
[8] Yandi, Puriza, Jumnahdi and Kurniawan IOP Conf. Ser.: Earth Environ. 599 012037.
[9] Syafii, Rusydi, Son and Zikri 2020 TEM J. 9 37–41, 2020, doi: 10.18421/TEM91-06.
[10] Bingham, Agelin-Chaab and Rosen 2019 Renew. Energy 132 1088–1103 doi: 10.1016/j.renene.2018.08.034.
[11] Li, Horan, Luther and. Ahmed 2019 Energy Build. 198 491–502 doi: 10.1016/j.enbuild.2019.06.036.
[12] Zander 2020 Energy Policy 142 111508 doi: 10.1016/j.enpol.2020.111508.
[13] Qiu, Kahn and Xing 2019 J. Environ. Econ. Manage. 96 310–341 doi: 10.1016/j.jeem.2019.06.003.
[14] Schuster 2020 Renew. Energy 152 1186–1191 doi: 10.1016/j.renene.2020.01.076.
[15] Chowdhury et al., 2020 Energy Strateg. Rev., 27 doi: 10.1016/j.esr.2019.100431.
[16] Irwansyah, Yandi, Sunanda and Puriza 2020 Konversi Energi Listrik Pada Pembangkit Listrik Tenaga Surya dan Pembangkit Listrik Tenaga BayuSebagai Perencanaan Pembangkit Hybrid pp. 113–127

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