Influence of shading to the output power of photovoltaic in Indonesia

U F Ramadhan, M E Apriansyah, G Alvianingsih and A R Utomo*
Department of Electrical Engineering, Universitas Indonesia, Depok, Indonesia

*Email: arutomo@eng.ui.ac.id

Abstract. Indonesia, being a tropical country, has a high photovoltaic (PV) energy generation potential that can help meet demand due to the impending shortage of power supplies in the coming years. The shading effect is a negative effect that causes the Photovoltaic power output to drop from its normal state. The performance of Photovoltaic Panels (PV) is a shared module surface exposed to sunlight. Shading effects usually occur from the influence of clouds, but the influence of these clouds often causes a lack of uniform illumination of sunlight received by the photovoltaic. This is also often called Partial Shaded. Partially shaded PV systems cannot operate at maximum efficiency because of shadows cast by surrounding structures, foliage and cloud cover. This is done to see the effect of partial shading pattern effect on solar cell PV. Characteristics of I-V can be influenced by pattern shading effect. The voltage and current of PV solar cells will drop from partial shading effect experiment which consists of 20%, 40%, 60%, 80% and 100% shading area.

1. Introduction
Along with the growth of existing industries throughout the world, electricity demand is getting higher. However, we cannot continue to depend on non-renewable energy which still uses fossil materials as the main ingredient for every energy conversion. Therefore, at this time various types of renewable energy have been used, for example utilizing conversion from solar energy to electricity known as photovoltaic [1,2]. The principle of photovoltaics is the principle that utilizes the display of photons from the sun that activate the P-N Junction area into electrical energy. Shortcomings of the principle of photovoltaic is output power instability which is influenced by various factors. One of them is a shade effect that will affect the output power performance [3].

Photovoltaics continues to develop, photovoltaics have gone through renewal for three generations. The first generation is the generation that is commonly used in this era, there are two types of the first- generation photovoltaic, monocrystalline and polycrystalline [4,5]. The second generation is more focused on the optimization of the fabrication process by reducing some materials from the first generation fabrication type. This is very cost-effective, but the efficiency produced is still smaller than the first generation, the second generation is called Photovoltaic Thin Film [6]. The third generation is better than the first generation working principle. Of the two types of first- generation, photovoltaic has advantages and disadvantages, the strength of monocrystalline is to convert solar radiation received into electrical energy better efficiency more than 10% of the type of polycrystalline [7-10].
But the disadvantage of the monocrystalline fabrication process requires a high cost. Regarding the type of polycrystalline manufacturing costs that are not too high because of the manufacturing process using mixed materials. But the disadvantages of polycrystalline are very sensitive to environmental changes. These changes not only have an impact on solar radiation but are more influenced by temperature and examples of the surrounding environment such as wind speed and ambient temperature [5].

Shade effects are phenomena that occur due to cloud movement or things that cause shade in photovoltaics. The consequence of this phenomenon is that the irradiation of sunlight received by photovoltaics is not optimal. The conditions explain that the effect of the sunshade is not always equal to zero, but shade only causes a decrease in solar radiation from normal conditions [11, 12]. Also, one of the shading parameters is a vertical or horizontal shading pattern in the photovoltaic cell module. This paper explains the effects of sunlight and pathways that form a shadow effect on photovoltaics. This parameter affects the value of the input power. The input power in photovoltaic is very influential on solar radiation and areas affected by solar radiation [13]. Therefore this paper will explain the effects of certain patterns that affect the voltage, current and output power.

2. Materials and Methods
Measurements made in open areas using polycrystalline photovoltaics have an area of 793,600 mm², with a length of 992 mm and a width of 800 mm. Measurements were carried out during solar irradiation of 1012 W/m². As well as the Photovoltaic characteristics will be explained in table 1. The measurement of shade effects is carried out when the ambient temperature is 31°C. Irradiation due to shade is set to 488 W/m² where the normal irradiation time that can be measured is 1012 W/m².

| Panel Characteristics                  | Unit | Value |
|----------------------------------------|------|-------|
| Nominal Max Power ($P_{max}$)          | Watt | 100   |
| Optimum Operating Voltage ($V_{mp}$)   | Volt | 17.1  |
| Optimum Operating Current ($I_{mp}$)   | Amp  | 5.84  |
| Open Circuit Voltage ($V_{oc}$)        | Volt | 21.2  |
| Short Circuit Current ($I_{sc}$)       | Amp  | 6.46  |
| Max System Voltage                     | Volt | 1000  |
| Dimension                              | mm   | 800*992*35 |
Figure 1. Methodology of shading effect study to the output power of photovoltaic.

Figure 1 illustrates the steps in conducting a shade effect experiment. Shade effect experiments carried out consisted of a variety of horizontal and vertical effects and variable changes from each area affected by shading ranging from 20%, 40%, 60%, 80%, and 100%. With variations in the shaded area, differences in the electrical characteristics of the system observed, namely electrical characteristics are the voltage, current, and output power whose values are based on the type of shade area based on horizontal and vertical patterns.

The photovoltaic used has the cell configuration as follows 108 cells. The configuration consists of 18 cell series which are natural series and 6 parallel cell circuits. The second image has 36 cells where nine cells in series and four sets of series cells are in parallel circuits as shown in figure 2. This configuration will cause differences table in horizontal and vertical pattern shading.

Figure 2. Example of cell in Photovoltaic

This method is based on a pattern. The pattern consists of two types, namely vertical and horizontal as shown in Figure 3 and 4, respectively. Each of these patterns shows the values of open circuit voltage and short circuit current according to the specified shade area. The radiation value is also very influential in the shaded area so indirectly the shade affects the voltage and current values. The relationship will be seen in the graph displayed by using the linear regression theorem which can see the value of the correlation coefficient.
3. Results and Discussion

The electrical responses of polycrystalline PV panels, such as current, voltage and power under the above said conditions were measured and its electrical characteristic.

According to Figure 5, this shows how the correlation is formed between (Open Circuit Voltage and (Shading Area (%))) in pattern, based on the principle of linear regression, the correlation is very significant, this is caused by the value correlation coefficient = 0.968 and 0.9675) almost worth one. Based on the graph above it can be concluded that the greater the value of the shaded area the smaller
the open circuit voltage value in photovoltaic.

![Graph of Current vs Shading Area (Pattern)](image)

**Figure 6.** Current (A) vs shading area (%) pattern.

According to Figure 6, this shows how the correlation is formed between (Short Circuit Current) and (Shading Area (%)) in pattern, based on the principle of linear regression, the correlation is very significant, this is caused by the value (correlation coefficient) = 0.9947 almost worth one. Based on the graph above it can be concluded that the greater the value of the shaded area the smaller the short circuit current value in photovoltaic.

![Graph of Input Power vs Shading Area (Pattern)](image)

**Figure 7.** Input power (W) vs shading area (%) pattern

According to Figure 7, this shows how the correlation is formed between Input Power (W) and (Shading Area (%)) in pattern, based on the principle of linear regression, the correlation is very significant, this is due to the value (correlation coefficient) worth one. Based on the graph above it can be concluded that the greater the value of the shaded area the smaller the value of the power input in photovoltaic.
According to figure 8, this shows how the correlation is formed between Output power (W) and (Shading Area (%)) in pattern, based on the principle of linear regression, the correlation is very significant, this is caused by the value (correlation coefficient) = 0.9961) almost worth one. Based on the graph above it can be concluded that the greater the value of the shaded area the smaller the output power value in photovoltaic.

4. Conclusions
In this experiment, shade pattern analysis was carried out to understand the effect of changing the output power on photovoltaic. The shade pattern methodology is used to optimize output power and make the regression equation have a significant correlation. Based on statistical analysis, the following conclusions are made. The greater the value of the shaded area the smaller the open circuit voltage value in photovoltaic, the short circuit current, Input Power and Output Power.

Acknowledgements
This research is funded by research grant of HIBAH PITTA B 2019 No. NKB 0694/UN2.R3.1/HKP.05.00/2019 from Universitas Indonesia.

References
[1] Quaschning V and Hanitsch R 1996 Solar Energy 56 513-520.
[2] Kaushika N D and Rai A K 2007 Energy 32 755-759
[3] Shimizu T, Hirakata M, Kamezawa T and Watanabe H 2001 IEEE Trans. On Power Electronics 16 293-300
[4] Kitamura and Matsuda H, "Long term degradation phenomena of crystalline Si solar modules," in PVSEC-12, Korea, 2001, pp. 757-758
[5] Cristaldi L, Faifer M, Rossi M, and Ponci F 2012 IEEE Transactions on Instrumentation and Measurement 61 2632-2641
[6] Villalva M G, Gazoli J R and Filho E R IEEE Transactions on Power Electronics 24 1198–1208
[7] Alonso-Garcia M C, Ruiz J M and Chenlo F Solar Energy Materials and Solar Cells 90 329–340
[8] Peña R A S, Gamara I C G, Pareja K A A and Macabebe E Q B Development of an Arduino-based I-V curve tracer for performance testing of photovoltaic modules under outdoor conditions Proc. 23rd International Photovoltaic Science and Engineering Conference
[9] El-Khozondar H J, El-Khozondar R J and Matter K 2015 *Energy Procedia* 74 1142-1149
[10] Zhang Q and Li Q 2012 Temperature and reverse voltage across a partially shaded Si PV cell under hot spot test condition *Photovoltaic Specialists Conference (PVSC)* 2012 38th IEEE (pp. 001344-001347), IEEE
[11] Satpathy P R., Jena S, Jena B and Sharma R. 2017 Comparative study of interconnection schemes of modules in solar PV array network. In Circuit, Power and Computing Technologies (ICCPCT) *International Conference on IEEE* (pp.1-6)
[12] Ye J Y, Reindl T, Aberle A G and Walsh T M 2014 *IEEE J. Photovolt* 4 1288–1294
[13] Vengatesh R P and Rajan S E 2016 *Int. J. Green Energy* 13 1507–1516.