P.Issn : 2808-859X
E.Issn : 2809-0853

SHADING SIMULATION ANALYSIS OF 5.348 WP ON-GRID SOLAR POWER PLANT

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Keywords:
Solar power plants, shadow, 5.348 Wp

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Abstract: Solar power plants are renewable energy plants that occupy the top ranking for renewable energy. The research's object is the polycrystalline type with a series connection in each module with a capacity of 5.348 Wp. Efficiency calculations of solar power plants must be carried out to determine the maximum potential of solar energy power plants. Shadows are one of the factors that can influence the optimal efficiency of solar power plants. The method used is experimental by simulating the influence of direct shades, percentages of 20 percent, 40 percent, and 60 percent, and indirect simulation. Data was collected using direct simulation from 11:00 WIB to 13:00 WIB for six days. Simulation-based analysis shows that with a total power of 5,348 Wp for 20% shadow conditions, it produces 3049 W of Power; for 40% shadow conditions, it makes 1834 W of energy; and for 60% shadow conditions, it creates 1227 W of Power, the influence of shadows on solar power plants has a loss contribution power of 0.9% / year.

INTRODUCTION

Solar Energy Plant occupies the highest place as alternative energy that can be developed in Indonesia, supporting Indonesia's astronomical location with a position of 6 LU-11 LS and 95 BT-141 BT. The use of photovoltaic (PV) with semiconductor materials in solar power plants directly converts radiation generated by the sun into electrical energy.

The process of energy change that occurs in semiconductor materials occurs when the band gap contained in semiconductor materials can be effective with a value range of 1.0 to 1.6 eV, wherein the value range electrons are free and do not cause excessive heating, with a solar spectrum value of 0.5 eV to 2.9 eV(Boxwell, 2012).

Solar power plants are divided into two classifications: off-grid solar power plants and on-grid solar power plants, where off-grid plants are electrical energy plants not connected to other electricity systems. On-grid solar energy plants do not use inverters to change the DC generated by the power plant, so this type of power plant can be used on a small scale or in remote areas that are difficult to get electrical energy supply from the State Electricity Company (PLN)(Rahmaniar et al., 2023). The on-grid solar energy power plant is a generating system connected to the network and is divided into two methods: using and without batteries. Batrai functions as a storage system for electrical energy generated by solar power plants and as a supplier of electrical energy to electrical loads(Rahmaniar et al., 2019). Another on-grid solar power plant is without the use of batteries, where the solar power plant is a supplier to the PLN power grid(Nathan et al., 2005).

Voltage and Current in Photovoltaics

Solar power plants use solar modules that can produce a current of 4 Amperes to 10 Amperes, with a 30 to 40 Volts voltage. Solar modules in solar power plants are arranged in series to achieve the highest Voltage. The input power on solar panels can be formulated as follows(Boxwell, 2012):

Pin = Irad x A (1)

With the:

Pin = Incoming Power on the solar panel (W)

Irad = Solar light intensity (W/m^2)

A = Solar panel cross-sectional area (m^2)

The output of the solar panel can be determined using the equation:

Pout = Vpv. Ipv (2)

With the:

Pout = Power output on solar panel (W)

Vpv = Voltage of Solar Panel (V)

Ipv = Outgoing Current of the solar panel (A)

To calculate the average power value during a test point using the equation:

$$P\ average = \frac{P1+P2+P3\ldots\ldots\ldots\ldots\ldots Pn}{n} \quad (3)$$

With the:

P average = Average Power (W)

P1 = Power at the first testing point

P2 = Power at the second testing point

P3 = Power at testing point three

Pn = Power at the testing point to

n = Number of tests

Efficiency (η) in determining the percentage of electricoutput from solar cells forenergy that comes in the form of solar irradiation can be calculated by the equation:

$$\eta = \frac{Vmp\ Imp}{I\ A} x\ 100\% \quad (4)$$

With the:

η = Efesisensi

V_{mp} = Voltage on peak power

I_{mp} = Current at peak power

I = Solar intensity per meter squared

A = Radiated area

The fill factor is a relevant quantity to determine the quality of solar cells and the efficiency of solar cells. The fill factor is used to determine storage parameters and measure storage capabilities. The fill factor can be calculated with the equation:

$$\text{Fill factor} = \frac{I_{mp}\ V_{mp}}{I_{SC}\ V_{oc}} \quad (5)$$

Shadow Effect

Solar power plants in the development process require several feasibility analyses, including an analysis of the shadows that can occur on solar modules (Gallardo- Saavedra & Karlsson, 2018). Some of the potential shadows that can fall on solar modules are:

1. The shadow of a tree;
2. Building shadows;
3. Shadow of solar panel.

Shadows on solar modules can cause a reduction in the absorption of solar radiation. They can also cause an increase in temperature so that the reduced absorption of solar radiation decreases the Voltage on the solar panel and can disrupt the performance of the solar power generation system. Solar modules that are exposed to shadows either from trees, buildings, or the solar panels themselves will not work optimally because the solar modules in the solar plant will experience power losses caused by increased heat in the solar modules. Another problem that can be caused by shadows that occur on solar modules is the occurrence of hot spots, so to overcome this condition, research has been carried out on Where the use of bypass diodes or using a micro-inverter (Rahmaniar, Khairul, 2023).

The calculation of the percentage of shadow on the solar module is done using the formula:

$$\% \text{ shadow} = \frac{Cells\ covered\ in\ shadow}{overall\ cell}\ x\ 100\% \quad (6)$$

To calculate the percentage of power reduction in solar power plants, can use the equation:

$$\% \text{ Power drop} = \frac{Pnormal - Pshadow}{P_{normal}}\ x\ 100\% \quad (7)$$

RESEARCH METHODS

In this research, a quantitative experimental method is used, where in this research, an assessment will be made of the solar radiation conditions on the solar cell module. This research uses an Arduino Arduino-based microcontroller for the flowchart data collection process as follows:

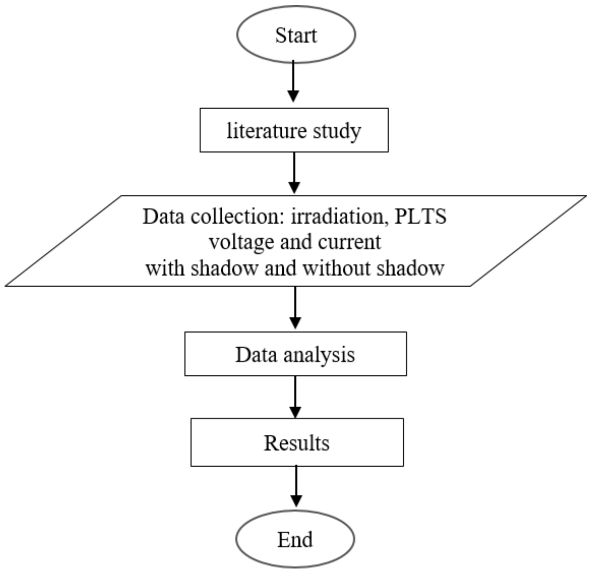

Figure 1. Research flowchart

The specifications of the research object are:

Total series	19
Nominal Maximum Power	6175 (325 x 19)
Optimum operating voltage (V_m)	745,1 (19 x 39,217)
Optimum operating current (I_m)	8,68
Open Circuit Voltage (V_{oc})	887,9 (19 x 46,132)
Short Circuit Current (I_{sc})	9,093
Maxium system Voltage	1500
Panjang(m)	1,955 x 19
Lebar(m)	0,990 x 19
Luas array (m^2)	32,473 (19 x 1,709064)

Figure 2: Solar Power Plant

The focus of the data points in the study is the output of the solar panel voltage and Current on the condition of giving the effect of shadows through banner media, namely on 2 modules, four modules, and six modules on 19 solar modules connected in series. In the process of measurement during the research, the Arduino uno that has been installed with the BH1750 sensor will be connected to the laptop. Then, the lux will be visible on the serial monitor on the Arduino software on the laptop. The process of measuring light and Current is carried out at the same time.

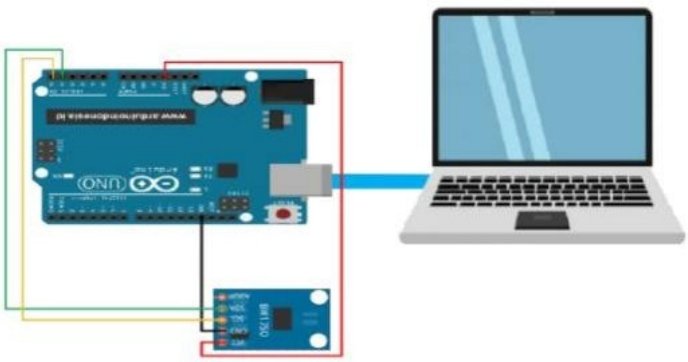

Figure 3. Schematic of Light Measurement Process on Serial Monitor

RESULTS AND DISCUSSION

The data obtained later will be calculated manually, experimentally, and through simulation to get the power value in the normal state and the shadow state; the following are the calculations that have been done:

To determine the output power of the solar power plant, the equation is used: $P_{wattpeak}$ = Luas PV x Psi x η PV

= 32,4722 m^2 x 1000 W/m x 0,16

= 5195,55 Watt peak

The study measured the irradiation value, Voltage, and Current, and the changes that occurred with Voltage and Current during data collection starting from 11:00 to 13:00:

Table1. Comparison of normal and shadow condition measurements on 2 Modules

Time	LUX	Normal		Shadow	
		I	V	I	V
11:00	**38681,48**	3,4	681	2,5	699
11:30	**26838,89**	2,5	692	2,2	685
12:00	**51300**	4,5	687	4,4	693
12:30	**48587,03**	4	688	3,4	685
13:00	**66137,04**	5,7	663	4,9	664

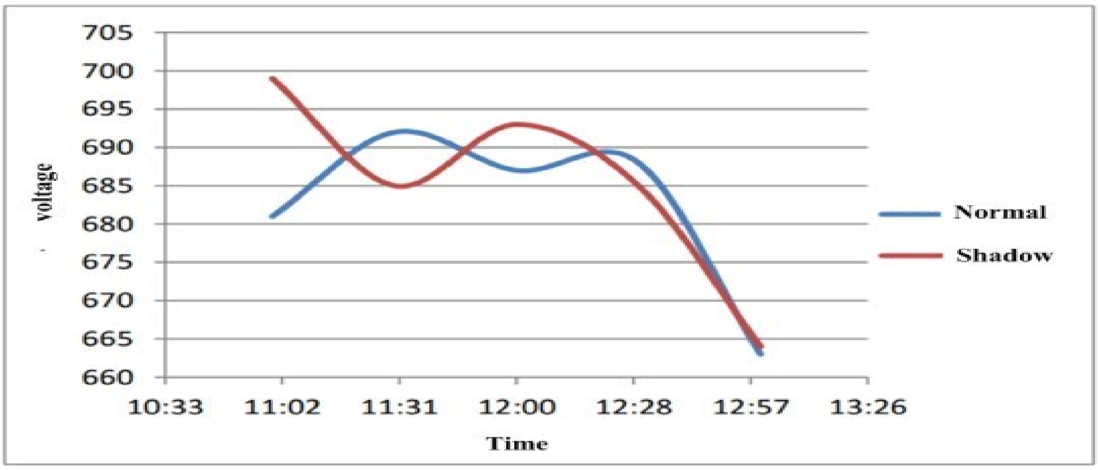

Image 3. Current versus Time Graph of Normal State and Shadow Effect on 2

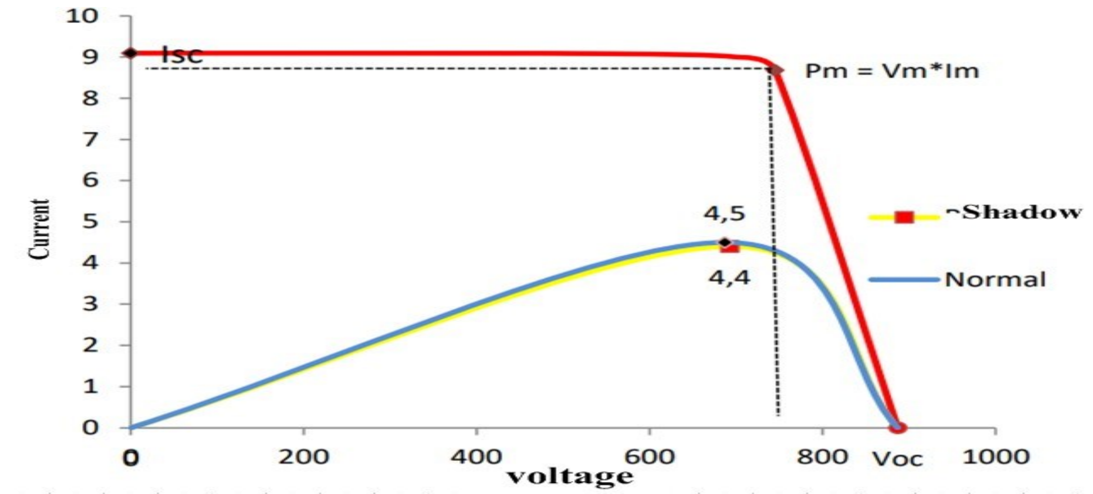

Figure 4. V-I Characteristic Graph of Normal State and Shadow Effect on 2 Modules

Figure 4 shows that the current value in a normal state of 3.4 A becomes 2.5 A when simulating shadows on two modules. It can be seen that the decrease in Current is 0.9 A, and the voltage value of 681 V normal state becomes 699 V shadow state; there is an increase in Voltage. Moreover, at 12:00 the average current value of 4.5 A becomes 4.4 A in the shadow state; it can be seen that the decrease in Current is 0.1 A, and the voltage value of 687 V in the normal state becomes 693 V in the shadow state, there is an increase in Voltage.

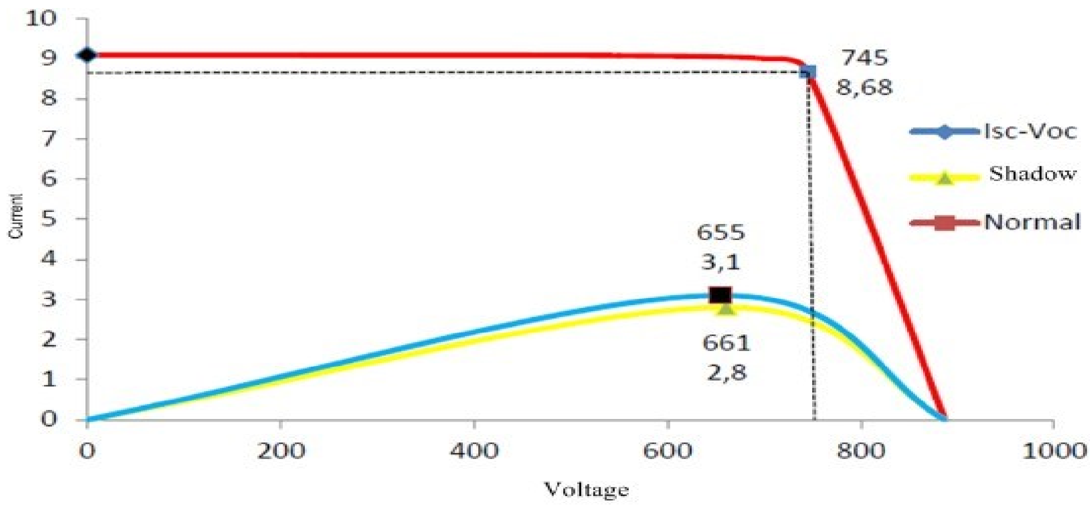

Figure 5. V-I Characteristic Graph of Normal State and Shadow Effect on Four Modules

The current and Voltage data listed in the table above are the voltage current data in normal conditions and the state of giving the effect of shadows on six modules of 19 solar cell modules connected in series, with changing solar conditions, 27492.59Lux at 12:00 WIB the normal current value of 2.3 becomes 1.8 A in the shadow state, there is a decrease in Current of 0.5 A in shadow conditions and the voltage value is 683 V normal conditions to 683 V shadow conditions. The value of the current drop in the condition of giving the shadow effect on 6 modules does not occur drastically due to the irradiation factor, which at the time of data collection is not in normal conditions.

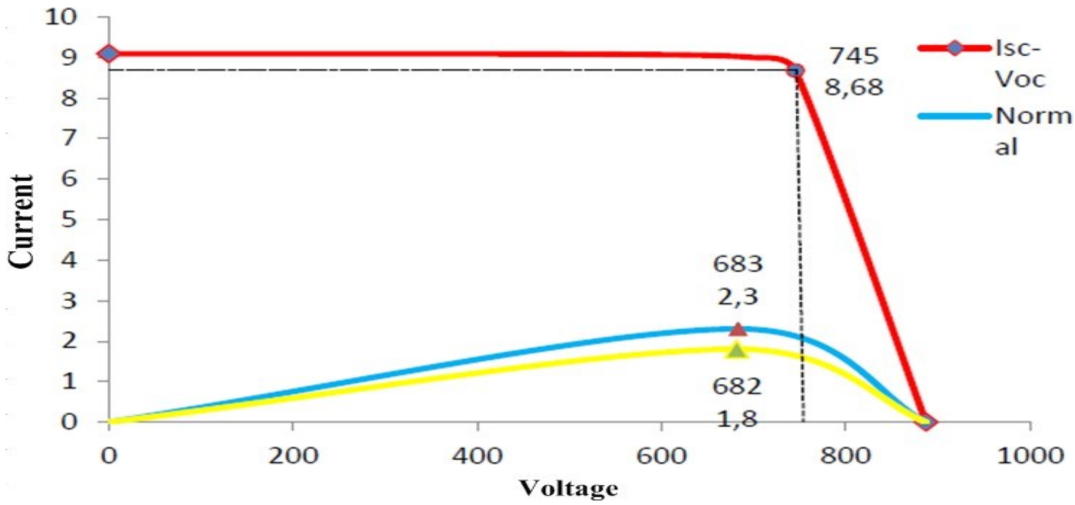

Figure 6. V-I Characteristic Graph of Normal State and Shadow Effect on Six Modules

When the above data collection was carried out, the solar power plant did not work optimally due to cloudy weather conditions and was carried out in the rainy season. The graph obtained represents the situation during the research process, which has been carried out at the Solar Power Plant with different output results. This research was conducted to see the amount of output power at peak hour conditions when given the effect of shadows manually using banner media; the research process was carried out during peak hours, namely 11:00 WIB to 13:00 WIB.

From the results of manual calculations, it is found that the estimated Power generated by the Array when it gets 100% sunlight is 5348.88 $Wattpeak$, and from the MPP array specifications obtained is 6175 watts, and the real Power that has been obtained is found to be a significant difference. To determine the Array's ability to convert solar radiation into electrical energy per change in time, the output power is measured as in the power table. Based on the power table, it can be observed that the output power in the condition of giving the shading effect to the Array of 2 modules that are given a shadow effect is 3049.2 watts at 12:00 pm. In normal conditions, the Power obtained is 3091.5 watts of power decrease, and when giving the shadow effect to 4 modules, the Power obtained is 1850.8 watts at 12 00 hours. In normal conditions, the Power obtained is 2030.5 watts, and when giving the shadow effect to 6 modules, the Power obtained is 1570.9 watts at 12:00 hours. In normal conditions, the Power obtained is 1227.6 watts. The Power generated in normal conditions and the shadow state has not reached the MPP specification on the Array.

CONCLUSION

Based on the discussion and calculations that have been carried out, it can be concluded that:

1. The estimated output power results obtained 5348.88 Wattpeak from 19 solar cell modules connected in series (Array). However, when calculated with inaccurate data, the output power was the most considerable Power obtained, only 4736.9 watts, and occurred on November 8, 2022, at 12:30 WIB.
2. After being given the effect of shading on two solar cell modules out of 19, there was a decrease in Power, 3091.5-3049.2 = 42.3 wat; then on four solar cell modules, there was a decrease in Power 2030.5-1834 = 196.5 watts. Then, on six solar cell modules, there was a decrease in Power 1570.9 - 1227.6 = 343.3 watts; a significant power drop was seen when the shading effect was given on six modules.
3. The natural shadow effect due to clouds covering the sunlight causes the solar power plant not to work optimally. On November 8, 2022, at 12:30, lux 83357.41 (sunny) produced a current of 6.7 A and a voltage of 707 V, and on November 13, 2022, at 12:30 with lux 23224.08 (cloudy), produced a current of 2.1 and a voltage of 690 V, there is a significant difference in current and Voltage.

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