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Study on the Effect of Solar Radiation Changes on Solar Panels Using Matlab/Simulink

Ahmad Dani, Dino Erivianto
[12] *Electrical Engineering, Sekolah Tinggi Teknologi Sinar Husni, Deli Serdang, Indonesia*
Corresponding Author:Ahmad Dani

Abstract:
Solar cells are a technology that can convert solar energy into electrical energy. The power output of a solar panel is proportional to the amount of solar radiation it receives. The purpose of this research is to investigate the changes in the power output of a solar panel with varying levels of solar radiation and temperature. The research method involves using Matlab/Simulink simulation software with a solar panel capacity of 220 Wp. Solar radiation data was obtained from power.larc.nasa.gov with the location of the solar radiation point being the Sekolah Tinggi Teknologi Sinar Husni College. The results show that the highest power output from the solar panel was 200.6 W with a radiation value of 925.05 W/m^2 at 12:00 pm, while the lowest power output was 39.9 W with a radiation value of 381.8 W/m^2 at 4:00 pm. The highest voltage and current were generated at 12:00 pm, with values of 34.40 V and 5.83 A, respectively. The lowest voltage and current were generated at 4:00 pm, with values of 15.34 V and 2.6 A, respectively.

Keywords:*Solar cells, Power output, Solar radiation, Temperature.*

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I. INTRODUCTION

The use of solar energy as an alternative energy source has witnessed significant progress in recent decades. Solar panels, consisting of photovoltaic cells, allow for the direct conversion of sunlight into electrical energy. However, the performance of solar panels can be influenced by various factors, such as temperature, humidity, and particularly the received solar radiation.(Al-Ezzi & Ansari, 2022). Solar radiation serves as the primary energy source for solar panels. However, solar radiation is not consistently available and is affected by factors such as weather, seasons, and time. Fluctuations in solar radiation can significantly impact the efficiency and power output of solar panels. Therefore, to optimize the use of solar energy, it is crucial to understand the effects of changes in solar radiation on solar panels.(Al-Sheikh, 2022; Buni, M. J., Al-Walie, A. A., & Al-Asadi, 2018)

In this study, Simulink software, a powerful and flexible simulation environment, is utilized to model solar panels and observe their response to changes in solar radiation. Simulink enables the construction of realistic models and the incorporation of various environmental factors to generate accurate simulations.(Guo et al., 2017; Islam et al., 2013). There are numerous factors that affect panel efficiency, including tilt angle(Ramli, M. A., Bouchekara, H. R., Shahriar, M. S., Milyani, A. H., & Rawa, 2021), shading, dust, solar radiation level, temperature(Karafil et al., 2016), and cable losses. Among these factors, solar radiation level and temperature play a more prominent role. (Shrestha, A. K., Thapa, A., & Gautam, 2019)

The solar radiation level that reaches a PV panel varies depending on its location and the time of day. Therefore, the solar radiation level directly impacts the panel's power output.(Al-Sheikh, 2022; Guo et al., 2017; Karafil et al., 2016). Consequently, a decrease in solar radiation levels results in a reduction in panel power. On the other hand, there is an inverse correlation between temperature and panel power. In other words, as the environmental temperature increases, the panel's power output decreases. Matlab and Simulink can simulate the effects on PV panel power by utilizing catalog data from PV panels as well as temperature and solar radiation information.(Al-Sheikh, 2022; Karafil et al., 2016)

The main objective of this research is to identify how changes in solar radiation affect the efficiency and power output of solar panels. The findings from this research can provide valuable insights for designing and optimizing more reliable and effective solar panel systems in response to inevitable fluctuations in solar radiation. Additionally, this research can establish a basis for developing adaptive power management strategies for solar panels to optimize the utilization of solar energy.

Several relevant journal references have been conducted in this context. For instance, Modelling of Photovoltaic Module Using Matlab Simulink (Zainal et al., 2016), The method is used to determine the characteristics of PV module in various conditions especially in different level of irradiations and temperature.

By having different values of irradiations and temperature, the results showed the output power, voltage and current of PV module can be determined. This proposed model helps in better understanding of PV module characteristics in various environment conditions.

Another study byZakri, Rosma, and Simanullang(Zakri, A. A., Rosma, I. H., & Simanullang, 2018) also employed MATLAB and Simulink to model and simulate solar panel systems. They analyzed the effect solar radiation to the photovoltaic module with different slope angles. It is not only the slope angle of module analysed in this article but also the weather condition such as: sunny or cloudy conditions. The results showed that the above conditions affected the voltage generated by solar photovoltaic system.

This study will build upon this previous work by investigating the influence of changes in solar radiation on the performance of solar panels using Simulink. This research will further develop a model that considers the physical characteristics of solar panels, such as conversion efficiency and current-voltage response. Subsequently, a series of simulations will be conducted with varying levels of solar radiation to evaluate their impact on the performance of solar panels.

The aim of this research is to gain a better understanding of how changes in solar radiation can affect the performance of solar panels. The findings from this study will be valuable in designing more efficient and reliable solar panel systems as well as developing adaptive power management strategies. Additionally, this research can contribute to the development of sustainable solar energy and reduce dependence on fossil fuel energy sources.

II. EXPERIMENTAL PROCEDURE

This research was conducted by simulating changes in solar radiation that occur every hour on a solar panel and the power output generated from the solar panel. The simulation was carried out using Matlab/Simulink, in order to determine the effect of changes in solar radiation on the power output of the solar panel. The research was conducted at Sinar Husni College of Technology from February 2023 to March 2023.
The method used in the research consisted of the following steps:

1. Literature review, which involved examining and analyzing theories that support the problem being researched. These theories can be sourced from scientific journals, previous research results, as well as books that support this research. In addition, literature review was also carried out to obtain data from previous research that could be used as a reference.
2. Data collection, which involved collecting the data needed to conduct the simulation from power.larc.nasa.gov.
3. Discussion, which involved consulting and guidance from lecturers and other parties who could assist in carrying out this research.
4. Testing data and collecting simulation results.

In this study, data was obtained from power.larc.nasa.gov. The website provides solar radiation data from various parts of the world. To obtain solar radiation data, the position of the location to be studied must be determined first. In this study, the location targeted was Sinar Husni College of Technology.The data collected were changes in solar radiation and temperature values at each hour. The values obtained at the location are displayed in the following table.

Table 1: Solar radiation and temperature value data

No.	Year	Month	Date	Time	Radiation (W/m^2)	Temp (°C)
1	2023	3	2	0	0	23,82
2	2023	3	2	1	0	23,3
3	2023	3	2	2	0	23,06
4	2023	3	2	3	0	22,93
5	2023	3	2	4	0	22,76
6	2023	3	2	5	0	22,62
7	2023	3	2	6	7,48	22,55
8	2023	3	2	7	156,38	22,81
9	2023	3	2	8	390,02	23,12
10	2023	3	2	9	607,4	23,51
11	2023	3	2	10	777,58	24,1

12	2023	3	2	11	886,98	24,64
13	2023	3	2	12	925,05	25,08
14	2023	3	2	13	888,98	25,37
15	2023	3	2	14	777,33	25,42
16	2023	3	2	15	602,6	25,27
17	2023	3	2	16	381,8	25,06
18	2023	3	2	17	149,85	24,8
19	2023	3	2	18	7,17	24,34
20	2023	3	2	19	0	24,15
21	2023	3	2	20	0	24
22	2023	3	2	21	0	23,87
23	2023	3	2	22	0	23,75
24	2023	3	2	23	0	23,69

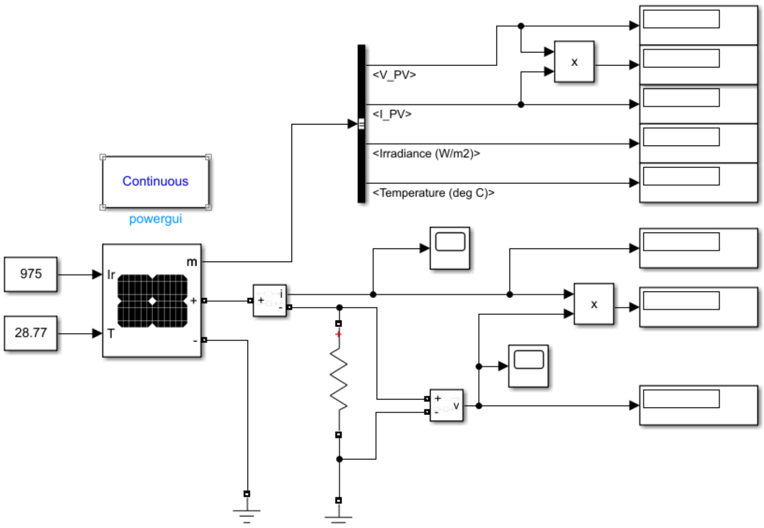

Figure 2 Simulink program to calculate solar panel output power

The simulation was performed using Simulink in Matlab. Matlab provides solar panel components for simulating. The simulation was built using components provided in the Lib. Simulink.

The simulation was conducted to measure the power output of the solar panel. This simulation does not add any additional devices or components to become a solar power generator, as shown in the following program image from Simulink.To run the simulation program, two variables are required, namely Ir and T. Ir is the input value of solar radiation and T is the input for temperature value.

III. RESULTS AND DISCUSSIONS

The testing data used are the data in Table 1, which contains solar radiation and temperature data. The testing data will be narrowed down according to the effective sunlight exposure time, which is from 9:00 a.m.to 4:00 p.m. The following is the effective sunlight exposure data.

Table 2 Effective sunlight exposure time data.

No.	Year	Month	Date	Time	Radiation (W/m^2)	Temp (ºC)
1	2023	3	2	9	607,4	23,51
2	2023	3	2	10	777,58	24,1
3	2023	3	2	11	886,98	24,64
4	2023	3	2	12	925,05	25,08
5	2023	3	2	13	888,98	25,37

6	2023	3	2	14	777,33	25,42
7	2023	3	2	15	602,6	25,27
8	2023	3	2	16	381,8	25,06

Testing was carried out using a solar panel that is widely sold on the market. The solar panel model used is a 220 Wp capacity solar panel, with the following data:

Table 3 Solar Panel Data.

OS SOLAR PANEL		
1	Model	OS-P72-220W
2	Rated Maximum Power (Pm)	220 W ±3%
3	Voltage at Pmax (Vmp)	36 V
4	Current at Pmax (Imp)	6.11 A
5	Open Circuit Voltage (Voc)	42.12 V ±3%
6	Short Circuit Current (Ioc)	7.14 A ±3%
7	Maximum System Voltage	1000 VDC
8	Maximum Series Fuse Rating	20 A
9	Operating Temperature	-40º~+85
10	Cell Technology	Poly-si
11	Dimension (mm)	1330 x 992 x 35

3.1. Radiation and temperature data testing at 9:00a.m.

From the solar radiation data received by the solar panels at 9:00a.m. of 607.4 W/m^2 and a temperature of 23.51 °C, the output power of the solar panel was 95.58 W with a large voltage of 23.75 V and a current of 4.025 A.

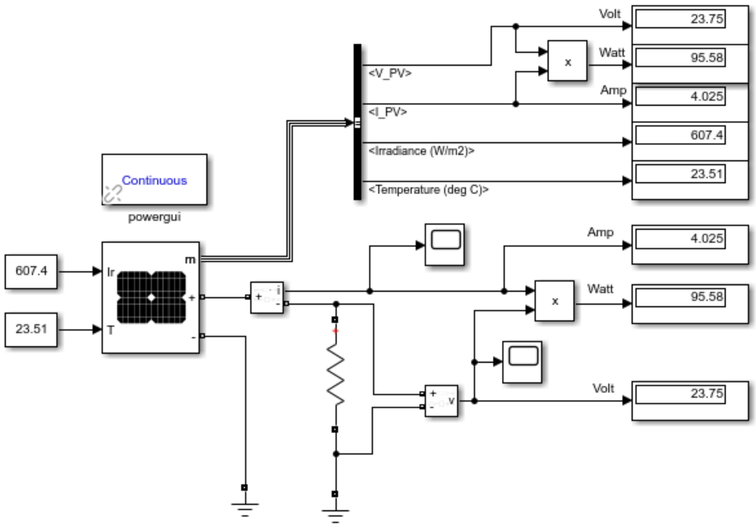

Figure 2 Measurement of the output power of the solar panel from the sun’s radius and temperature at 9:00a.m.

3.2. Radiation and temperature data testing at 12:00p.m.

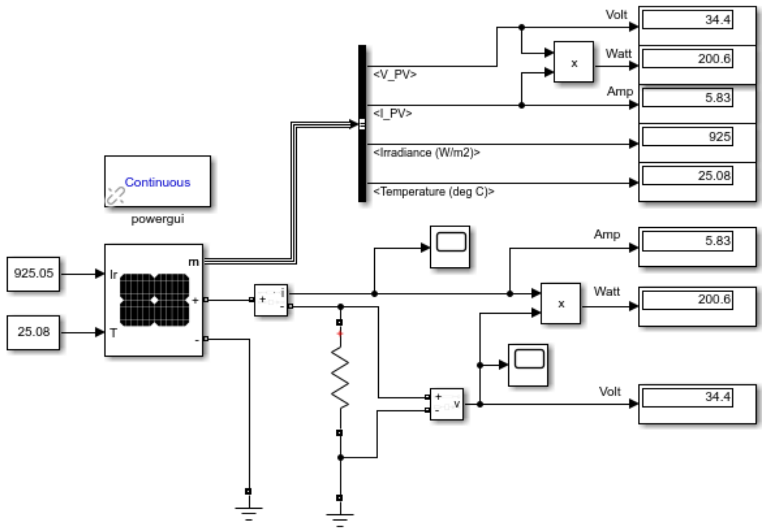

Figure 3: Measurement of the output power of the solar panel from the sun's radius and temperature at 12:00p.m.

The solar radiation data received by the solar panels at 12:00p.m. of 925.05 W/m^2 and a temperature of 25.08 °C produced an output power on the solar panel of 188.6 W with a large voltage of 34.4 V and a current of 5.83 A. As shown in Figure 3.

3.3. Radiation and temperature data testing at 4:00p.m.

From the solar radiation data received by the solar panels at 4:00 p.m. of 381.8 W/m^2 and a temperature of 25.06 °C, the output power of the solar panel was 39.9 W with a large voltage of 15.3 V and a current of 2.6 A. As shown in Figure 4.

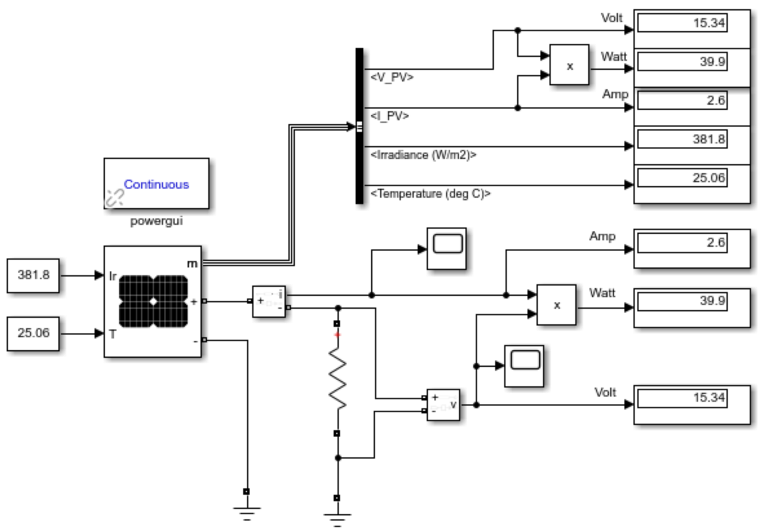

Figure 4: Measurement of the output power of the solar panel from the sun's radius and temperature at 4:00 p.m.
From the results of the measurement of the power of emission to the values of solar radiation and the temperature affecting it. Then you get the value as shown in the table below.

Table 4.3: Power output values of solar panels

No.	Time (t)	Radiasi (W/m^2)	Temp (°C)	Power (W)	Voltage (V)	Current (I)
1	09.00 a.m.	607,40	23,51	95,58	23,75	4,025
2	10.00 a.m.	777,58	24,10	150,60	29,81	5,052
3	11.00 a.m.	886,98	24,64	188,60	33,36	5,653

4	12.00 p.m.	925,05	25,08	200,60	34,40	5,830
5	01.00 p.m.	888,98	25,37	189,20	33,41	5,663
6	02.00 p.m.	777,33	25,42	150,90	29,83	5,507
7	03.00 p.m.	602,60	25,27	94,52	23,61	4,002
8	04.00 p.m.	381,80	25,06	39,90	15,34	2,600

From the table above, it can be seen how the difference in the values of sunlight radiation at each hour affects the value of the output power on the solar panel. Here is a graphical explanation of the differentiation of several variables against the value of change.

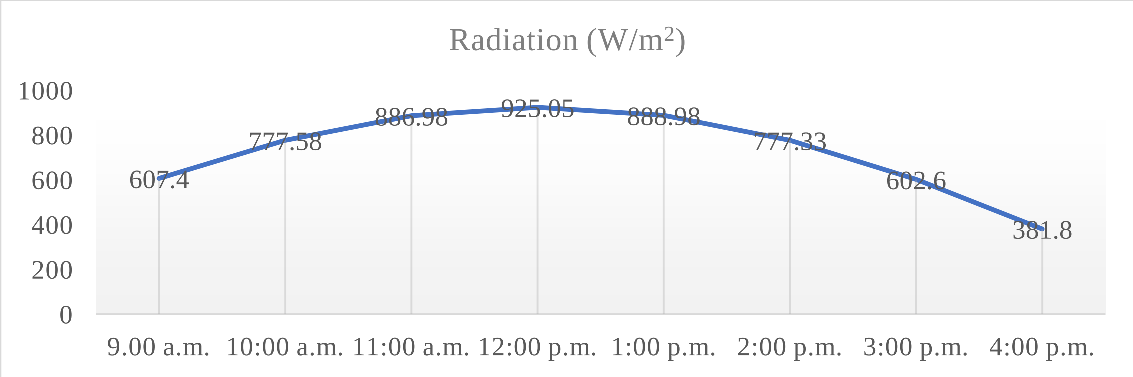

Figure 5 shows changes in the sun's radiation value every hour.

Figure 5 shows a chart of changes in the values of sunlight radiation every hour.The highest was observed at 12:00 p.m. at 925,05 W/m^2, and the lowest at 4:00 p.m. at 381,8 W/m^2

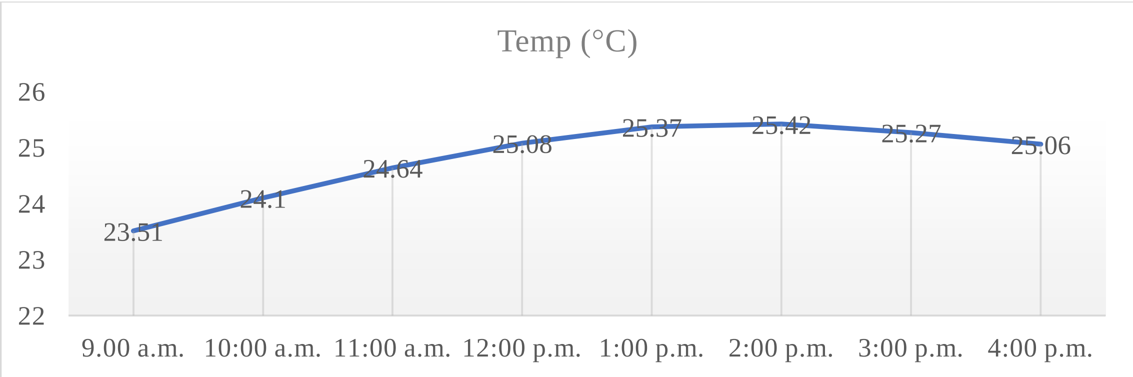

Figure 6 Changes in temperature values every hour

The changes in temperature, as shown in Figure 6, can be seen from the lowest temperature at 9:00 a.m., which was 23.51 °C, and the peak at 25.42 ˚C at 2:00 p.m. Afterward, it gradually decreased towards the evening.

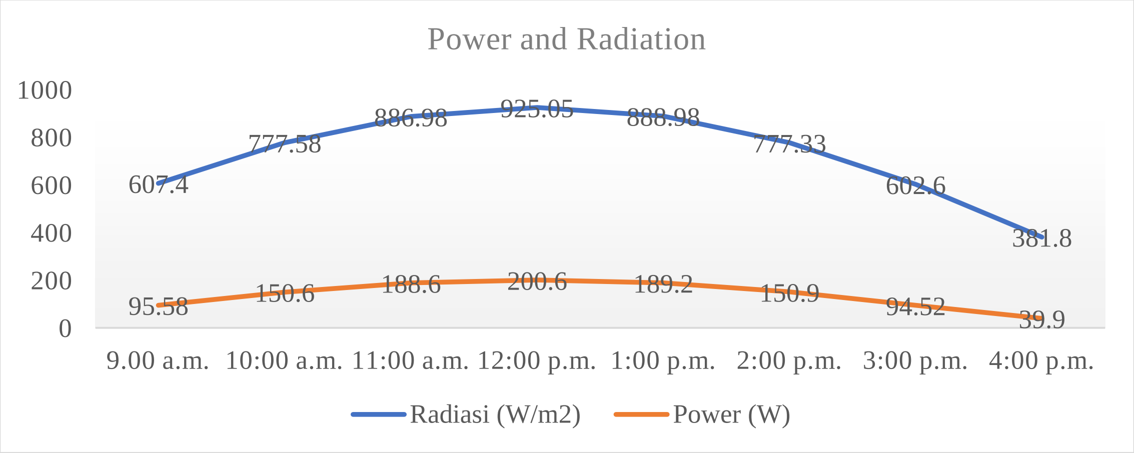

Figure 7Comparison graph of the changes in radiation values on solar panel power output

Figure 7 shows a comparison graph of the changes in radiation values on solar panel power output that occur every hour. The changing solar radiation at each hour has an impact on the power output of the solar panel. It can be seen that the highest power output from the solar panel was 200.6 W with a radiation value of 925.05 W/m^2 at 12:00 p.m., while the lowest power output was 39.9 W with a radiation value of 381.8 W/m^2 at 4:00 a.m.

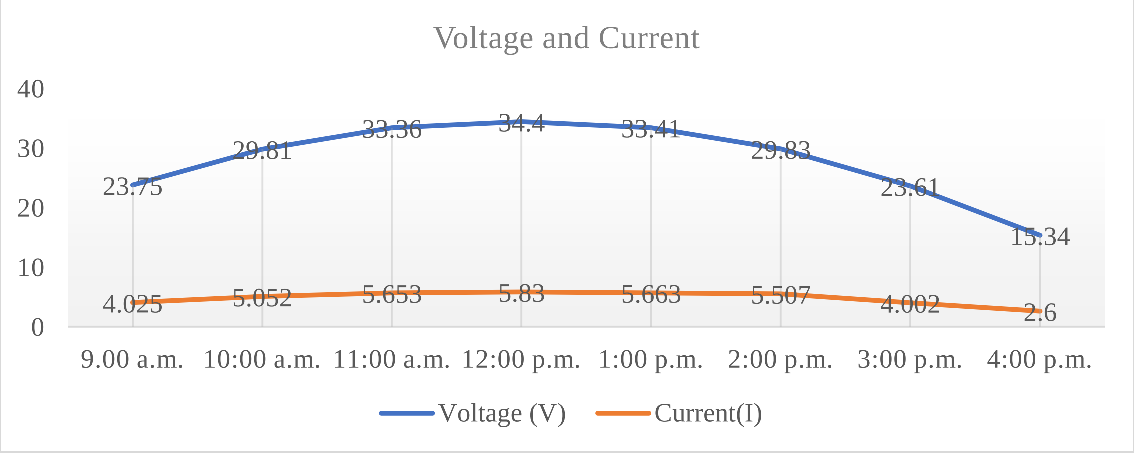

Fig. 8: The changes in current and voltage values that occur every hour

Figure 8 shows The changes in current and voltage values that occur every hour. The changes in radiation values have a proportional effect on the voltage and current values generated by the solar panel. The highest voltage and current were generated at 12:00 p.m., with values of 34.40 V and 5.83 A, respectively. The lowest voltage and current were generated at 4:00 p.m., with values of 15.34 V and 2.6 A, respectively.

IV. CONCLUSION

From the results and discussion, it can be concluded that the value of solar radiation received changes every hour, with effective sunlight shining from 9:00 a.m. to 4:00p.m. and the highest solar radiation occurringat 12:00 p.m. The changes in the solar radiation value affecting the solar panel have an impact on the power generated by the panel. The power output is proportional to the solar radiation received. The characteristics of the current and voltage of the solar panel change according to the power generated by the panel. The simulation using Matlab or Simulink can provide an approximate value for the use of solar panels as a renewable energy source.

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