EFFECT OF DUST ON THE PERFORMANCE OF PV PANEL AND PROPOSING EFFECTIVE CLEANING TECHNIQUES

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ABSTRACT

Solar power plays a significant role in the contribution of energy worldwide. The performance of solar panels mainly depends upon geographical and environmental factors. The manuscript examines the influence of dust accumulation on the performance of solar panels, with a particular focus on the adverse effects of dust on power generation efficiency and dependability. The performance of solar panel glazing is affected by the gathering of dust on solar panels which leads to the reduction of its efficiency due to low levels of irradiance reaching the cells. Dust is an important well known ecological factor that reduce the performance of solar panels in achieving power production by renewable sources. As a result, an effective cleaning techniques are proposed which will help in improving the amount of power generation. It underscores the necessity for periodic cleansing of solar panels to avert power loss and proposes the adoption of an advanced cleansing method that obviates the need for an external power source or supplementary cleansing agents. The manuscript introduces the notion of electro-dynamic screening (EDS) as a means of purifying solar panels, which operates on the basis of the movement of particles with opposing charges. Additionally, it remarks that the EDS technique consumes a minimal amount of energy and has the capacity to reinstate the surface of photovoltaic (PV) panels to their original pristine state, thereby achieving enhanced efficiencies.

Key words: *Dust; Solar power; Photovoltaic panel; Electro-dynamic Screening; hydrophobic surface.*

1.0 INTROODUCTION

Dust is a major ecological factor that must be considered during the development of materials for the production of PV modules which has a massive effect on solar cell performance, (Bagnold *et a.l*, 2012). A report based on a research article evaluates the present state of research on the impact of dust on PV system performance and highlights research problems. This research also presents a framework for understanding the numerous factors that influence dust settling and assimilation, as well as potential mitigation techniques, (Mani *et al.*, 2010). The amount of dust that settles on solar panels is determined by the angle at which they are mounted. In general, raising the mounting tilt angle of solar panels decreases the dust surface density on surfaces due to gravity’s influence, (Gholami *et al.*, 2017). The deposition of dust, especially over long periods, is found to have a significant impact on the predicted power production of any solar power plant, (Saidan *et al.*, 2016). Due to air pollution, the energy production of solar modules might be reduced by more than 60, (Asl-Soleimani *et al.*, 2001). The effect of dust particles on the solar panels also depends upon the local areas where the panels are installed (Kaldellis *et al.*, 2011), but the performance of PV panels can be recovered by adopting various types of cleaning techniques, (Sayyah *et al.*, 2014). A comparison of different types of pollution and their effects on the current, voltage, and efficiency of solar modules are studied in one of the review articles, (Sarver *et al.*, 2013) The local factors which are affected by human activities, environmental and weather conditions are also discussed, (Mani *et al.*, 2010). The effect of dust on the performance of PV cells mainly depends on the material used for their construction and the environmental factors in which these PV cells are to be used, (Beattie *et al.*, 2012), the effect of dust on the solar cells due to the densest population and industrial growth in urban areas is discussed, (Tian *et al.*, 2018) The performance of the PV modules is also affected by light rain, because it lets the dirty material on its surface, (Kimber et *al*, 2006). A cost-effective and simple method was used to create transparent coatings with varying hydrophobicities. Silica solution and nano SiO2 are used to reduce the surface energy of coatings and increase their surface roughness, respectively, (Quan *et al.*, 2017), long-term deposition of dust particles on the PV panels can reduce the efficiency by up to 30%, while this may reduce by up to 17% only in some days if the panels are installed in dusty areas, as (Wakim *et al.*, 1981). The decrease in power output varies linearly with time, (Sharma *et al.*, 2013), while in another review article, the concept of compound parabolic concentrator (CPC) and design principles were presented. It has been organized into categories based on structure and applicability, (Tian *et al.*, 2007) dust particles mainly affect the absorption and reflection power of sunlight, (Al-Hasan *et al.*, 2005).

1.1 LITERATURE REVIEW

A solar cell, or photovoltaic cell, is an electrical device that converts the energy of light directly into electricity (Beattie *et al.*, 2012) by the photovoltaic effect, which is a physical and a chemical phenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Solar cells are the building blocks of photovoltaic modules.

Characteristic resistance, parasitic resistances, temperature, light intensity, and dust are some important parameters that influence the performance and efficiency of a solar PV panels. Dust, however, is the lesser acknowledged factor that significantly influences the performance of the PV installations. This may be because the dust natural accumulation is not a global issue but, a site-dependence process. Few studies and investigated this effect and the consequent efficiency degradation. A village near Riyadh, KSA is using a solar PV system was considered as one of the excellent sites to study this phenomenon. Accordingly, (Mani *et al.*.) and (Salim *et al.*, 1988) studied dust accumulation effect for eight months and indicated a 32% reduction in solar panels performance. The effect of dust on the performance of (Poly-crystalline) photovoltaic modules had been investigated in Oman desert climate by (Kimber *et al.*, 2006), their work shows that a reduction in panels performance depend on the pollutant type and deposition level. The highest reduction in PV voltage was caused by ash pollutant with (25%)

The difference between the output parameters of clean and dirty modules provided the information of percentage loss at different dust densities. At the end of three months the dust density deposited on the modules surface was 0.99 mg/cm2. The monocrystalline and polycrystalline modules showed about 20% and 16% decrease of average output power respectively compared to the clean modules of same type (Beattie *et al.*, 2012). Efficiency reduction of a monocrystalline and a polycrystalline module was 3.55% and 3.01%, respectively.

A reduction in PV panel efficiency due to dust accumulation by 15–35% was recorded by (Tanesab *et al.*, 2019) as results of outdoor experiments were conducted to study the dust effect under natural operating conditions.

2.0 CAUSES OF DUST ACCUMULATION

The energy production of PV panels is profoundly affected by several factors, such as the wind speed and direction, solar irradiance, shading, temperature, cleanliness, air pollution, etc.. A slight change in the climatic conditions affects the solar irradiance as well as the ambient temperature, thus, leading to differences in the output energy obtained from the PV panels. The dust, which can be measured in micron layers, can accumulate over a certain period on the PV panels based on the environment, dust type, location, and installation of the solar plant, the PV panel's tilt angle also influences the rate of dust deposition on its surface.

The solar panel's efficiency is influenced by the size and the weight of the dust particles deposited on the panel's surface. The relationship between the power losses from the PV panel and the mass of the dust accumulated on its surface has been deeply investigated by plenty of studies (Tanesab *et al.*, 2019). It was concluded that there is a linear relation between the two variables; as the size of the deposited dust particles gets smaller, the more the radiation on the PV module surface is blocked and, consequently, the more prominent the decrease in the power output is. Some types of deposited pollutants include ash, red soil, sand, etc. These pollutants are affected by various environmental factors such as air temperature and humidity, along with the wind speed; these factors play a significant role in altering the size, phase, physical and chemical properties of these pollutants, in addition to how it accumulates on the panel's surface (Darwish *et al.*, 2013). Air pollution may decrease the panel's energy yield substantially, even if the PV panels are exposed to the outdoor environment for a short period of time. Several researchers investigated the effect of changing the tilt angle on the soiling effect and the efficiency of the PV panels (Chaichan *et al.*, 2011). It was concluded that there is a relationship between the tilt angle and the soiling effect; the soiling effect increases as the tilt angle of the solar panel decreases.

2.1 THE CONCEPT

Solar power plays a significant role in the contribution of energy worldwide. The performance of solar panels mainly depends upon geographical and environmental factors. Dust is an import- ant well known ecological factor that significantly impacts the performance of solar panels in achieving the overall target of power production by renewable sources. Study about the performance of solar panels under the influence of dust particles becomes more effective when these are to be worked out in hot and dusty areas (Beattie *et al.*, 2012). The current goal of this review article is to provide the impact of dust particles on the performance of solar panels. To fulfil this goal, the researcher's contribution is updated in minor for 2015 to 2018 and signed for 2019 and 2020. The current authors of this review article also recommended the adoption of a modern cleaning technique for PV modules, which would save time because it could be operated away from the PV modules (Beattie *et al.*, 2012).

2.2 SELF CLEANING OF PV PANELS

Self-cleaning techniques of the solar panel can be broadly classified into active techniques, passive techniques, and a combination of both techniques (Kimber *et al.*, 2006). An active technique is an active restoration cleaning method, which utilizes external energy, such as water cleaning, mechanical cleaning, and electrodynamics screen. On the other hand, a passive cleaning technique does not make use of external energy (Tanesab *et al.*, 2019). An example of passive cleaning is natural cleaning, which uses rainfalls to wash away the dust accumulated on the surface of PV panels. However, due to the shortage of rainfalls in many regions, two other passive techniques were developed, which make use of changing the morphology of the PV module surface by using super hydrophilic or super hydrophobic coatings (Mondals *et al.*, 2018). Another type of coating is the antistatic coating, which prevents the dust from sticking to the surface of the PV panel without being repelled from the panel's surface. A combination of both active and passive techniques has been developed to benefit from the advantages of both techniques such as using an antistatic coating with mechanical vibrations. The antistatic coating prevents the sticking of dust on the PV panel surface, while the mechanical vibrator shakes the panel, allowing the dust to fall off by the gravitational force from the panel's surface.

3.0 ACTIVE CLEANING METHODS

3.1 MECHANICAL CLEANING

Most of the mechanical cleaning systems use wipers and brushes. They move either vertically or horizontally, based on the dirt location. The mechanical cleaning systems can be activated either manually or automatically (e.g., robotic cleaners by using electrical or electronic systems). removes the dust from the PV panel's surface by using brushes analogous to windshield wipers of motor vehicles (Mani *et al.*, 2010).

Figure 1: PV panel dry cleaning using robot (Bagnold 2012)

The robotic cleaning of solar panels offers additional more integrated features over the ordinary manual cleaning systems, such as quick response, high stability, and reliability. They may be used whenever robust autonomous and unmanned control is required in addition to solving the labor problems (Mani *et al.*, 2010). Nevertheless, the capital cost for purchasing the robot itself is high, especially for large PV plants due to the usage of various mechanical parts and the additional costs required for installing the system. Maintenance costs of the hardware system such as gears and chains need to be taken into account, when calculating the robotic cleaning system's expenses; the maintenance schedule should be performed according to a timely manner in order for the system to work properly. As previously mentioned, since wipers and brushes are the cleaning tools used in the vast majority of the mechanical cleaning systems, the PV panel might be subjected to severe surface damage during cleaning (Mondals *et al.*, 2018). Therefore, without proper maintenance, dirt and dust will accumulate on the cleaning tools and the other parts, which contact the PV panel surface directly, and accordingly, the efficiency decreases (Mani *et al.*, 2010). Moreover, an important aspect that needs to be considered is that the active cleaning systems are electrically powered either from a frequently replaceable external battery used for charging or from the PV system itself. However, the later condition will decrease the output power of the PV system during the cleaning process leading to high power consumption rates, especially in large PV systems.

3.2 MANUAL CLEANING OF PV PANELS

Manual cleaning is accustomed mostly to water cleaning techniques by labor. The cleaning techniques are chosen according to the location of the plant and the availability of water resources. This method uses manpower in order to remove bird wastes, and cemented dust from the surface of the PV panel. Besides, this method is considered efficient if arranged according to a regular and proper schedule (Heliotex, 2009). Nevertheless, this method has several drawbacks. Not only does the manual cleaning of PV panels require qualified, professional, and well-trained labor to remove the hard soiling, which makes this method relatively costly, but also the labor safety, health considerations, and government-related regulations, as well as the high cost of water, maintenance, cleaning detergents and systems are several aspects that need to be considered thoroughly (Mondals *et al.*, 2018). However, using the cleaning tools should be handled in a proper way or else, the PV panel surface might be subjected to severe damage. Moreover, manual cleaning is not adequate, in case the PV modules are located at high altitudes and unreachable areas. Water cleaning is shown in Figure below.

Figure 2: Water cleaning of PV panels (Bagnold 2012)

3.3 ELECTRO-DYNAMIC CLEANING

The dust electrostatic property was the main concept used to develop the electrodynamics screen cleaning technique, which is known as electro-dynamic screening (EDS). The electrodynamics screen cleaning technique was further developed using the electric curtain (Bagnold 2012). This concept is based on the movement of oppositely charged particles due to the dust electrostatic reactions. Therefore, once the dust settles on the panel's surface, it keeps moving from one edge to a neighboring one and so on until it is removed entirely from the surface of the panel. Furthermore, this technique shows high flexibility, as it does not need an external power supply or any additional cleaning detergents. The EDS technique consumes a low amount of energy that is capable of restoring the surface of the PV panel back to its default clean conditions achieving high efficiencies, which are greater than 90% (Bagnold 2012).

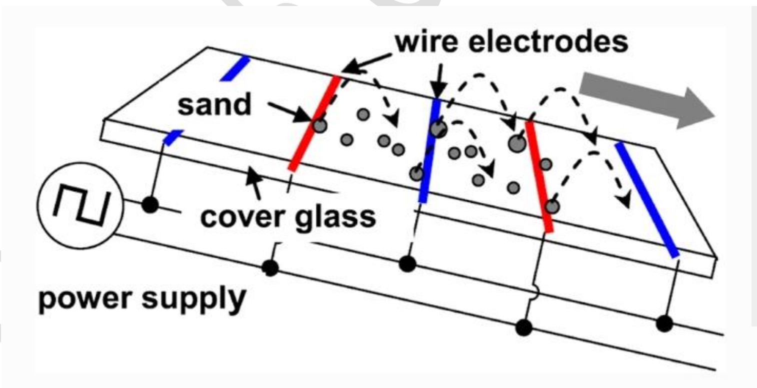

Figure 3: electrostatic cleaning system (Bagnold 2012)

4.0 PASSIVE CLEANING METHODS

4.1 HYDROPHOBIC SURFACE

A hydrophobic surface is a surface having low wettability. This property helps to repel water droplets and prevents them from sticking on the surface. The ability of water droplets to roll off a surface while picking up the contaminants determines the hydrophobicity of a surface, in addition to measuring the contact angle between the surface and the water droplets. Super hydrophobic surfaces have a high capability of hydrophobic characteristic and high contact angles; therefore, rainfalls or any other cleaning technique can easily remove any dust or dirt accumulation. Besides, a super hydrophobic surface means a low hysteresis of the contact angle, in which a water droplet can easily bounce on the surface of the PV panel while also removing the accumulated dirt. This will enlarge the effective area of the PV module to absorb the maximum solar irradiance, in addition to increasing the probability of the PV module surface cleaning conditions recovery Bagnold (2012) found that the cleaning effect of this method could last for about 3 to 4 years. The hydrophobic surface is made from polymer layers, which exhibit high initial transmittance. Unfortunately, some of these layers are characterized by having high surface energy, which might increase the probability of dust accumulation. Moreover, these layers often degrade more rapidly upon frequent exposure to ultraviolet radiations, as compared with glass. Furthermore, this hydrophobic surface might suffer severe corrosion and severe damage upon exposure to certain chemical solvents found in acidic rain and salty air.

5.0 SUMMARY

The main factor of degrading the generation of PV modules is dust accumulation on the top surface of PV module. Dust accumulation on panel's surface blocks the solar radiation to enter directly on the solar cell, which would decrease the spectral transmittance and PV power generation efficiency. This leads to a decrease in the reliability of the solar PV module. The loss in the output power of the modules can be avoided if modules are cleaned periodically.

5.1 CONCLUSION

It is evident with succinct literature survey that the performance of PV modules is truly influenced by the aggregation of dust particles on their surfaces. The effect of accumulated dust particles on the PV panels depend upon the geographical conditions in which PV panels are to be worked out. Moreover, it is observed that the efficiency of uncleaned panels may reduce up to 70%, if modern technology like artificial intelligence is not adopted for their cleaning purposes. The life and the output performance of the PV modules can only be increased by adopting the proper policy of the cleaning process. The cleaning frequency should be adopted after every three weeks, if the modules are working in the dusty areas.

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