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CHARACTERISTICS OF THE TBP 1275 MODULES AND THE EFFECT OF DUST ON THE PERFORMANCE OF SOLAR PHOTOVOLTAIC (PV)

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ABSTRACT

A solar cell, often known as a photovoltaic cell, is a gadget that produces electricity directly from daylight. Their effectiveness is, however, somewhat poor. As a result, compared to other energy resource goods, solar cells are pricey. Solar cell efficiency is influenced by various factors. The current study looked into how the dust affected the photovoltaic (PV) TBP 1275 module's ability to produce power. The experiments were carried out with two identical 75 Watt PV modules that were positioned in the same weather (Tripura). Both of them have been used in all necessary tests, with one being used as a standard module as a reference panel. The findings demonstrate that as dust and sun irradiation increase, the PV efficiency is negatively impacted. Power is significantly reduced as a result of dust. Quantified, the power reduction lowers power generation by 10.83% to 17.81%. Additionally, as we demonstrate, the colour of the dust can alter performance. Therefore, it is necessary to clean the solar panel on the red soil locale region more frequently in order to get the most power from it.

Keywords: Fill factor, Insolation, Open circuit voltage, PV module, Short circuit current.

1. INTRODUCTION

Humanity's basic needs include energy. Simply take a step back and realise that developing any form of activity was necessary even for the most rudimentary of men. Currently, waste from fossil fuels like oil, coal, and gas is the main source of energy consumption. These resources are not endless, and they have the potential to harm the ecosystem. The developed world's rising energy demand, which includes us, is a result of their way of life. As a result, it is predicted that the primary energy demand for the entire planet in the middle of the twenty-first century will double or treble from what it is now due to rising industrialization, economic development, and population expansion. The fossil reserves that nature has built up over millennia will disappear as a result of this usage. Oil, gas, and coal reserves are expected to run out at the current rate in 21, 65, and 155 years, respectively. Nuclear fusion energy, which still needs to advance significantly, and alternate forms of energy are the only options left. In contrast to traditional energy sources, renewable energy sources are unpolluted, limitless resources that are offered by nature. Hydropower is one of the renewable energy sources that call for extensive land areas. The estimated increase in global energy consumpdtion between 2015 and 2035 is 36%, up from 355 quadrillion Btu in 1990 to 495 quadrillion Btu in 2007 [1]. As one of the most promising energy generation options, photovoltaic power generation has drawn a lot of interest. The world's electrical consumption can fit inside. In recent years, the photovoltaic (PV) business has been expanding steadily and quickly. PV modules made of silicon crystalline are widely utilised worldwide. These days, new PV technologies including amorphous silicon (a-Si), cadmium telluride (CdTe), and copper indium selenium are accessible on the global market with lower manufacturing costs than conventional silicon crystalline based modules (CIS). In order to be comparable with the new or enhanced technology, new standards and testing methodologies are also being developed. One of the most promising sources of renewable energy is photovoltaic. Here, the goal of my research is to maximize the PV performance for various technologies in order to provide the most power and energy possible under various circumstances. The price of a PV system has significantly decreased, making it competitive with the cost of utility energy, particularly in areas with high solar radiation like the Sun Belt regions. To promote investment in PV projects, many nations began to pass special legislation. Even with the same technology, two PV modules with the same rated power will not produce the same output power or energy yield. Because the PV module is impacted by a number of external elements and the physics of solar cells, the various thermal characteristics also play a significant role in module efficiency as well as output power. In order to check system performance and facilitate effective troubleshooting for photovoltaic module/system by taking into account hourly, daily, monthly, or annual basis, testing and modelling the PV module/system in the outdoor environment with specifying the influences of all significant factors is very important [2]. Numerous variables, including the location of the sun, the outside temperature, the thermal properties of the module, the material composition of the module, and the mounting system, affect the output power of photovoltaic systems. Because a large penetration of PV production could lead to system instability, real-time electricity generation should be carefully examined for grid performance [3]. The effect of dust on solar cells has been the subject of numerous studies. Dust settling mostly depends on the characteristics of the dust (chemical characteristics, size, form, weight, etc.), as well as on the surrounding circumstances (site-specific factors, environmental features and weather conditions). The dust settlement is also impacted by the surface finish, tilt angle, humidity, and wind speed [4, 5]. By converting the sun radiation on the cell into electricity, photovoltaic solar energy is created. The installed capacity of solar photovoltaic power plants has increased steadily during the past twenty years. Performance of the system may be impacted by many weather factors. Researchers have found that when module performance tests were conducted in a specific location in Tripura, India, there was a strong association between the ambient temperature and module efficiency and a weak correlation between wind speed and module efficiency. [6].

2. SOLAR CELL PARAMETERS

Four parameters—short circuit current I_{sc}, open circuit voltage V_{oc}, fill factor FF, and efficiency —are used to describe and compare solar cells.

According to the Ideal Diode Law, a solar cell responds to light by behaving as shown in the following formula. [10]:

$$I = I_L - I_0 \left[\exp\left(\frac{qv}{nkT}\right) - 1\right] \qquad (1)$$

Where:

- I is the current.
- Io is the current that flows through a cell when no light is shining on it; it rises with both temperature and material quality.
- q is the charge on an electron.
- k is Boltzmann's constant.
-T is the absolute temperature.
- n is the ideality factor (between 1 and 2). It increases as the current decreases, for silicon n=2.
- IL is the light generated current.

All of the current and voltage configurations that may be used to operate or load the module or cell are represented by the characteristic curve. These curves, which are typically of a basic shape, really offer the most thorough assessment of the condition and capability of a PV module or array, including far more details than conventional electrical test techniques [7]

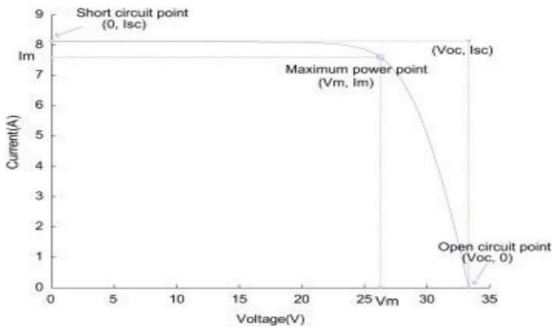

Figure 1: Typical plot of a solar cell I-V curve and its parameters.

Here, it is necessary to add two distinct parameters:

• I_{sc}, or short circuit current. When voltage is zero, the maximum current, or I_{sc}, is produced.

Open circuit voltage (Voc) is the highest voltage that can be measured with zero current.

Another important fact is that MPP, or maximum power point, is where the product of V_{mp}*I mp is at its highest value. The fill factor (FF), which is the difference between P max and I_{sc}*V_{oc}, is another crucial component. It provides information about the solar cell's quality; as it raises, the quality of the solar cell

2.1 Fill factor

The largest rectangle that fits inside the I-V curve is represented by the fill factor, which is a crucial parameter for PV cells and modules. The magnitude of the output power is related to the significance of FF. The output power increases as the FF increases. It is assessed by comparison to both the theoretical maximum power output ($P_{theoritical}$) and the maximum real power output (P_{max}), which would be produced if the voltage and current was both equal to the open circuit voltage and the short circuit current, respectively, at the same time.

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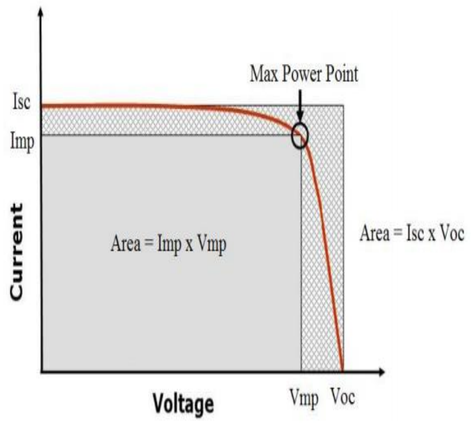

Figure 2: Fill factor

Figure 2 illustrates the fill factor which is the ratio between the two rectangular areas and is given by the following formula.

$$FF = \frac{P_{max}}{P_{theoretical}} = \frac{V_m I_m}{V_{oc} I_{sc}} \qquad (2)$$

The size of the FF is a good indicator of the solar cell's quality. Fill factors typically vary from 0.50 to 0.9. The fill factor is frequently shown as a percentage.

2.2. Efficiency

The capacity to convert sunlight into energy is referred to as the PV cell/module efficiency. It is explained as the proportion of power input to power output. The power output of a solar cell is its maximum power point P_m, and its input power is the power of solar radiation P_{rad}. According to the global standard for characterization of solar cells, P_{rad} is equivalent to either 100mW/cm2 or 1000mW/m2.

$$\eta = \frac{P_m}{P_{rad}} \qquad (3)$$

Using Eq.2 and Eq.3 can be written in alternative forms:

$$\eta = \frac{P_m}{P_{rad}} = \frac{V_m I_m}{V_{oc} I_{sc}} \qquad (4)$$

where P_{rad}=G*A, where G is the total radiation, which is taken to be 1000 W/m2 at (STC), and A is the PV module's area.

2.3. Characteristics of Photovoltaic Panel

The current generated by a solar cell in an ideal situation may be viewed as a current source, with the amount of current produced directly proportional to the amount of solar radiation hitting the cell. Despite the fact that optical and electrical losses cause a cell's actual behaviour to diverge from ideal, the right components should be included with an ideal current source in order to create a model of a solar cell's electrical equivalent circuit (representing solar cell). An electrical circuit representing a PV cell is shown in Fig.3.

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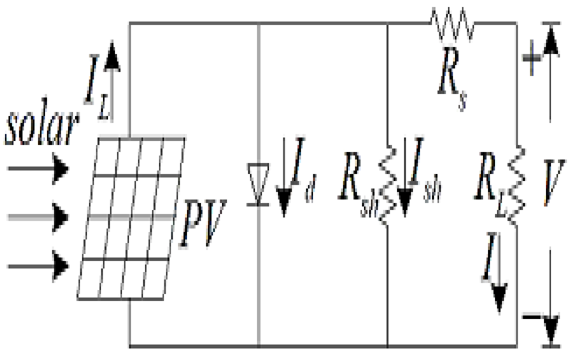

Figure 3: Equivalent circuit of a PV cell.

The cell current can be expressed as

$$I = I_L - I_0 \left[\exp \left\{ \left[q \frac{(V + IR_s)}{ApKT} - 1 \right] - [\frac{(V + IR_s)}{ApKT}] \right\} \right] \qquad (5)$$

Where the symbols are defined as follows:

I_L = Light generated current.

I_o = reverse saturation current of diode (.0002 A).

q = electron charge (1.602 * 10-¹9 C)

A = Diode ideality factor.

K = Boltzmann constant (1.38 * 10-²³ J/°K).

R_s = series resistance of cell (0.0002 A).

T_c = reference cell operating temperature.

The temperature unit for both k and Tc should be the same, either Kelvin or Celius. The I-V characteristics of the cell, as determined by (1), are adjusted to the actual characteristics discovered during testing using the curve fitting factor A. The voltage of a single solar cell is given by Eq. (1), and the total voltage of the solar array is calculated by multiplying that voltage by the number of solar cells linked in series.

Table 1: Specification of Electrical parameters of TBP1275 of 75 Watt at STC

Sl. No.	Performance Parameters	Value	Unit
1.	Peak Power (P_{max})	75	Watt
2.	Voltage (V_{mp})	17	Volt
3.	Current (I_{mp})	4.4	A
4.	Open- Circuit Voltage (V_{oc})	21.8	Volt
5.	Short-Circuit Current (I_{sc})	4.9	A

2.4 Effect of Dust

To understand how dust affects solar photovoltaic (PV) performance, it is important to take into account the following factors: the blockage of sunlight, the rise in surface temperature, and the effect of surface corrosion on sunlight transmission. PV panels may have a heavy coating of dust deposited on their surface. It has a big impact on how well a PV module works. Dust buildup on the surface has a greater impact on the effectiveness of PV power generation.. Studying the fouling effect on PV power generation installations is therefore required. The glass cover of a filthy PV module becomes heated by repeated refraction when light of a specific intensity strikes it.. The PV module's temperature will rise as a result. Dust on PV modules has the effect of obstructing light, which is why this phenomenon is known as fouling (dust). Moreover, dust reduces the panel's irradiated area, leaving just a portion of the panel exposed to radiation. As a result, the module's temperature rises, and the output power efficiency decreases by 0.5% for every degree the temperature raises.

3. METHODOLOGY

The two TBP1275 solar panels, rated at 75 W each, were fixed on a platform that was placed on the roof to conduct the experiment. The test-bed is made up of two identical open rack mounted solar modules that are placed next to one another and facing northeast. The instantaneous amounts of insolation, ambient temperatures, and wind incidence were same for both panels. It was done to set up an experimental setup to determine how much dust settles and how it affects the electrical output of solar panels. One of them served as a standard module for reference while the other unit was utilized for all necessary testing. Voltage and current measurements have been made in order to examine the impact of ambient dust. The net impact of dust on the power decrease was assessed and studied. By comparing the effectiveness of panels with and without dust exposure, the impact of dust may be measured. The solar photovoltaic panel underwent testing, and the variables like V_{oc}, I_{sc}, solar irradiance, etc. required for the systems evaluation were measured.

3.1 Formula for Obtaining the Percentage Reduction of Various Parameters of PV Module

The power output of the PV panel can be obtained from the following equation

$$P = V_{oc} * I_{sc} * FF \qquad (6)$$

Using the above equation the solar panel efficiency can evaluated as follows:

$$\eta = \frac{V_{oc} I_{sc} * FF}{A * I} \qquad (7)$$

Where

V_{oc} is the open circuit voltage

I_{sc} is the short circuit current

P is the output power (Watt).

η is the efficiency of the solar panel (%)

V_{oc} is the open circuit voltage (volt)

I_{sc} is the short circuit current (ampere)

FF is the fill factor

A is the panel area (square meter), I is the solar radiation (W/m²)

$$\text{Percentage reduction in power output of the PV panel} = \frac{P_{without\ dust} - P_{with\ dust}}{P_{without\ dust}} * 100 \qquad (8)$$

$$\text{Percentage reduction in efficiency of the PV panel} = \frac{\eta_{without\ dust} - \eta_{with\ dust}}{\eta_{without\ dust}} * 100 \qquad (9)$$

Percentage reduction in open circuit voltage can be obtained as follows:

$$\frac{V_{oc(clean)} - V_{oc(unclean)}}{V_{oc(clean)}} \qquad (10)$$

Percentage reduction in open circuit voltage can be obtained as follows:

$$\frac{I_{sc(clean)} - I_{sc(unclean)}}{I_{sc(clean)}} \qquad (11)$$

3.2 Effect of Dust on Open Circuit Voltage and Short Circuit Current Characteristics

Surprisingly little research has been done in the field of science on the impact of dust on Photovoltaics' peak power. No broad grasp of the underlying physical principles could be drawn because no information on the type of dust, dust density, or dust accumulation rate was reported. This exam is therefore only applicable to the day, time, and place of their test. The amount of dust that accumulates on the photovoltaic (PV) panel surface is dependent on a number of factors, including the installation style and angle of the PV panel. A solar cell's short circuit current (I_{sc}) and open circuit voltage (V_{oc}) were determined in my study during a period of exposure to constant radiation, fixed tilt angles, and varying amounts of dust deposition.

With the fluctuation of short circuit current and open circuit voltage for clean and unclean surfaces for the solar panel under investigation, together with the berved value of solar radiation. The nature of short circuit current with clean and unclean solar radiation is seen in Fig. 4.2. Short circuit current with a clean surface is represented by the colour red, whereas short circuit current with a dirty surface and solar radiation is represented by the colour blue. Due to dust, short circuit current has been significantly lowered. As a result, the solar cell's output was decreased.

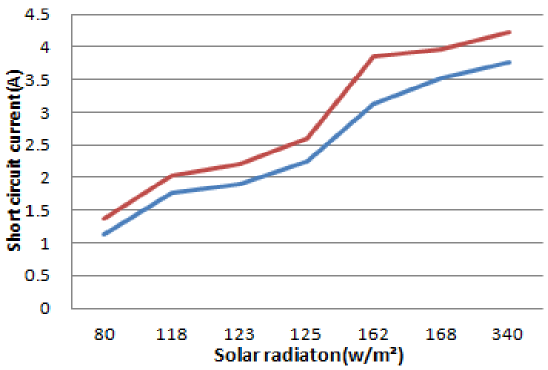

Figure 4(a): Nature of short-circuit current with clean (red) and unclean (blue) surface with solar radiation

The following factors must be taken into account in order to comprehend how dust affects solar photovoltaic (PV) performance: the blockage of sunlight, the rise in panel temperature, and the effect of sunlight transmission due to surface corrosion The surface of PV panels can occasionally develop a heavy coating of dust. It has a big impact on how well a PV module works. The quantity of dust is kept constant in this experiment, while the short circuit current, I_{sc}, and open circuit voltage, V_{oc}, are measured with changes in sun light. Graph features illustrate how dust affects solar panel performance factors like short current and open circuit voltage. The nature of open circuit voltage with clean and unclean solar radiation is seen in Fig. 4.3. The blue colour represents the nature of open circuit voltage with solar radiation and an unclean surface, whereas the red colour represents the nature of open circuit voltage with a clean surface. Due to dust, open circuit voltage has also been significantly lowered.

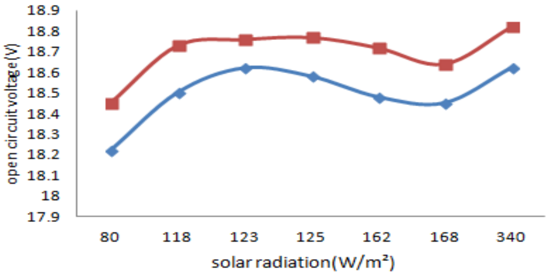

Figure 4(b) Nature of open-circuit voltage with clean and unclean surface with solar radiation.

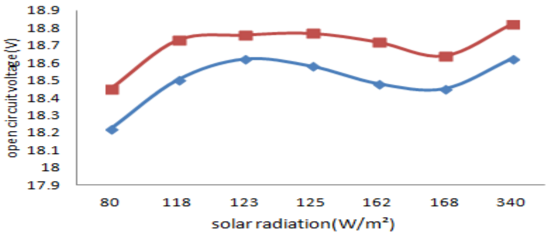

Fig 4(c): Nature of open-circuit voltage with clean and unclean surface with solar radiation.

3.3 Degration due to the Impact of Dust on the Solar Performance

Now, to determine the percentage drop in open circuit voltage, short circuit current, power output, and efficiency that resulted from the deposition of dust particles on the solar panel, the aforementioned equation was used to compute the values. The results are shown in Table 2.

Panel without dust		Panel with dust		Solar Irradiance	Power without dust	Power with dust	% Power drop	Efficiency without dust	Efficiency with dust
V_{oc1} (V)	I_{sc1} (A)	V_{oc2} (V)	I_{sc2} (V)	W/m^2	W	W			
18.82	4.66	18.62	4.20	340	53.17	59.63	10.83	11.22	10
18.64	4.23	18.45	3.77	168	53.18	46.91	11.79	20.25	17.87
18.46	3.97	18.26	3.53	165	49.83	43.83	12	19.32	17
18.72	3.65	18.48	3.24	162	46.46	40.71	12.37	18.35	16.08
18.77	2.61	18.58	2.25	125	33.31	28.42	14.68	17.11	14.55
18.76	2.21	18.62	1.91	123	28.19	24.18	14.22	14.66	12.58
18.73	2.04	18.50	1.76	118	25.98	22.14	14.78	14	12
18.45	1.37	18.22	1.14	80	17.18	14.12	17.81	13.37	11.29

Table 2: Result observed due to deposition of dust particles on the solar panel

Due to dust's ability to scatter, reflect, and absorb solar light, power generation overall is decreased, decreasing panel efficiency. In light of the dust buildup, the power output decreases to a real amount.

On exposed surfaces, dust ultimately accumulates to for a thin film. In our experiment, we compared two different types of dust: red sand and sea sand. The I-V curve for the panel's clean surface with a 4 ohm resistor is shown in Fig. 4.5. Figures 4.6 and 4.7 depict the I-V curve for the sand-covered, unclean surface, respectively, for the red sea sand with 4 ohm resistor. All materials must conform to a specified size in order to have the optimum coating.

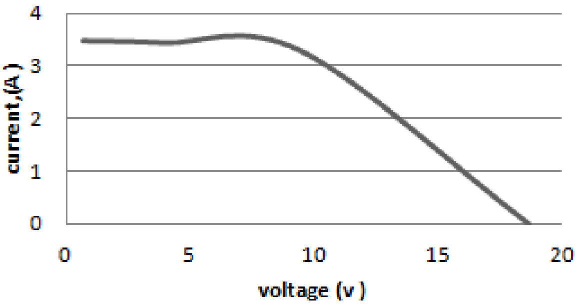

Figure 4(d): Nature of I-V curve for the clean surface with 4 ohm resistor.

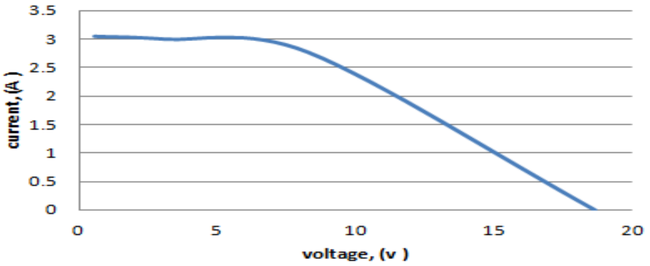

Figure 4(e): Nature of I-V curve for the unclean surface with sea sand with 4 ohm resistor.

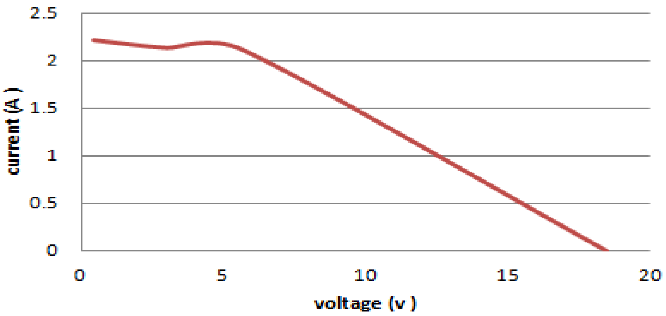

Figure 4(f): Nature of I-V curve for the unclean surface with red sand with 4 ohm resistor.

4. CONCLUSION

The findings indicate that the dust significantly lowers power generation, from 10.83% to 17.81%. The PV solar model must be kept clean in order to receive the most power from it and to ensure optimum performance because the electrical characteristics of solar panels are sensitive to the quantity of dust. As we observed, the colour of the dust may also alter performance. Therefore, it is necessary to clean the solar panel on the red soil location region more regularly in order to get the most electricity possible from it.

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