Journal of Engineering Research and Education
Volume 13, 2021 [44-52]

Analysis of the Effect of Solar Temperature and Radiation on Characteristics I-V on 170 WP Photovoltaic Module Based on Matlab Simulink

Arnawan Hasibuan[1], Muhammad Daud[2], Hendra Marjuli[3], Muzamir Isa[4]

[1]Department of Electrical Engineering, Bukit Indah, Lhokseumawe, Indonesia
[1]School of Electrical System Engineering, Universiti Malaysia Perlis, Kampus Tetap Pauh Putra, Perlis, Malaysia
[2]Department of Electrical Engineering, Bukit Indah, Lhokseumawe, Indonesia
[3]Department of Electrical Engineering, Bukit Indah, Lhokseumawe, Indonesia
[4]School of Electrical System Engineering, Universiti Malaysia Perlis, Kampus Tetap Pauh Putra, Perlis, Malaysia

ABSTRACT

The need for greater energy use and the depletion of conventional fuels makes scientists start researching renewable energy that can be used as a substitute for energy in the future. One of them is through the potential generated by solar energy. Solar Power Plant (PLTS) is an alternative power plant that utilizes solar radiation to then be converted through a photovoltaic process to produce direct current electrical energy. In its utilization, when coupled with other components such as a solar charge controller, battery, and inverter, it can be converted into alternating electric current that can be used for daily needs, both on a small and large scale. In this paper, the author will discuss the current and voltage characteristics of a 170 WP photovoltaic module with variations in temperature and intensity of sunlight. This study aims to describe the characteristics of solar cells and describe the graph of current against voltage and graph of power against voltage for various temperatures and solar radiation. This research method was carried out using the Matlab-Simulink software to simulate the photovoltaic module. Based on the results and discussion, the current, voltage and power values are obtained which are then made a graph of the current and voltage relationship and a graph of the power and voltage relationship.

Keywords: Photovoltaic module, Matlab-Simulink, current, voltage and power graph

1. INTRODUCTION

Energy is a basic need for human life and is an important factor for economic growth. The need for electrical energy continues to increase in line with population growth & development, as seen from the consumption of electrical energy which increases by an average of 5.1% per year[1][2]. Energy is one of the most important needs that must be met. Energy is one of the important aspects in life which if not fulfilled will have an impact on human survival, one of which is electrical energy[3][4]. Due to the enormous need, it is not uncommon to build power plants ranging from small to large scale with fossil fuels to maintain the supply of electrical energy[5][6]. World energy needs and electricity consumption continue to increase in line with population growth and economic improvement. Global electricity consumption in 2018 increased by around 3.5% through 2017, with an average increase of 3.1% per year since

*Corresponding Author: arnawan@unimal.ac.id

2000[7][8]. Electricity consumption in Indonesia also increased by 5.1% in 2018 compared to 2017, with an average increase of 6.2% per year since 2000[9][10]. But along with technological advances and the depletion of fossil fuels, researchers began to conduct research and try to take advantage of the natural potential that is around us, one of which is solar energy[11][12]. And one alternative that can be applied is innovation regarding solar cell technology[13][14].

2. MATERIAL AND METHODS

In this study the author uses Matlab-Simulink to simulate the photovoltaic design mathematically by describing the predetermined formula. In Figure 1 the photovoltaic used is simulated on Matlab-Simulink. Then make a photovoltaic design mathematically by describing the predetermined formula.

After a road simulation, by inputting parameter data on the photovoltaic module, temperature and solar radiation obtained, it can be seen the current, voltage and power generated by the photovoltaic module.

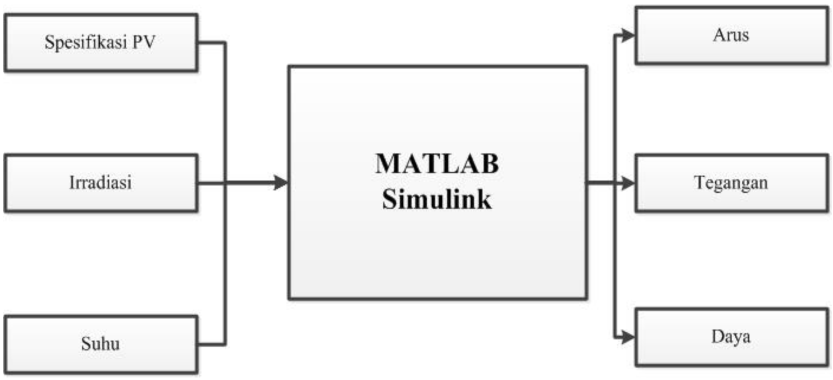

Figure 1. Research block diagram

2.1 Methodology

This research was conducted with the following steps:

1. The first step is to collect references as references and literature to determine problems and analyze the effect of temperature and solar radiation on the I-V characteristics of the 170 WP photovoltaic module based on matlab simulink.
2. The second step is to do mathematical modeling of the photovoltaic module.
3. The third step is to simulate the photovoltaic module using matlab simulink.
4. Variation of data to see changes in temperature and solar radiation to I-V (output current and voltage).
5. Make a plot to see graphic images that occur in variations in temperature and solar radiation with respect to I-V (output current and voltage).

2.2 Model and Data

In this photovoltaic modeling, all the parameters that affect the performance of photovoltaic analyzed. Photovoltaic can be modeled mathematically by looking at the general equivalent circuit shown in Figure 2.

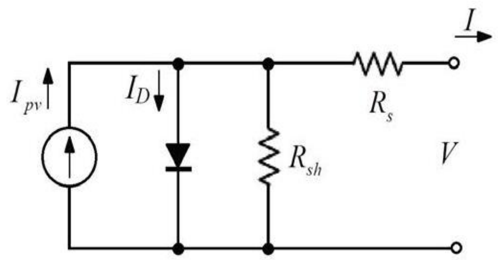

Figure 2. Equivalent circuit of photovoltaic

According to the equation, the mathematical modeling is obtained as follows[15]:

$$Ipv = Iph - ID - IRsh \text{..} (1)$$

The above equation can be explained by the following equation:

$$Ipv = Iph - ID.\left[exp\left(\frac{q.(V+I.Rs)}{n.K.Ns.T}\right) - 1\right] - Ish \text{...........................} (2)$$

With :

$$Is = Irs\,.\left(\frac{T}{Tn}\right)^{3}.\,exp\left[\frac{q.Eg0.\left(\frac{1}{Tn}-\frac{1}{T}\right)}{n.K}\right] \text{...} (3)$$

$$Irs = \frac{Isc}{e\left(\frac{q.Voc}{n.Ns.K.T}\right)-1} \text{...} (4)$$

$$Ish = \left(\frac{V+I.Rs}{Rsh}\right) \text{...} (5)$$

$$Iph = (Isc + Ki(Tk - Tref))\,\frac{G}{Gref} \text{..} (6)$$

The following photovoltaic parameters will be simulated in matlab simulink:

Table 1 Photovoltaic module parameters 170 WP

Specification	Value
Max.power (Pmax)	170 W
Max.power voltage (Vmp)	24,6 V
Max.power current (Imp)	6,93 A
Open circuit voltage (Voc)	30,5 V
Short circuit current (Isc)	7,38 A
Ns	50
Temperature	25°C
Rs	0,221 Ω
Rsh	10570 Ω
Quality faktor dioda (n)	1,3

2.3 Whole Circuit Simulation System

Here is a view of the whole circuit in matlab simulink, combining all the circuits into one subsystem. So it can be seen in Figure 3.

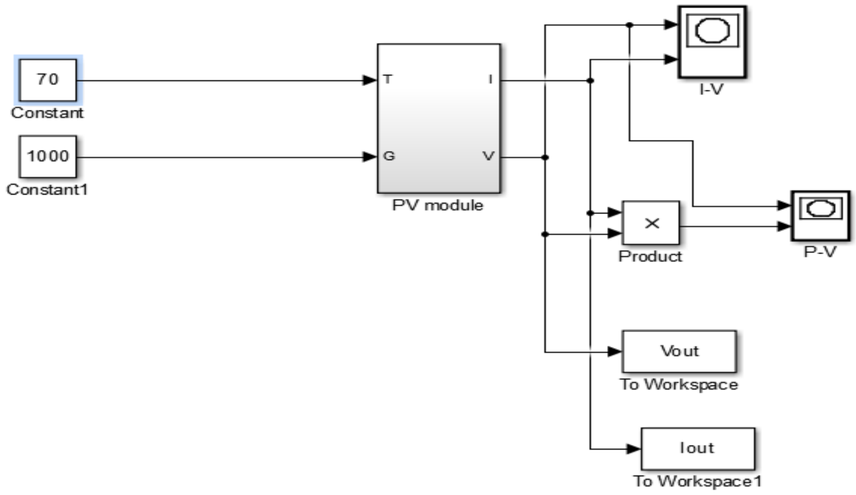

Figure 3. The overall display of the simulation circuit

3. RESULTS AND DISCUSSION

3.1 Effect of Radiation on Current and Voltage in 170 WP Photovoltaic Module.

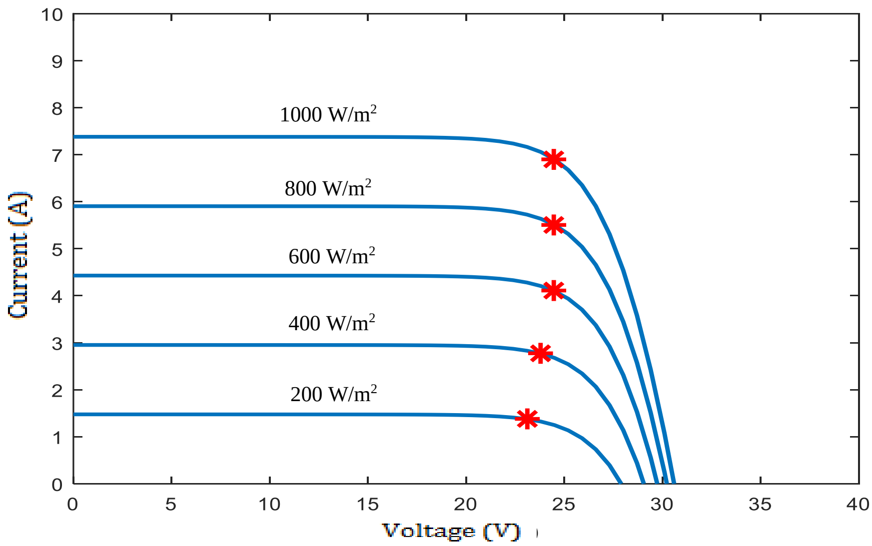

Figure 4. Graph of radiation effect on current and voltage characteristics

In Figure 4 it can be seen that when under standard test conditions (STC), namely in a state of solar radiation of 1000 W/m² and a photovoltaic module temperature of 25°C, the current and voltage generated by the photovoltaic module can be seen in table 4.1 where at the time of solar radiation that hits the solar module is 1000 W/m², the short circuit current (Isc) generated by the photovoltaic module is 7.3 A and the open circuit voltage (Voc) generated is 30.5 V. When solar radiation hits the photovoltaic module, it is 800 W/m², the short circuit current (Isc) produced by the photovoltaic module is 5.9 A and the open circuit voltage (Voc) is 30.2 V. When solar radiation hits the photovoltaic module, the current is 600 W/m². short circuit (Isc) produced by the photovoltaic module is 4.4 A and the resulting open circuit voltage (Voc) is 29.8 V. When solar radiation hits the photovoltaic module, it is 400 W/m² then the short circuit current (Isc) produced by the photovoltaic module is 2.9 A and the resulting open circuit voltage (Voc) is 29.1 V. When solar radiation hits the photovoltaic module at 200 W/m², the short circuit current (Isc) produced by the photovoltaic module is 1.4 A and the resulting open circuit voltage (Voc) is 28.2 V. The results of the effect of solar radiation on the power generated by the photovoltaic module can be seen in Figure 5 below.

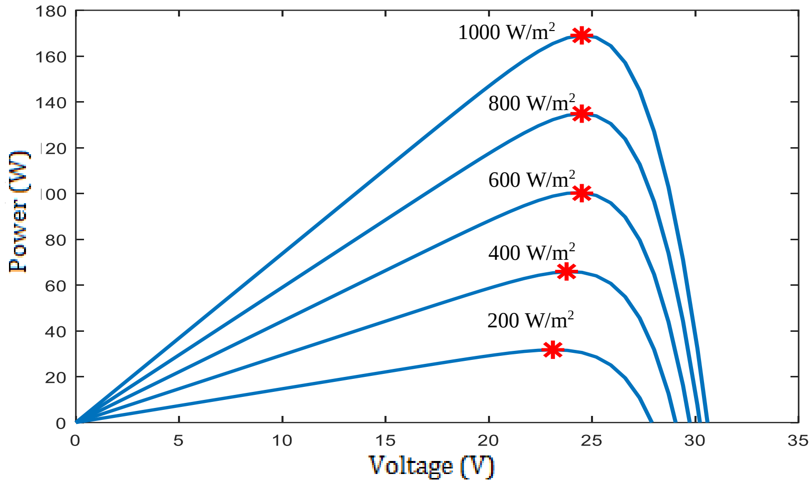

Figure 5 Graph of radiation effect on power and voltage characteristics

In Figure 5 it can be seen that when under standard test conditions (STC), namely in a state of solar radiation of 1000 W/m2 and a photovoltaic module temperature of 25°C, the results of the power and voltage generated by the photovoltaic module can be seen in table 4.1 where at the time of solar radiation which hits the solar module is 1000 W/m², the maximum power (P) generated by the photovoltaic module is 169.05 W and the open circuit voltage (Voc) generated is 30.5 V. When solar radiation hits the photovoltaic module, it is 800 W/m2, the maximum power (P) produced by the photovoltaic module is 134.86 W and the open circuit voltage (Voc) generated is 30.2 V. When solar radiation hits the photovoltaic module at 600 W/m2, the maximum power (P) the resulting photovoltaic module is 100.35 W and the resulting open circuit voltage (Voc) is 29.8 V. When solar radiation hits the photovoltaic module at 400 W/m2, the maximum power The maximum (P) generated by the photovoltaic module is 65.87 W and the resulting open circuit voltage (Voc) is 29.1 V. When the solar radiation hitting the photovoltaic module is 200 W/m2, the maximum power (P) generated by the module is photovoltaic is 31.74 W and the resulting open circuit voltage (Voc) is 28.2 V. For the results of the current, voltage and power generated by the photovoltaic module with several variations of solar radiation, it can be seen in Table 2 below.

Table 2 Effect of radiation on current, voltage and power in photovoltaic modules

Radiasi (W/m²)	I_{SC} (A)	V_{OC} (V)	I_{MPP} (A)	V_{MPP} (W)	P_{MPP} (W)
1000	7,3	30,5	6,90	24,50	169,05
800	5,9	30,2	5,50	24,50	134,86
600	4,4	29,8	4,09	24,50	100,35
400	2,9	29,1	2,76	23,80	65,87
200	1,4	28,2	1,37	23,10	31,74

Based on Table 2 above, it can be seen that for every increase in solar radiation that hits the photovoltaic module, the current generated by the photovoltaic module is greater, while for the voltage value on the photovoltaic module the increase in solar radiation does not significantly affect the voltage value generated by the photovoltaic module. When under standard test conditions (STC), when solar radiation hits the module is 1000 W/m^2, the short circuit current (Isc) generated by the module is 7.3 A and the open circuit voltage (Voc) generated by the module is 30.5 V. To achieve a maximum power of 169.05 W, the maximum current (IMPP) generated by the module is 6.90 A and the maximum voltage (VMPP) generated by the module is 24.50 V.

3.2 Effect of Temperature on Current and Voltage in 170 WP Photovoltaic Module

Based on the simulation results using Matlab-Simulink, the effect of temperature on current and voltage on the 170 wp photovoltaic module can be seen in Figure 6 below:

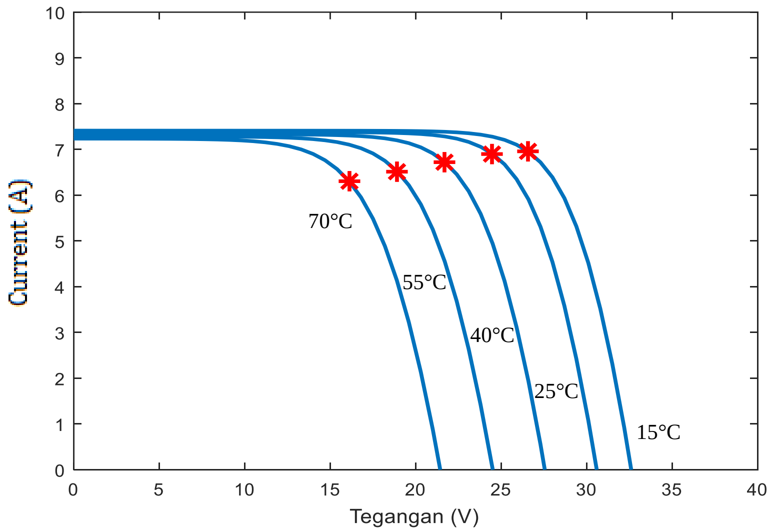

Figure 6. Graph of the effect of temperature on current and voltage characteristics

In Figure 6 it can be seen that when under standard test conditions (STC), namely in a state of solar radiation of 1000 W/m^2 and the photovoltaic module temperature of 25°C, the results of the current and voltage generated by the photovoltaic module can be seen in table 6.1 where when the temperature of the module is photovoltaic at 70°C, the short circuit current (Isc) produced by the photovoltaic module is 7.2 A and the open circuit voltage (Voc) is 21.4 V. When the temperature of the photovoltaic module is 55°C, the short circuit current is (Isc) produced by the photovoltaic module is 7.2 A and the resulting open circuit voltage (Voc) is 24.5 V. When the photovoltaic module temperature is 40°C, the short circuit current (Isc) generated by the photovoltaic module is 7,3 A and the resulting open circuit voltage (Voc) is 27.6 V. When the photovoltaic module temperature is 25°C, the short circuit current (Isc) produced by the photovoltaic module is 7.3 A and the open circuit voltage is (Voc) generated is 30.5 V. When the photovoltaic module temperature is 15°C, the short circuit current (Isc) produced by the photovoltaic module is 7.4 A and the open circuit voltage (Voc) generated is 32.6 V. The results of the effect of temperature on the power generated by the photovoltaic module can be seen in Figure 7 below.

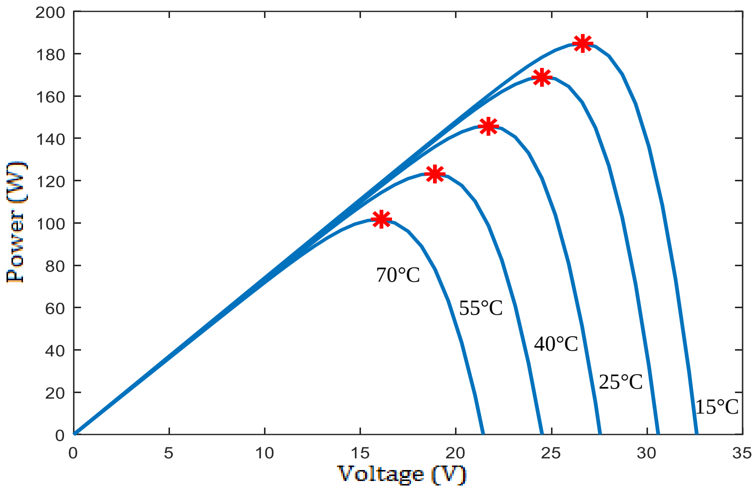

Figure 7. Graph of the effect of temperature on power and voltage characteristics

In Figure 7 it can be seen that when under standard test conditions (STC), namely in a state of solar radiation of 1000 W/m^2 and the photovoltaic module temperature of 25°C, the results of the current and voltage generated by the photovoltaic module can be seen where when the temperature of the module is photovoltaic at 70°C, the maximum power (P) produced by the photovoltaic module is 101.55 W and the open circuit voltage (Voc) is 21.4 V. When the photovoltaic module temperature is 55°C, the maximum power (P) is) produced by the photovoltaic module is 123.35 W and the resulting open circuit voltage (Voc) is 24.5 V. When the photovoltaic module temperature is 40°C, the maximum power (P) produced by the photovoltaic module is 145.91 W and The resulting open circuit voltage (Voc) is 27.6 V. When the temperature of the photovoltaic module is 25°C, the maximum power (P) produced by the photovoltaic module is 169.05 W and the open circuit voltage (Voc) produced is n is 30.5 V. When the photovoltaic module temperature is 15°C, the maximum power (P) produced by the photovoltaic module is 184.81 W and the open circuit voltage (Voc) is 32.6 V.

Table 3 Effect of temperature on current, voltage and power in photovoltaic modules.

Suhu (°C)	I_{SC} (A)	V_{OC} (V)	I_{MPP} (A)	V_{MPP} (W)	P_{MPP} (W)
15	7,4	32,6	6,94	26,60	184,81
25	7,3	30,5	6,90	24,50	169,05
40	7,3	27,6	6,72	21,70	145,91
55	7,2	24,5	6,52	18,90	123,35
70	7,2	21,4	6,30	16,10	101,55

Based on Table 3 above, it can be seen that for each photovoltaic module temperature increase, the voltage generated by the photovoltaic module is lower, while for the current value in the photovoltaic module, the photovoltaic module temperature increase does not significantly affect the current value generated by the photovoltaic module. When under standard test conditions (STC), when solar radiation hits the module is 1000 W/m^2, the short circuit current (Isc) generated by the module is 7.3 A and the open circuit voltage (Voc) generated by the module is 30, 5 V. To achieve a maximum power of 169.05 W, the maximum current (IMPP) generated by the module is 6.90 A and the maximum voltage (VMPP) generated by the module is 24.50 V.

4. CONCLUSION

From the results of the discussion of this study, some of the results of the analysis that can be concluded are as follows:

1. Solar radiation greatly affects the amount of current generated by the photovoltaic module, where the greater the radiation that hits the module, the greater the current generated.
2. The temperature of the module greatly affects the voltage generated by the photovoltaic module, the greater the temperature in the module, the smaller the voltage generated.
3. Based on the simulation results, the maximum power point to achieve maximum power on the 170 wp module is at 6.90 A (IMPP) and 24.5 V (VMPP).

REFERENCES

[1] F. S. Lukman, A. Hasibuan, A. Setiawan, dan M. Daud, "Performance Of 25 KWP Rooftop Solar PV At Misbahul Ulum Building , Lhokseumawe City," *Electr. Telecommun. Comput. Eng.*, vol. 4, hal. 81–86, 2020.

[2] L. Abubakar, "Energi Terbarukan Dalam Pembangunan Berkelanjutan," *J. Badan Pengkaj. dan Penerapan Teknol.*, vol. 8, no. 2, hal. 155–162, 2007.

[3] S. Mekhilef, R. Saidur, dan M. Kamalisarvestani, "Effect of dust, humidity and air velocity on efficiency of photovoltaic cells," *Renew. Sustain. Energy Rev.*, vol. 16, no. 5, hal. 2920–2925, 2012, doi: 10.1016/j.rser.2012.02.012.

[4] R. Ismail, E. S. Nasution, A. Hasibuan, dan W. V. Siregar, "Solar Power Generation System Design : Case Study of North Sumatra Muhammadiyah University Building," *Electr. Telecommun. Comput. Eng. Sol.*, vol. 4, hal. 191–194, 2020.

[5] N. Kannan dan D. Vakeesan, "Solar energy for future world: - A review," *Renew. Sustain. Energy Rev.*, vol. 62, no. 1, hal. 1092–1105, 2016, doi: 10.1016/j.rser.2016.05.022.

[6] T. T. Gultom, "Pemanfaatan Photovoltaic Sebagai Pembangkit Listrik Tenaga Surya," *J. Mudira Indure*, vol. 1, no. 3, hal. 33–42, 2015.

[7] H. Kristiawan, I. N. S. Kumara, dan I. A. D. Giriantari, "Potensi Pembangkit Listrik Tenaga Surya Atap Gedung Sekolah di Kota Denpasar," *J. SPEKTRUM*, vol. 6, no. 4, hal. 66–70, 2019.

[8] A. H. Andriawan dan P. Slamet, "Tegangan Keluaran Solar Cell Type Monocrystalline Sebagai Dasar Pertimbangan Pembangkit Tenaga Surya," *J. Penelit. LPPM Untag Surabaya*, vol. 2, no. 1, hal. 39–45, 2017.

[9] H. Suyono, D. O. Prabawanti, M. Shidiq, R. N. Hasanah, U. Wibawa, dan A. Hasibuan, "Forecasting of wind speed in malang city of indonesia using adaptive neuro-fuzzy inference system and autoregressive integrated moving average methods," in *Proceeding - 2nd International Conference on Technology and Policy in Electric Power and Energy, ICT-PEP 2020*, 2020, vol. 3, hal. 131–136, doi: 10.1109/ICT-PEP50916.2020.9249867.

[10] A. Rendy, *INTEGRALISTIK PERENCANAAN DESAIN KAPAL NELAYAN DAN PARIWISATA TENAGA SURYA DAN MOTOR GAS UNTUK BANYUWANGI*, 1 ed. Surabaya: Institut Teknologi Sepuluh Nopember, 2017.

[11] A. Mohammad Bagher, M. Mahmoud Abadi Vahid, dan M. Mirhabibi, "Types of Solar Cells and Application," *Am. J. Opt. Photonics*, vol. 3, no. 5, hal. 94, 2015, doi: 10.11648/j.ajop.20150305.17.

[12] S. G. Ramadhan dan C. Rangkuti, "Perencanaan Pembangkit Listrik Tenaga Surya Di Atap Gedung Harry Hartanto Universitas Trisakti S.G.," *Semin. Nas. Cendekiawan*, hal. 1–11, 2016.

[13] Z. Şen, "Solar energy in progress and future research trends," *Prog. Energy Combust. Sci.*, vol. 30, no. 4, hal. 367–416, 2004, doi: 10.1016/j.pecs.2004.02.004.

[14] P. G. V. Sampaio dan M. O. A. González, “Photovoltaic solar energy: Conceptual framework,” *Renew. Sustain. Energy Rev.*, vol. 74, no. 1, hal. 590–601, 2017, doi: 10.1016/j.rser.2017.02.081.

[15] J. Cubas, “New Method for Analytical Photovoltaic Parameter Extraction,” in *International Conference on Renewable Energy Research and Applications*, hal. 873–877.