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Comprehensive Analysis of Effect of Accumulation of Dust on a Solar Panel

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Abstract

In the pursuit of a cleaner and sustainable environment, solar photovoltaic (PV) power has been established as the fastest growing alternative energy source in the world. This extremely fast growth is brought about, mainly, by government policies and support mechanisms world-wide. Solar PV technology that was once limited to specialized applications and considered very expensive is becoming more efficient and affordable. Solar PV promises to be a major contributor of the future global energy mix due to its minimal running costs, zero emissions and steadily declining module and inverter costs. Deposition of airborne dust on outdoor photovoltaic (PV) modules may decrease the transmittance of solar cell glazing and cause a significant degradation of solar conversion efficiency of PV modules. Dust deposition is closely related to the tilt angle of solar collector, exposure period, site climate conditions, wind movement and dust properties. In this practical field study, an experimental-based investigation is conducted. Thus, we conducted a study to gauge the effect of dust on the solar panel over a pre-determined period.

1. Introduction

Energy is basic need for humanity. Currently energy consumption is based on waste from fossil fuels like oil, coal and gas. These sources are not inexhaustible and these can causes environmental degradation. The increasing energy demand generally in developed countries, where we are included, is due to their lifestyle. Thus, it is anticipated that the primary energy demand in the world in mid-century will double or triple the current demand, owing to the increasing industrialization, economic development and the population growth. With this consumption of fossil reserves created by nature during centuries will be extinct. It is estimated that reserves of oil, gas and coal will be exhausted in 21, 65 and 155 years respectively, at current rates. Thus, the only alternatives that remain are nuclear fusion energy, which still has much to develop, and renewable energies. In front of conventional sources, the renewable energies are clean and inexhaustible resources provided by the nature with practically no impact on the environment. Within the renewable energies, there is hydropower energy, which is almost saturated, requiring large extensions of land; the wind energy which is the one which has had the greatest boom in recent; without underestimating the biomass, and probably /will be the future fuel for vehicles, along with solar thermal and photovoltaic, which are those with higher expectation for the future.

As we know any shadow made on a solar collector can affect many parameters of the operating performance. In order to take electricity from a PV module we have the need of the main source which is the sun. The irradiation of the sun absorbed from each PV cell and conversed to electricity due to the photovoltaic phenomenon. If shadowing effect takes place on our PV module we have a performance decrease, due to the decreased irradiation absorption. The research activity and development in PV field has usually been focused on solar radiation analysis, efficient operating strategies, design and sizing of these systems. Solar cell efficiency is an important input parameter in PV-powered product design. As a basic parameter, cell efficiency serves as an input in calculating the optimal system configuration, e.g., as a cost related trade-off between the storage unit and its lifetime, PV size and its efficiency, and finally the demand side. Power measurements of PV modules in test laboratories and industry are usually performed with solar simulators. Dust is the lesser acknowledged factor that significantly influences the performance of the PV installations.

The accumulation of dust on the surface of the photovoltaic modules decreases the incoming irradiance to the cell and produces power losses. In these cases the only solution is to clean the modules with water. In large-scale photovoltaic plants this task is often expensive, especially in those areas with water shortage.

Sand dust is expected to be a detrimental agent in most arid zones of the world; at least as far as solar energy applications are concerned. When particles are deposited on photovoltaic (PV) modules, they interfere with illumination quality by both attenuating and scattering light.

The degree to which the particles interfere depends on their constitution, density and size distribution. Particles impinge onto a surface due to gravity, electrostatic charge or mechanical effects. After deposition, they are held by a charge double layer, surface energy effects and capillary effects, in addition to gravity and electrostatic forces.

Dust is one of the natural elements present in most environments. The particle size and composition depend on the location. In some regions, dusty weather conditions tend to be more severe than in others. For example invisibility decreases during dusty days. Dust eventually settles on exposed surfaces, creating a fine layer of accumulated dust. Different parameters are reported to influence the dust accumulation such as gravitational forces, wind speed, wind direction, electrostatic charges and the wetness of the surface. Of those parameters, the most dominating ones are the gravitational effect, particle size and wind speed. Slow wind speeds increase the deposition of dust, whereas high wind speeds help to remove dust if the wind is incident in an appropriate direction spots vary in shape, location and dust density. Then it appears obvious that

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dust has a direct effect of reducing the performance of solar PV modules.

A progressive effect has been reported for certain weather parameters such as relative humidity, rain and ambient temperature. Both settled as well as airborne dust reduces the amount of solar radiation incident on the surface of a PV module. They showed that there is an aerodynamic relation between airborne dust, accumulated dust and the reduction in PV power output.

2. Dust Concentration

The transmission of the deposited dust on the glass reduces more for lower wavelengths than for higher wavelengths. The small discontinuity in the transmittance curve at 350 and 800 nm happens during the detector change in the spectrophotometer and is a normal measurement uncertainty for the device used. For dust densities above 19 mg/cm2, the wavelength-dependence of the transmission reduction is significantly reduced. For wavelengths >570 nm, the variation between density–transmittance curves with respect to average is 2.5% whereas for wavelengths <570 nm, it is 11%. Thus, dust affects lower wavelengths more severely.

Heavy Dust on Solar Panel

Another concern with dust is that accumulation of dust on the surface of a PV module can produce spots with varying concentrations of dust particles. These spots vary in shape, location and concentration density. The variation in dust accumulation in any place can lead to different transmittance of light into the module, thus leading to small random areas on the PV module with reduced solar radiation. These effects can produce inhomogeneous shading on the surface of the cell. It also increases the possibility to trigger the hot spot effect for modules that are installed in a string where the operating current of a module exceeds the short circuit current of the affected cell, e.g. due to shading or dust accumulation. When this case occurs, the affected cells are forced into reversed bias and thus dissipate power. Variation in dust accumulation can lead to different transmittance of light into the module, thus leading to small.

The installation of PV systems for optimum yield is primarily dictated by its geographic location and installation design to maximize solar exposure. However, there are other depending factors that arise in determining the system performance (efficiency and output). Dust is the lesser acknowledged factor that significantly influences the performance of the PV installations. PV modules are highly reliable. However, in polluted environments, over time, they will collect grime and dust. There are also limited field data studies about soiling losses on PV modules.

The photovoltaic cells already have low conversion efficiencies in the range of 12% to 15%; the accumulation of sand and dust particles from the outdoor environment on their surface further reduces the generated output power. This is due to the reduction the solar radiation incident on the solar cell. Further dust changes the dependence on the angle of incidence of such radiation. This limitation makes photovoltaic cells an unreliable source of power for unattended remote devices, such as solar-powered traffic and other remote applications in environmentally hazard areas. For large-scale solar plants to maintain their maximum efficiency, the photovoltaic cells must be kept clean, which can be a challenging task in dusty environments.

PV modules are highly reliable. However, in polluted environments, over time, they will collect grime and dust. There are also limited field data studies about soiling losses on PV modules. The inherent material property of this semi-conductor limits the PV system efficiency of the photovoltaic system to within 15–20%. Appropriate installation design to maximize solar insulation can potentially ensure sustained yield. However, these are vulnerable to, often overlooked, on-site omnipresent practicalities such as deposition of dust, bird droppings and water-stains can significantly degrade the efficiency of solar thermal installations. For PV installations module efficiency is further reduced by 10–25% due to losses in the inverter, wiring, and module soiling.

Studies related to dust accumulation is critical as a further decrease in the (practical) system efficiency will tend to make PV systems an unattractive alternative energy source, particularly for the larger domestic markets. Current research into characterizing deposition of dust and their impact on PV system performance is limited given the fact that dust deposition is a complex phenomenon and is influenced by diverse site-specific environmental and weather conditions. Dust is a term generally applying to minute solid particles with diameters less than 500 mm.

It occurs in the atmosphere from various sources such as dust lifted up by wind, pedestrian and vehicular movement, volcanic eruptions, and pollution. Dust would also refer to the minute pollens that are omnipresent and easily scattered in the atmosphere and consequently settle as dust.

The characteristics of dust settlement on PV systems are dictated by two primary factors that influence each other, viz., the property of dust and the local environment. The local environment comprises site-specific factors influenced by the nature of prevailing (human) activities, built environment characteristics, environmental features and weather conditions. The property of dust (type –chemical, biological and electrostatic property, size, shape), is as important as its accumulation/aggregation. Likewise, the surface finish of the settling surface (PV) also matters. A sticky surface is more likely to accumulate dust than a less sticky, smoother one. It is also a well known that dust promotes dust, i.e. with the initial onset of dust, it would tend attract or promote further settlement, i.e. the surface becomes more amenable to dust collection.

Taking into account the effect of gravity, horizontal surfaces usually tend to accumulate more dust than inclined ones. This however is dependent on the prevalent wind movements. Generally a low-speed wind pattern promotes dust settlement while a high-speed wind regime would, on the contrary, dispel dust settlement and have a cleaning. However, the geometry of the PV system in relation to the direction of wind movements can either increase/decrease the prospects of dust settlement at specific locations of the PV system.

Dust is likely to settle in regions of low-pressure induced by high-speed wind movements over inclined/vertical surface. The dispersal of dust attributed to wind movements and geometry of PV system depends on the property of dust (weight, size, type). It is easy to discern that the phenomenon of dust settlement is extremely complex and challenging to practically handle/comprehend given all the factors that influence dust settlement

3. Analysis

In this analysis, we have taken the current readings of individual modules of two strings comprising of 10 modules each. We have taken the current readings before cleaning the set of panels and after cleaning the panels after specific time intervals and then calculated the percentage decrease in the current ratings of PV module due to the dust accumulation. The base value is the current reading taken after cleaning the panel.

We have taken two strings, each with 20 modules. We started the experiment on 6th February 2015, by taking reading of both the strings, without cleaning and then we cleaned the First string i.e. the first 10 modules, and left the next 10 modules as it is.

Now, we again took the current reading with the clamp meter on 13th February, So, we have dust accumulated of one week on the panels, then what we did was we cleaned the first 10 modules i.e. string 1 and left the next 10 modules as it is.

The graph which we obtained was as shown belo Now, when we took the readings again on 21st February we had two weeks dust accumulated on string 2, and the current readings were observed to be as shown in the graph.

Again, when we took the readings on 27th February, we had three weeks dust accumulated on string 2.

So, what we were able to achieve through this was a comparative analysis and the results obtained are listed in the conclusion part.

$$\text{Current decrease after 1 week} = \frac{3.74 - 3.54}{3.74}$$

=5.35%

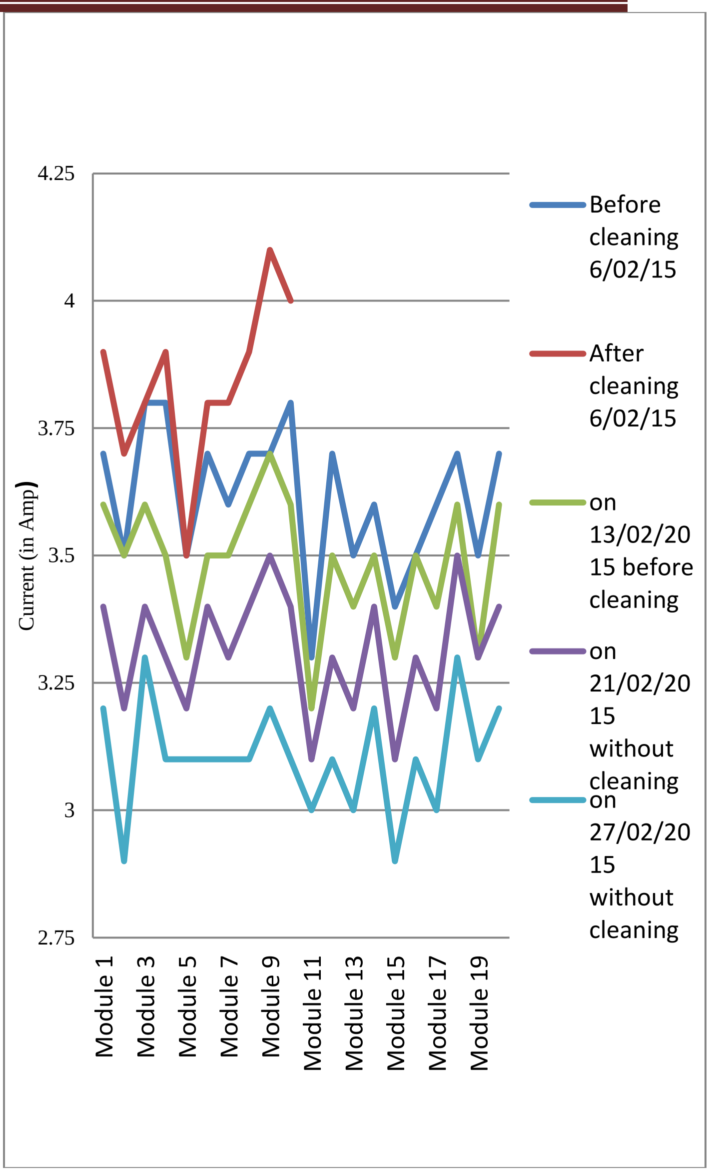
$$\text{Current decrease after 2 weeks} = \frac{3.74-3.31}{3.74}$$

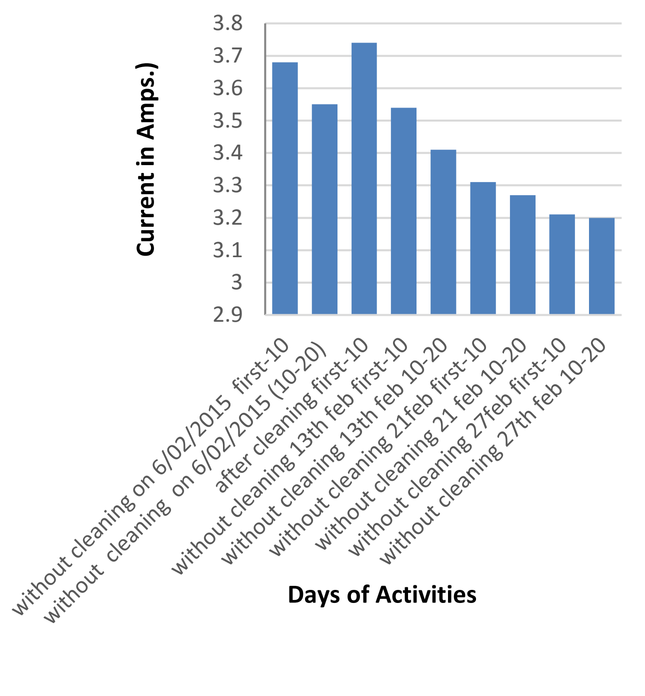
= 11.5%

$$\text{Current decrease after 3 weeks} = \frac{3.74-3.21}{3.74}$$

= 14.7%

As Shown in the graph, clearly, we can infer that there is a decrease in the current rating as the accumulation of dust increases with time. The percentage decrease in current increases as the dust accumulation on the panels increases with the increase in the number of days.





4. Conclusions

- The current sharply increases after cleaning the panels.
- The percentage decrease in current increases as the dust accumulation on the panels increases with the increase in the number of days.
- The current value of panels depends on the load connected to the system, weather changes, and the dust accumulation on the panels.
- The blowing wind also affects the performance of the modules.

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