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Performance and Degradation Analysis of Real Time Operating PV Panels

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Abstract: The most dependable constituent of the photovoltaic system is considered to be PV modules. The energy conversion performance and degradation modes of the modules are crucial for their reliability and lifetime. Understanding PV systems' performance and degradation through their lifetime is the objective of this study.To that end, the work in our paper presents a simplified examination of various causes for degradation specially hotspot degradation in silicon PV modules and different types of methodologies incorporated to investigate these degrading mechanisms.Under STC condition and when module is not dust covered it can be observed that the maximum power generated by the module id 360.8 watts at the voltage 39.09 V. The efficiency observed is 17.55 and the fill factor is 78.4. How ever when module was subjected to real out door condition drastic change in the outpower was noticed due to presence of the dust deposition. It can be observed that in case 2 when the module was subjected to irradiance of 1100 watts per meter square the power generated dropped to 255.9 watts creating a loss of 29 % of power . Similarly, the efficiency drops to 11.75 and fill factor drop to50.23. Along with the temperature of the dust accumulated area was observed to be 55 degrees Celsius.

Keywords: Photovoltaics, power output, performance parameter, soiling

1 INTRODUCTION

The total solar energy coming on Earth is far more than the global energy needs at the moment and in coming future [1]. This highly distributed source has the ability to meet all future energy demands if properly exploited. Due to its limitless supply and lack of pollution, solar energy is predicted to become a more appealing renewable energy source in the twenty-first century than the finite fossil fuels to be very precise examples like coal, petroleum, and or natural gas [2].

The problem at hand is the degradation of photovoltaics of hotspots development due to the a layer of accumulation of dust on the surfaces. Photovoltaic systems so are designed so as to capture and convert solar energy into electricity, but when dust and debris settle on the surface, it can reduce the efficiency of the system by hindering the sunlight and reducing the output. Hotspots are areas where excessive heat is generated due to a localized increase in resistance, which can occur as a result of the accumulation of dust or other factors. If left unaddressed, the degradation of photovoltaics due to dust accumulations can lead to a very noticeable decrease inenergy production, reduced lifespan of the system, and increased maintenance costs. Therefore, it is important to develop effective cleaning strategies and maintenance plans to prevent the build-up of dust and other sorts of contaminants on the surface of photovoltaic systems. One eye-catching agenda accumulation of dust on photovoltaic systems is the development of hotspots. Hotspots occur when there is an increase in resistance in a localized area, which can cause excessive heat generation that can damage different components of thePV system. Hotspots can occur due to a variety of factors, including shading, manufacturing defects, and the accumulation of dust and debris on the surface. The accumulation of dust on photovoltaic systems can also lead to other issues, such as reduced lifespan of the system, increased maintenance costs, and the need for more frequent cleaning. In addition, the buildup of dust can also impact the performance of the system during periods of low sunlight, such as cloudy days or during the winter months.To address the problem of degradation of photovoltaics due to dust accumulation, there are various strategies that can be employed.

These include regular cleaning and maintenance of the system, the use of self-cleaning coatings or surfaces, and the installation of monitoring systems that can detect hotspots and other issues before they become a major problem. Additionally, proper installation and location of the photovoltaic system can also help to reduce the accumulation of dust and debris, thereby improving its performance and lifespan.

2 DEGRADATION IN SOLAR CELL

Renewable energy is allowing a significant and fast growing source of energy worldwide. It is predictable that solar PV and wind energy will chief in all the energies by 2025 [3]. How ever the PV module reliability seems a great issue where its manufactures give a warranty of 25-30 years [32]. With such a long run of installation its very well obvious that the PV module can degrade . Recent studies has determine the degradation rate of 0.6-0.7% per year [4]. Some studies also show s that degradation can also reach up to 0.7% [5].

Depending upon degradation the degradation bifurcated in short-term and long-term.The life of the PV system hugely impacted by the degradations [6][7]. According to very famous lab name by NREL spotted that the most seen degradation in last decade is mentioned below as shown in figure 1:

I. Ribbon Discoloration – 20%
II. Glass Breakage– 12%
III. Encapsulant discoloration - 10%
IV. Cell breakage -9%
V. PID - 8%

Degradation in photovoltaic (PV) modules refers to the loss of performance or efficiency over time due to various factors. While PV modules are designed to be durable and have long lifetimes, they can experience degradation, which can impact their power output and overall effectiveness.To mitigate degradation, manufacturers employ various techniques, such as using high-quality materials, improved encapsulation techniques, and implementing rigorous quality control measures during the manufacturing process. Regular maintenance and inspections of PV systems can also help identify and address degradation issues at an early stage.

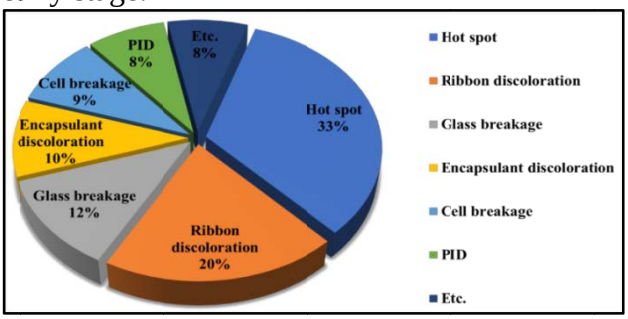

Figure 1 : representation of percentage of degradation in solar cell.

3 HOTSPOT DUE TO SOIL AND DUST – LITERATURE SURVEY

Degradation can me defined as phase when there is a decline in theperformance of the PV panel output[37]. However PV module might still continues to perform after degradation depending upon the severity . If the degradation crosses the value of its critical threshold , creates a very dangerous situations [8].

Hotspots in a PV module is one such degradation where a portion on PV module attains very high value . There could be many reason for hotspot in PV modules such as

I. Shadow
II. Dusting
III. Cell mis match
IV. Any interruptions in connections between the cells.

Hot spots result from this defective solar cell's either shaded or soiled forms burden on the other cells and create high heat-dissipation sites [9][10]. Figure 2 show different conditions arising in a PV module due to hotspots.

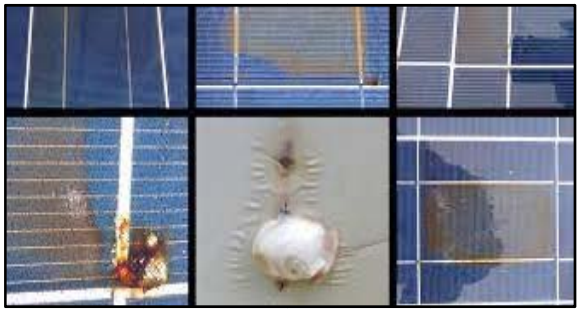

Figure 2 : Different types of hotspots in a PV panel.

It has been seen that the efficacy of the PV module can get decline by 25% due to presence

of soil , dust and deposition upon debris on the surface [11]. This process of soil or dust deposition limits the sunrays incidence on the surface of PV panel , hence forcing the panel output to decline. This causes the mismatch in the output of covered cell and uncovered cell in the module[12]. Dust usually is small particles nearly 500 micro meters of size disperse in the air from different sources like wind,vehicle movements ,pollution etc.[13]. A development of hotspot can be easily seen through the figure 3 below . The soiled or dusted cell develop hotspot [14]. One such example is a module installed in desert area are subjected to soil deposition by climatic zone[15]. According to article by Goossens et all, the accumulation of dust decreases as there is increase in the speed of wind and this is highly influence by the orientation and titlt installation of a PV modules.

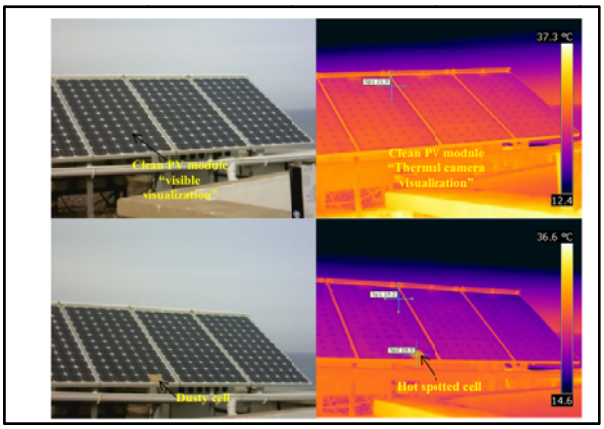

Figure 3 : Hotspot generation due to soiling

The deposition of dust layer has one more parameter which is the density of soil layer was demonstrated in the presented research by EL-Shobokshy [16]. The research paper by researchers Montes et al showed that dust of Sahara desert is creating some impact on the PV system performance. The Soil was of texture thin reddish brown [17]. In a research study dust deposition causes reduction of output of approximate 7 % with solar radiation drop due to dust by 3% [18].A new aspect was analysed by a study from University of Malaga, which showed that the time period from which the soil is deposited is also very important, [19]. According to research work if dust retains on a module for one to six months can cause rapid decline in the efficiency[20] . Various types of soiling images can be seen in the figure 3

Figure4 : Possible soil and dust- deposition on PV module

A work showed that the impact of various types of dust like sand ;lime-salt ; ashes; soil; that impact the what we call the optical transmission glass used in module [21].The accumulated dust creating a thermal run-away impact in the PV module causing reduction in the electrical performances [22]. On the other dusting may lead a well known impact of hotspots causing over heating of a module [23]. The main reasons for dust accumulation can be noticed in figure 4 and figure 5.

I. Figure 17 A.- shows the image of modules covered with mineral dust layer
II. Figure 17 B.- shows the modules covered with birds excreta.
III. Figure 17 C. - shows the deposition of algae.
IV. Figure 17 C . - shows deposition of pollens.
V. Figure 17 C. - shows engine exhaust layer over module .
VI. Figure 17 C. - shows deposition of agricultural emission.

There are two forms of shading. The first sort of shadowing is hard shading, which happens when solar panels are covered by a solid object, like a structure or a cloud of dust. Smog in the air might result in the second form, subtle shading. The voltage drops with the first one. The voltage is unaffected by the second, but the current is. Both have an impact on PV module performance. Soiled or darkened surfaces are linked to performance and power loss. In actuality, cells that are darkened exhibit resistance to generated current. They get hot and produce hot spots.

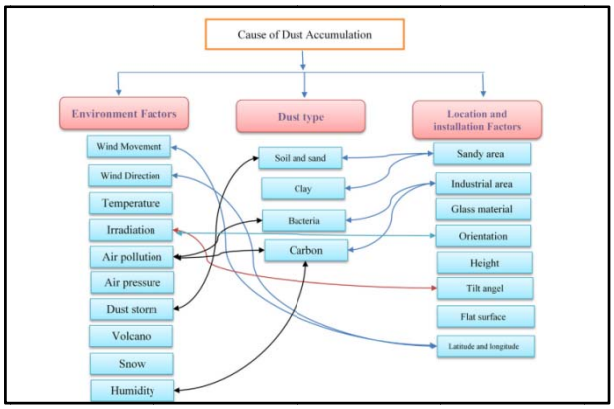

Figure 5 : The main reason for dust accumulation

4 RESULTS

The entire frame work depends on various factors that impact the soil deposition. The figure 5 shows what are the factors impacting the settlement of dust on surface of PV panel [24]. The full experiment is divided into 2 parts:

1. Visual inspection
2. Electrical Characterization

4.1 VISUAL INSPECTIONS

The visual inspection was performed on the roof top of the Solar panel installed on the Dr K.N.Modi University, Newai Rajasthan. The panel is first experiment with visual inspection. The panel used for the experiment is mono-crystalline roof top panels. The panels have heavy deposition of dust over the entire modules and edges of the PV modules. A single module of 380 Watts have used for the test purpose. The module specification can be seen in Table 1.

The module specifications are as follows:

Table 1: Module Specification

Type of solar panel	Mono-PERC
Wattage	380
Operating Voltage	24V
Number of cells	72
Brands	Patanjali

As we can see in the through visual inspection a lot of dust is deposited on the panel . And the edges of the panel also have more deposition of the sand . Nothing can be seen through just overlooking the panel. Figure 6 shows that the panel is heavily loaded with the dust especially on the edges.

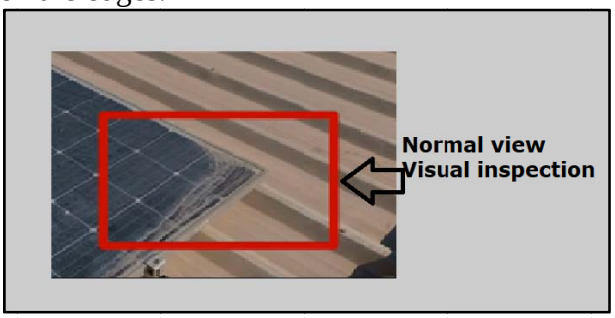

Figure 6 : The picture of the module under inspection

4.2 I-V CHARACTERISTICS

4.2.1 Under Normal condition

The graph shown below are the I-V curves under STC conditions that is irradiance of 1000 watts per meter square and temperature with 25 degrees Celsius. Figure 7 represent the I-V and P-V characteristics when no dust is present. This is under condition when module is clean that is when there is no dust deposition. The x-axis represent the voltage and Y axis represent the current of the PV module under test.

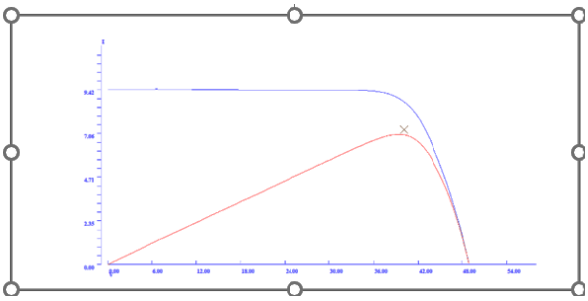

Figure 7: I-V and P-V characteristics of the PV module when no dust deposition is applied in the lab.

4.2.2 I-V Graph under test conditions

To find out the impact on working and performance characteristics of PV module and to understand the difference between the outputs whenthe module is shaded or not , the module was put under real condition on roof top and not cleaned for 1 month and allowed on the module sand to deposit .

The dust deposition has impacted the output in following ways:

I. The Module efficiency dropped.

II. The power generated dropped.
III. The fill factor of the module dropped.
IV. The hotspot created in the panel.

The curves get distorted and multiple maximum points can be seen in I-V &P-V curve which is the representation of any kind of shade or dust available on the panel which can be seen in figure 8 .

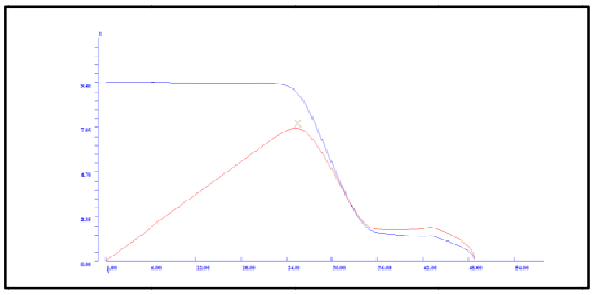

Figure 8: The electrical characteristic curve with dust deposition .

4.3 TEMPERATURE-IRRADIATION RESPONSE OF THE CELL COVERED WITH DUST

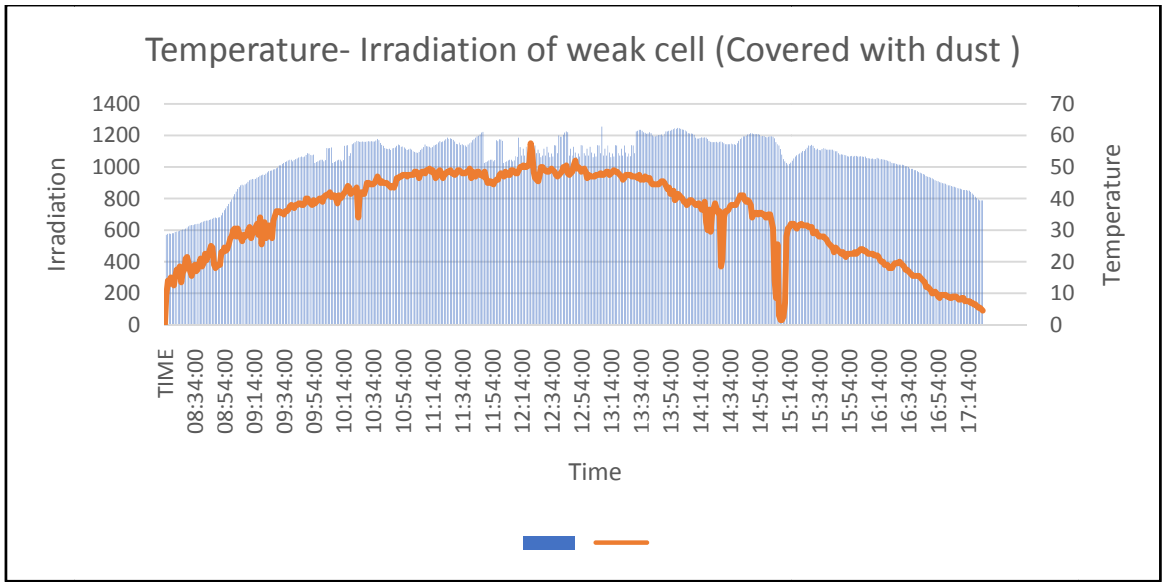

Figure 9 : The modulation of the weak cell temperature (cell covered with Dust) for entire day .

The module was tested on 5th April, 2023 on the roof top of Dr. K.N.Modi University. The temperature of cell covered with the shadow is measured with the help of the thermocouple attached at the back of the PV Module. The irradiation was measured with the help of pyranometer attached to the module. It can measure irradiation for whole day. We have measured the reading from 08:15:00 till 17:24:00. The figure 9 shows the variation of hotspot with the irradiation. The orange line shows the variation of irradiation from morning to evening. While the blue graphs were temperature variation of the soiled cell. Table 2 show the temperature profile of the hotspot created on the test solar panel due to soil and dusting. It can be noticed that the hotspot maximum temperature is 60.8 degree Celsius. Also, table 3, table 4 shows the various performance parameters. It can be seen that due to outdoor testing the power and due to creation of hotspot the power drops to the level of 201 watts from 360. 2 watts when measured in STC conditions. There is also drop in the parameters like efficiency from 17.55 to 9.2 percentage and fill factor drop from 78.4 – 45.6 percentage which represents the deterioration of the module due to hotspot.

Table 2: Temperature configuration of the formed hotspot due to dust.

Average Temperature	50.4^0C
Maximum Temperature	60.8^0C
Minimum Temperature	41.9^0C

Table 3 : Comparison of Experimental Results with 1100 Watts/ m^2Irradiance

Irradiance Watts/m2	**Pmax (W)**	**Efficiency** (%)	**Fill Factor F.F.(%)**	**Module Temp.**
1100	201	9.2	45.6	55.5

Table 4: Comparison of Experimental Results at STC

Irradiance Watts/m2	**Pmax (W)**	**Efficiency** (%)	**Fill Factor F.F.(%)**	**Module Temp.**
STC	360.8228	17.55	78.4	24.8

5 CONCLUSION

The IV curve clearly showed that module under STC and when soil were not deposited. It was clearly observed that Under STC condition and when module is not dust covered it can be noted that the maximum power generated by the module id 360.8 watts at the voltage 39.09 V. The efficiency observed is 17.55 and the fill factor is 78.4 . How ever when module was subjected to real out door condition drastic change in the outpower was noticed due to presence of the dust deposition . It can be observed that in case 2 when the module was subjected to irradiance of 1100 watts per meter square the power generated dropped to 255.9 watts creating a loss of 29 % of power . Similarly the efficiency drops to 11.75 and fill factor drop to50.23. Along with the temperature of the dust accumulated area was observed to be 55 degree Celsius.

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