Analysis of the Output Power 10Wp Polycrystalline Photovoltaic Panels on the Effect of Sand Dust and Brick Dust

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***Abstract*— Panel Fotovoltaik Polikristalin merupakan salah satu perangkat yang berperan dalam mengubah energi foton dari sinar matahari menjadi energi listrik. Pemasangan panel fotovoltaik di luar ruangan dapat mengakibatkan penumpukan debu pada permukaannya, berpotensi mempengaruhi daya keluaran panel karena cahaya yang dapat dikonversikan menjadi energi listrik menjadi terbatas akibat tertutupi oleh debu. Sebuah eksperimen dilakukan dengan menaburkan 3 gram debu pasir dan batu bata berukuran kurang dari 425 µm pada panel tersebut. Berdasarkan pengukuran dan analisis, panel tanpa perlakuan menunjukkan nilai tegangan, arus, dan daya keluaran tertinggi masing-masing sebesar 12,69 V, 0,28 A, dan 3,55 W. Sementara pada panel dengan debu pasir, nilai tegangan adalah 12,19 V, arus 0,244 A, dan daya keluaran 2,97 W. Panel dengan debu batu bata mencatatkan nilai tegangan terendah sebesar 11,84 V, arus 0,211 A, dan daya keluaran 2,49 W. Terdapat penurunan nilai tegangan, arus, dan daya keluaran pada panel tanpa perlakuan dibandingkan dengan panel yang terkena debu. Panel dengan debu pasir menghasilkan daya keluaran lebih tinggi dibandingkan dengan panel yang terkena debu batu bata, dikarenakan perbedaan karakteristik debu pasir yang lebih kasar dengan partikel yang lebih besar dibandingkan dengan debu batu bata yang memiliki tekstur lebih halus dan partikel yang lebih kecil. Sebagai akibatnya, partikel debu pasir yang lebih besar menyebabkan luas permukaan panel yang tertutupi oleh debu lebih sedikit jika dibandingkan dengan debu batu bata, sehingga cahaya matahari yang dapat dikonversikan menjadi energi listrik menjadi lebih banyak.**

Kata Kunci—Panel Fotovoltaik, Polikristalin, Debu, Daya Keluaran.

***Abstract*— Polycrystalline Photovoltaic Panels are a device that plays a role in converting photon energy from sunlight into electrical energy. Installing photovoltaic panels outdoors can result in dust buildup on their surfaces, potentially affecting the panel's output power because the light that can be converted into electrical energy is limited due to being covered by dust. An experiment was carried out by sprinkling 3 grams of sand and brick dust measuring less than 425 µm on the panel. Based on measurements and analysis, panels without treatment show the highest voltage, current and output power values of 12.69 V, 0.28 A and 3.55 W respectively. Meanwhile for panels with sand dust, the voltage values are 12, 19 V, current 0.244 A, and output power 2.97 W. Panels with brick dust recorded the lowest voltage values of 11.84 V, current 0.211 A, and output power 2.49 W. There was a decrease in the values of voltage, current, and output power on panels without treatment compared to panels exposed to dust. Panels with sand dust produce higher output power compared to panels exposed to brick dust, due to the different characteristics of sand dust which is coarser with larger particles compared to brick dust which has a finer texture and smaller particles. As a result, the larger sand dust particles cause less panel surface area covered by dust compared to brick dust, so that more sunlight can be converted into electrical energy.**

Keywords—Photovoltaic Panel, Polycrystalline, Dust, Output Power.

I. INTRODUCTION

Energy plays a vital role in human survival. As much as 80% of total global energy consumption still depends on fossil fuels [1], which in turn is the main trigger for climate change. Therefore, the use of renewable energy, such as photovoltaic panels, wind turbines and biomass, is a crucial solution to reduce environmental impacts and replace non-renewable energy sources. Photovoltaic panels (PV) are a technology that is capable of producing significant energy with low pollution levels [2]. Indonesia, with its geographical location along the equator, has great solar potential with radiation intensity reaching 4.8 kwh/m^2 per day [3]. Therefore, the use of photovoltaic panels in Indonesia can be an effective solution to reduce dependence on fossil energy. However, the performance of photovoltaic panels can be influenced by various factors, such as solar cell material, thermal cycling, absorption of ultraviolet light, loss of adhesion between cells, and entry of water into the cells [4]. Apart from these factors, dust adhering to the surface of photovoltaic panels is also a serious problem. Based on the IQAIR 2021 world air quality report, Indonesia is listed as the 17th country with the highest level of air pollution, especially with a PM 2.5 concentration of 34.3 µg/m^3.

Industrial areas, such as the sand industry in South Sumatra and the brick industry in Talang Buruk Village, are the main sources of dust. Dust particles less than 500 µm in size are considered dust, and their presence can inhibit or reduce the amount of sunlight reaching the photovoltaic panels. Therefore, photovoltaic panels need to be cleaned regularly, both manually and automatically. This research refers to a study conducted by Yotham Andrea, Tatiana Pogrebnaya, and Baraka Kichonge [1], which explored the impact of dust types on the performance of photovoltaic modules.

Dust particles adhering to the surface of solar panels can create a layer that reduces light transmission to the solar cells below. This leads to a decrease in the amount of light absorbed by the cells, resulting in reduced efficiency in converting sunlight into electricity. Consequently, this diminishes the performance of solar panels in converting solar energy into electrical energy. Additionally, the accumulation of sand and brick dust can heighten the risk of physical damage to the panels, particularly if the dust contains abrasive particles. Scratches or other damage to the panel surface can disrupt the electricity conversion, diminishing overall panel performance. Ultimately, dust buildup can cause a reduction in the power output of the photovoltaic panel, thereby negatively impacting the entire photovoltaic system, especially during adverse weather conditions or natural events such as sandstorms or dust storms. Therefore, it is crucial to address and manage the risk of dust accumulation by conducting routine maintenance and regularly cleaning the panels. This will help ensure the performance and durability of photovoltaic panels against extreme environmental conditions and enhance the overall energy productivity of the photovoltaic system. In this study, the types of dust tested were sand dust and brick dust. This option was chosen to represent conditions in the brick industry and sandy areas, in the hope of providing a better understanding of the impact of these two types of dust on the output power of polycrystalline type photovoltaic panels.

II. LITERATURE REVIEW

A. Solar panels

Solar panels are devices that produce electricity using solar energy. This tool consists of photovoltaic cells or solar cells that are specifically designed to convert solar radiation into electrical energy [7]. The structure of solar cells is generally made of a layer of silicon with the addition of boron to produce a positive charge, and phosphorus which plays a role in forming a negative charge [8]. The basic principle of operation of solar panels is to convert solar energy into electrical energy through the interaction of photons in solar cells. When sunlight contains photons, these tiny particles interact with the atoms in the semiconductor of the solar cell. This interaction process results in the separation of electrons from the atomic structure. The released electrons create an electric current, and when these electrons move, the solar panel produces electrical energy in the form of direct current (DC). To convert direct current to alternating current (AC), an inverter device is needed. Although solar panels can function without using batteries, this carries the risk of electricity not being available at night. As an alternative, other methods can be applied as energy supplements when the solar panels are not active.

B. Dust

Particles with dimensions less than 500 µm can be identified as dust. The structure, dimensions and density of dust depend on the characteristics of a particular place [9]. Areas with industrial activities, such as burning wood and coal, as well as other industrial processes, tend to produce greater amounts of dust. Dust buildup on solar panels can result in accumulation that reduces solar panel performance. According to a journal article entitled "Effect of Industrial Dust Deposition on Photovoltaic Module Performance: Experimental Measurements in the Tropical Region," this type of coal dust has the most significant impact on reducing the efficiency of solar panels [1]. The finer particle size causes this compared to other types of dust tested, so it covers the surface area of the solar panel and reduces the intensity of light that can enter. Particles with a size of 20 µm - 45 µm cause a decrease in efficiency of 64%, while particles with a size of 90 µm - 180 µm cause a decrease in efficiency of 48%.

C. Bricks and Sand

Bricks and sand can be classified into various types, depending on the material from which they are made and where the sand is taken. Red bricks, for example, are made from compacted and molded clay before being dried in the sun to make it dense and hard. Mundu sand, one commonly used sand type, has a coarser texture than other types of sand and is usually used in bricklaying and plaster work [10].

D. Dust Characteristics on Solar Panel Performance

Particles measuring less than 500 µm can be called dust [1]. The structure, size and density of dust are highly dependent on location characteristics [9]. Locations with intense industrial activity, such as burning wood and coal, as well as other industrial processes, tend to produce greater amounts of dust. Dust buildup on solar panels can result in decreased performance of the panels. In this study, the type of coal dust had the most significant impact in reducing the efficiency of solar panels. This is caused by the finer particle size compared to other types of dust tested, so that coal dust covers the surface area of the solar panels and reduces the intensity of light that can enter. Particle sizes between 20µm - 45µm cause a decrease in efficiency of up to 64%, while particles with a size of 90µm - 180µm cause a decrease in efficiency of around 48% [1].

E. Power

Power is a measure of the energy expended to do work. In the context of an electric power system, power includes the total energy used to do work or business. The unit commonly used to measure power is Watts. In the power triangle concept, there are three main types of power: active, reactive, and apparent.

1) Active power

Active power (P) is a type of power that can be used directly in everyday life. Examples involve energy in the form of heat, light, and mechanical power.

$$P = V.I.Cos\,\varphi \quad (1)$$

2) Reactive Power

Reactive power (Q) is a type of power that can be used to create a magnetic field. Examples of electrical devices or loads that cause reactive power include transformers, electric motors and incandescent lamps.

$$Q = V.I.Sin\,\varphi \quad (2)$$

3) Apparent Power

Apparent power (S) is the result of calculations of active power (P) and reactive power (Q) in complex vector form. The difference in value between active and reactive power is exemplified in the phase angle (phi). The cosine of this angle is called the power factor or the ratio between active power and apparent power. This ratio has a value between 0 and 1, and closer to 1 indicates higher efficiency.

$$S = V.I \quad (3)$$

where:

P = Active Power (Watts)

Q = Reactive Power (VAR)

S = Apparent Power (VA)

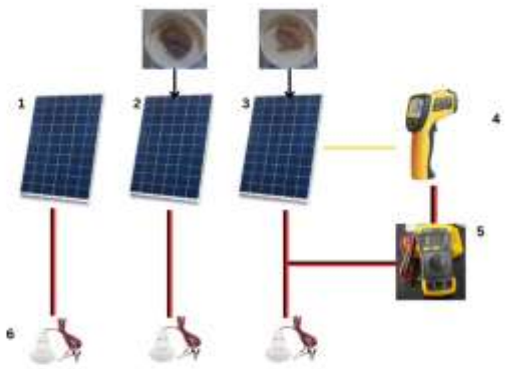
V = Voltage (Volts)

I = Current (Ampere)

Cos φ = Power factor

III. RESEARCH METHODOLOGY

This research was carried out in the Department of Electrical Engineering, Sriwijaya University, Indralaya, from August 2022 to March 2023. The research process includes the literature study stage, determining the topic, preparing tools and materials, collecting and processing data, data analysis, and drawing conclusions.



Note :

1. Untreated Polycrystalline Panel
2. Polycrystalline Panel With Sand Dust
3. Polycrystalline Panels With Brick Dust
4. Infrared Thermometer
5. Digital Multimeter
6. 12V 5W LED light

Figure 1. Research schematic.

Sand and brick dust that has been filtered using a 425 µm mesh, each weighing 3 grams. The two types of dust are then spread over the surface of the 10Wp polycrystalline-type photovoltaic solar panel. Solar panel measurements were carried out by connecting the solar panel to a 12V 5W lamp, and data on temperature, current, and solar panel voltage were recorded in the time range 09.00 to 16.00 WIB, with measurement intervals every 1 hour.

IV. RESULTS AND DISCUSSION

The solar panel design in Figure 2 involves three 10 Wp polycrystalline solar panels with three different conditions. Each panel experienced three conditions: one without treatment and two with treatment. This treatment includes sprinkling sand dust and brick dust on the surface of the solar panels. In Figure 2, the left panel shows the impact of sand dust, the middle panel received no treatment, and the right panel was exposed to brick dust. In this research, voltage and current measurements were carried out to calculate the output power of solar panels. Measurements were carried out using a digital multimeter connected to a DC 5V lamp when the solar panel was exposed to sunlight. The weight of the applied dust is 3 grams, enough to cover the surface area of a solar panel with dimensions of 415x245 mm.

Figure 2. 10 Wp polycrystalline solar panel with three different conditions

Table I. Measurement Data of without treatment Solar Panel

Day	Temperature (ºC)	Current (A)	Voltage (Volt)	Power Output (Watt)
1	46	0.157	11.28	1.92
2	41.75	0.211	12.07	2.82
3	40.25	0.227	12.04	3.21
4	45.5	0.280	12.69	4.21
5	43.5	0.255	12.17	3.53
6	39.875	0.178	11.42	2.38
7	39.125	0.165	11.37	2.08
8	41.875	0.146	11.12	1.72
9	42	0.193	11.55	2.51
10	38.875	0.133	10.47	1.49

Table II. Solar Panel Measurement Data With Sand Dust

Day	Temperature (ºC)	Current (A)	Voltage (Volt)	Power Output (Watt)
1	46.125	0.144	10.83	1.68
2	41.875	0.186	11.51	2.32
3	40	0.194	11.60	2.65
4	44.5	0.244	12.19	3.56
5	43	0.237	11.75	3.15
6	40	0.158	11.01	2.04
7	38.625	0.155	10.94	1.94
8	41.5	0.138	10.63	1.57
9	41.75	0.179	11.16	2.31
10	38.75	0.130	10.41	1.45

Table III. Solar Panel Measurement Data With Brick Dust

Day	Temperature (ºC)	Current (A)	Voltage (Volt)	Power Output (Watt)
1	44.63	0.127	10.64	1.43
2	41.75	0.159	10.86	1.92

3	39.88	0.177	10.99	2.23
4	44.00	0.211	11.84	2.93
5	43.13	0.205	11.48	2.72
6	39.13	0.142	10.77	1.78
7	38.25	0.137	10.68	1.68
8	41.38	0.122	10.43	1.33
9	41.25	0.156	10.83	1.81
10	38.75	0.118	10.22	1.28

Graphs of voltage, current, and power measurements are used to visualize the differences between solar panels without treatment, solar panels with sand dust, and solar panels with brick dust.

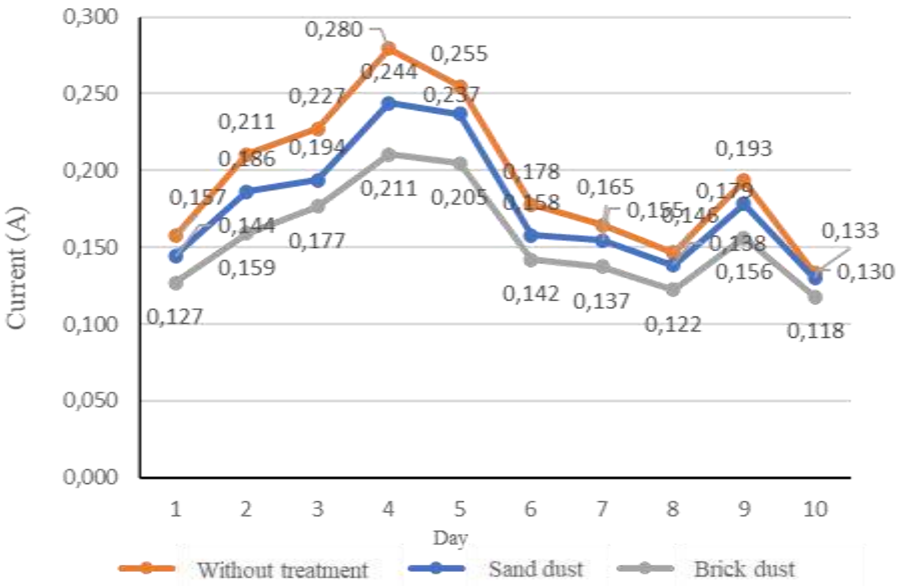


Figure 3. Solar panel current graph without treatment, with sand dust, and with brick dust

Figure 3 shows the average current produced by the solar panels during the 10 days of data collection. Solar panels without treatment have a current value range between 0.133 A to 0.280 A. Meanwhile, solar panels with sand dust, the current value range ranges from 0.130 A to 0.244 A. Solar panels with brick dust, on the other hand, have a range of values current between 0.118 A to 0.211 A. Analysis of graphic data shows that untreated solar panels have the highest current value compared to other panels. On the other hand, solar panels with brick dust have the lowest current value compared to solar panels without treatment and with sand dust.

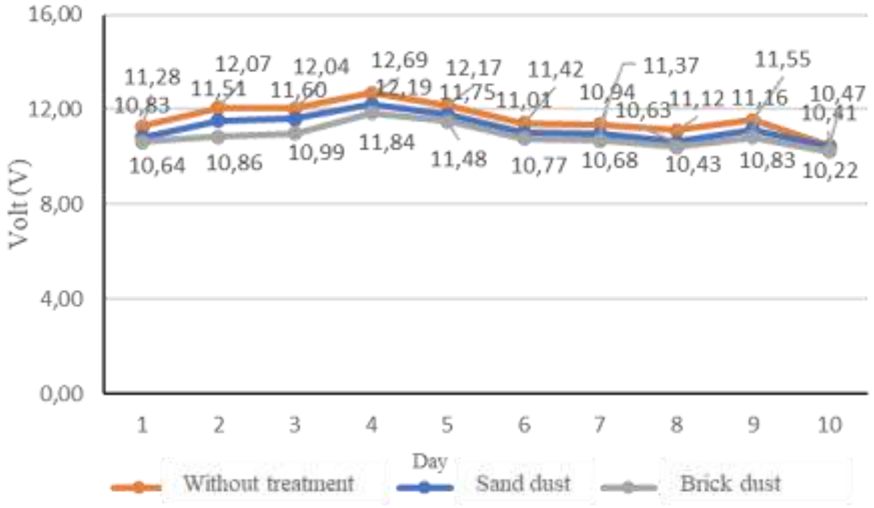


Figure 4. Solar panel voltage graph without treatment, with sand dust, and with brick dust

Figure 4 displays the average voltage produced by solar panels without treatment, solar panels with sand dust, and solar panels with brick dust. On solar panels without treatment, the voltage varies between 10.47 V to 12.69 V. Solar panels with brick dust have the lowest voltage of 10.41 V and the highest voltage of 12.19 V. Meanwhile, on solar panels with sand dust, the voltage varies between 10.22 V and 11.84 V. From these data, it can be concluded that solar panels without treatment have the highest voltage range, while solar panels with sand dust have the lowest voltage range.

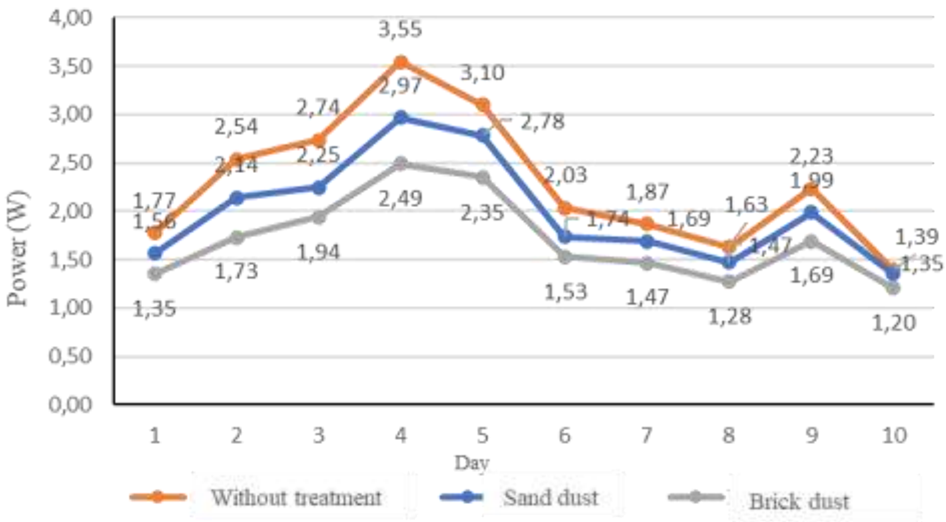


Figure 5. Solar panel power graph without treatment, with sand dust, and with brick dust

The average power produced by solar panels without treatment, solar panels with sand dust, and solar panels with brick dust is shown in Figure 5. Solar panels without treatment achieved the lowest power of 1.39 W and the highest of 3.55 W. Compared with solar panels with sand dust, which reached the lowest power of 1.35 W and the highest 2.97 W, and solar panels with brick dust, which reached the lowest power of 1.20 W and the highest 2.49 W. Graphic analysis in Figure 5 shows that untreated solar panels produce higher power than solar panels with sand dust and brick dust. Sand dust and brick dust produce the lowest power compared to other panels.

Solar panels with brick dust have the lowest power compared to solar panels with sand dust. This difference can be caused by the finer texture characteristics of brick dust and smaller particles than sand dust. Although the weight of sand dust and brick dust is the same, namely 3 grams, the finer texture of brick dust allows it to cover a greater surface area of the solar panel, reducing the light that the solar panel can absorb. On the other hand, sand dust with a coarser texture and larger particles covers the surface of the solar panel less, causing higher power output in solar panels with sand dust compared to solar panels with brick dust.

V. CONCLUSION

Based on the results of research on the effect of sand and brick dust on the output power of 10 Wp polycrystalline type photovoltaic panels, 3 units of polycrystalline type solar panels were designed, and sand dust and bricks weighing 3 grams with a size of less than 425 µm were prepared. Solar panels are divided into solar panels without treatment, solar panels with sand dust, and solar panels with brick dust. It was found that solar panels without treatment produced the highest voltage and current of 12.69 V and 0.28 A. Meanwhile, solar panels with brick dust produced the lowest voltage and current of 11.84 V and 0.211 A. Solar panels achieved the highest output power without treatment at 3.55 W, while solar panels with sand dust reached 2.97 W, and solar panels with brick dust achieved the lowest output power of 2.49 W. With the characteristics of brick dust, which has a fine texture and particles smaller than sand dust, at the same dust weight (3 grams), brick dust is able to cover more of the surface space of the solar panel, resulting in a decrease in the light that the solar panel can absorb.

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