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Influence of Environmental Dust on the Operating Characteristics of the Solar PV Module in Tripura, India

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Abstract :The production of PV power depends on different meteorological parameters. Accumulation of dust is one of the factor which reduces the output power. The recent study was done in Tripura, India and there is maximum of 13% and minimum of 9% reduction in efficiency has been observed during the period of experiment.

Keywords - Photovoltaic, Dust, Open circuit voltage, Short circuit current, Module efficiency, Degradation in efficiency.

I. Introduction

The photovoltaic solar energy is produced by the conversion of the solar radiance on the cell in electricity. Over the last two decades, there has been a steady rise in the installed capacity of solar photovoltaic power plants. Different meteorological parameters can affect the system performance. It has been reported by the researchers that there has been a good correlation between the ambient temperature and module efficiency and a moderate correlation between wind speed and module efficiency when the module performance were performed in a particular area of Tripura, India. [1]. The photovoltaic cells already have low conversion efficiencies in the range of 16% to 18%, the accumulation of sand and dust particles from the outdoor environment reduces the generated output power. Recently drop in system performance due to deposition of dust has become a major issue. Photovoltaic system performance is brought down 7-20% per month by the accumulation of dust on the cell surfaces [2, 3]. Current research into characterising deposition of dust and impact on PV system performance is limited given the fact that deposition of dust is a complex phenomenon and is influenced by site specific environmental and weather conditions [4].

Study also shows that the nature of dust accumulation may vary by geographical locations. Moreover 5 to 15% reduction in peak power has been obtained by various climatic conditions, especially accumulated dust on the panel. Also a reduction by 20.78% per day of I_{sc} has been obtained. On the other hand Voc has been decreased by 0.863% per day time [5]. Effect of dust is very prominent in Nigeria especially during the Harmattan period; December, January and February [6].

It was found that a reduction of power of 2%, 14.5% and 30% after one, thirteen and thirty two days, respectively, without cleaning the surface of solar panel. In a rainless thirty day experiment in India, a study shows that dust reduced the transmittance by an average of 8% for glass cover tilted at 45° [7]. It is also reported by the researchers that the dust deposition does not significantly alter the open circuit voltage of the PV system but short circuit current is drastically affected by dust deposition, which reduces the power output. [8].

Dust consists of small particles in air. Dust is generally measured in micrometers. Dust is covered on the solar panel naturally. The layer of the dust on the solar panel increasing with the time respectively. The value of short circuit current, power decreases with respect to the amount of dust on the solar panel. The study represents a weekly investigation for six months of two identical panels maintaining one panel clean throughout the period of experiment. Survey shows that average suspended matter particulate (SPM) in different areas Tripura covering industrial and commercial areas ranges between 97 – 177 μg/m^3. The average solar irradiation received by Tripura is around 4 - 4.5 kWh/m^2. For receiving maximum output power the solar panels were tilled at its latitude of 23.53^0.

II. Material and Methodology

The experiment has been done with two identical module of manufactured by M/S TATA BP SOLAR INDIA LTD, INDIA. A digital clamp meter (**Mastech MS 2101 Digital AC/DC clamp meter**) to measure the short circuit current and open circuit voltage. The temperature lead has been used to measure the ambient temperature, and cell temperature. TM-207 Solar Power meter (Make: TENMARS) has been for the measurement of the solar radiation that is emitted by the sun from a nuclear fusion reaction that creates electromagnetic energy. The units of measure are watts per square meter (W/m^2). The experimental study was done in the North Eastern region of India called Tripura. The latitude and longitude of the location are 23°50' N and 91°25'. The PV panes used for this study are of monocrystalline type. The specifications are listed below.

Cells per module: 37 W
Cell area: 0.3239 sq. meter.
Maximum power: 37 W
Voltage at maximum power: 16.4 V
Open circuit voltage: 21 V
Current at maximum power: 2.26 Amp
Short circuit voltage: 2.5 Amp
Fill Factor: 0.85

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

$$P = V_{oc} * I_{sc} * FF \quad (1)$$

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

$$\eta = \frac{V_{oc} I_{sc} * FF}{A * I} \quad (2)$$

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/m^2)

$$Percentage\ reduction\ in\ efficiency = \frac{\eta_{clean} - \eta_{unclean}}{\eta_{clean}} \quad (3)$$

$$Percentage\ reduction\ in\ open\ circuit\ voltage = \frac{V_{oc(clean)} - V_{oc(unclean)}}{V_{oc}\ (clean)} \quad (4)$$

$$Percentage\ reduction\ in\ short\ circuit\ current = \frac{I_{sc}(clean) - I_{sc}(unclean)}{I_{sc}\ (clean)} \quad (5)$$

The experiment is done using two identical 37W solar modules placed on the rooftop of Tripura Renewable Energy Development Agency, Agartala, Tripura, India. The panels have been oriented facing south and tilted at an angle equal to the latitude of the measuring place. One panel was maintained free of dust for the period of experiment and the other panel was tested for the accumulation of dust throughout the duration of the test period. The electrical parameters like open circuit voltage (Voc) and short circuit current (Isc) have been measured to study the effect of environmental dust effect. The net effect of dust on the reduction in efficiency have been evaluated and analysed. In the recent study the effect of dust on panel efficiency has been analyzed for the period as mentioned above when the atmosphere is covered by maximum dust. The whole experiment has been done for six months period. The short circuit current and open circuit voltage values were recorded for each day from 10:00 a.m. to 5:00 p.m. at an interval of one hour for the each experimental day. The dusty and clean panels have been shown in Fig. 1.

Figure 1. Image of dusty (left) and clean (right) surface.

From the measured values of short circuit current, open circuit voltage and the solar radiation data daily average values of efficiency have been calculated using equation (2). For the convenience of measurement the experiment has been observed on weekly basis and accordingly the values of efficiency for each week for both clean and unclean surface have also been segregated.

III. Results and Discussions

In the recent work the percentage reduction of module efficiency was observed for each week and then the average percentage reduction is calculated. The data measured for the electrical parameters have been depicted in Table 1(The table has been splitted). It is seen from the table 1 that, there is a very little difference in the open circuit voltage for the clean surface and the unclean surface. It is confirmed from the ratio of the open circuit voltage for the unclean surface to the open circuit voltage for the clean surface. The ratio becomes almost nearest to 100%, which means that dust does not affect much in open circuit voltage. But in case of short circuit current, the ratio ranges from 83 – 91%, which means the dusty panel has a considerable affect on short circuit current. Also the values of efficiencies have been evaluated using the measured values of the electrical parameters using equation (2). What percentage of power or efficiency is degrading can be understood which will be helpful for cleaning purposes at a certain time interval.

Table 1. Experimental measured parameters.

Solar Insolation (w/m^2)	Ambient Temperature (°C)	Average Efficiency (%)	
		Clean	Unclean
129	20.1	11.47	10.00
135	22.5	11.67	9.85
210	34.66	12.95	11.29
230	35.8	13.64	12.04
235	34	13.39	12.15
240	32.35	13.77	12.52

Open circuit voltage (V_{oc})		Short circuit current (I_{sc})		V_{oc}(unclean) / V_{oc} (clean)	I_{sc}(unclean)/ I_{sc} (clean)
Clean	Unclean	Clean	Unclean	(%)	(%)
13.45	13.41	0.54	0.45	99.70	83.33
13.51	13.43	0.66	0.59	99.40	89.39
15.01	14.93	0.76	0.68	99.46	89.47
15.23	15.19	0.78	0.71	99.73	91.02
15.35	15.31	0.78	0.71	99.73	91.02
15.51	15.46	0.81	0.73	99.67	90.12

With the measured value of solar radiation, the variation of short circuit current and open circuit voltage for clean and unclean surface for the solar panel under investigation shown in Fig. 2 and 3 respectively. It is seen that the amount of reduction is increased gradually from first week to fourth week of each month. The degradation occurred from the beginning of the month to the end have been observed for each month. Accordingly the measurements have also been taken each day

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for the dust free module. Generally the efficiencies of the clean surface are always higher in magnitude than the unclean surface. These differences were attributed to the deposition of dust particles on the surface of the solar module. Figure 4 shows the variation of efficiency for clean and unclean surface with solar radiation is shown in a 3D surface plot

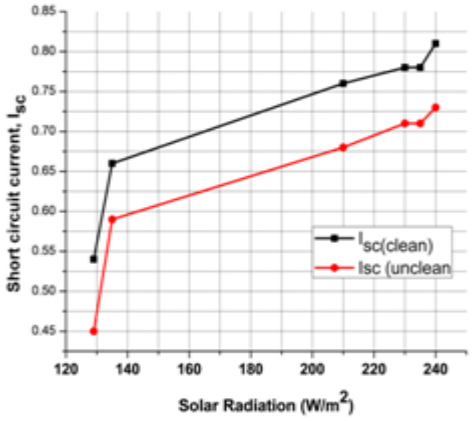

Figure 2 The nature of short circuit current for clean and unclean surface with solar radiation

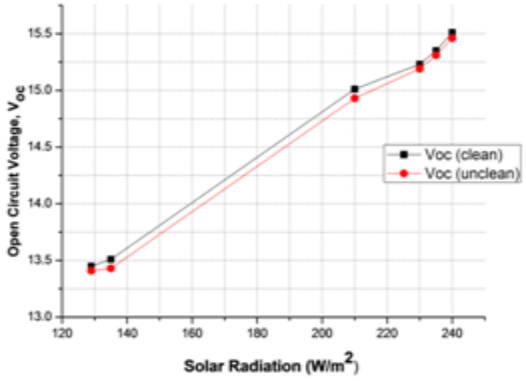

Figure 3 The nature of open circuit voltage for clean and unclean surface with solar radiation

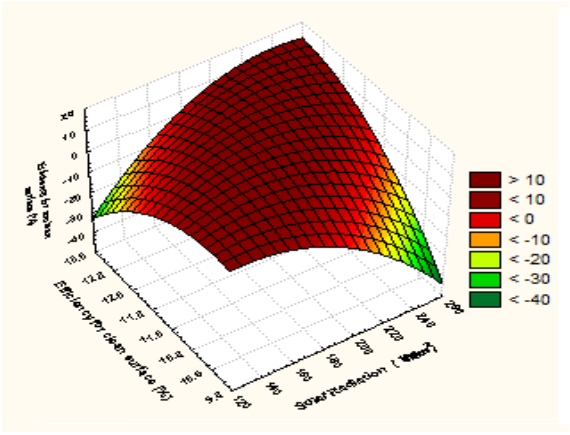

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Figure 4 Variation of efficiency for clean and unclean surface with solar radiation.

Now, to check the degradation occurred due to the deposition of dust particles on the solar panel have also been studied and the values of percentage reduction in efficiency as well as short circuit current and open circuit voltage, for example, Table 2. It is observed that the percentage reduction in open circuit voltage with compared to short circuit voltage is really negligible which lies from 0.29- 0.32%. On other hand the percentage reduction in short circuit current which lies in the range of 9.87% to 16.66%, affects the efficiency of the solar panel linearly.

Table 2 Degradation of electrical parameters.

Percentage reduction in efficiency (%)	Percentage reduction in I_{sc} (%)	Percentage reduction in V_{oc} (%)
12.81	16.66	0.29
15.59	10.60	0.59
12.95	10.52	0.53
11.73	8.97	0.26
9.26	8.97	0.26
9.07	9.87	0.32

This reduction is due to scattering, reflection and absorption of solar radiation by dust which decreases the overall power production thus reducing the panel efficiency. The variation of percentage reduction of module efficiency, short circuit current and open circuit voltage are shown in Table 2. In actual case the values of short circuit current appears high for the panel which is maintained clean throughout the test period than the dusty panel. Moreover the average reduction in panel efficiency lies between 9-12% for the test period. That, the generated power reduces to a significant value for the accumulation of dust.

IV. Conclusion

Thus from the recent study it can be concluded that due to the effect of dust the output power reduces to a large extent resulting to a lower value of efficiency occurred during the period of experiment in the North eastern region of India. To maintain the solar power plants efficiency maximum, they must be kept clean. The efficiency gradually decreases over time for dusty environment. Therefore it is very much important to clean the surface after a certain period probably after one month. Therefore it is very essential to provide the photovoltaic system with cleaning device to achieve high performance.

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