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STUDY ON EFFECT OF DUST ACCUMULATION ON THE PV SYSTEM

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Abstract - *One of the major reasons for the poor performance of PV systems is dust accumulation. Unlike concentrated solar power (CSP), poly-crystalline and single-crystalline PV panels have shown power reduction in excess of 60% due to dust particles. This paper presents a study on the impact of dust on power generation by the PV system . Dust is a term which is applied to solid particle with less than 500µm. The main sources of dust are; dust laden winds, volcanic eruptions etc. It also includes micro pollens, microfiber, which are scatter with atmosphere. Efficiency of solar PV system are degraded due to dust and similar pollutants. The accumulation of dust on the surface of a photovoltaic module decreases the radiation reaching the solar cell and produces losses in the generated power. Dust not only reduces the radiation on the solar cell, but also changes the dependence on the angle of incidence of such radiation. This work presents losses caused by the accumulation of dust on the surface of photovoltaic modules. The power output delivered from a photovoltaic module highly depends on the amount of irradiance, which reaches the solar cells. Many factors determine the ideal output or optimum yield in a photovoltaic module. However, the environment is one of the contributing parameters which directly affect the photovoltaic performance.*

***Key Words*: *Dust Accumulation, PV panels, Effect of Dust on PV performance, XRD, XRF, SEM,* concentrated solar power (CSP).**

1. INTRODUCTION

The PV solar power represents one of the most promising renewable energy in the world. There are different types of PV cells which make solar modules: crystalline silicon, multi-crystalline (multi), mono-crystalline (mono-c), amorphous silicon (a- Si), etc. PV technology is well-proven for producing electricity. PV systems can be either grid connected (with electricity fed directly into the grid system) or PV systems used in off-grid applications in small power systems in combination with diesel power gen-sets. Solar PV technology is especially suitable for electricity generation in off-grid power plants in rural desert areas and the use of solar energy in such hybrid systems can reduce diesel fuel use. The output of PV is rated by manufacturers under Standard Test Conditions (STC), temperature = 25C; solar irradiance (intensity) = 1000 W/m2, and solar spectrum as filtered by passing through 1.5 thickness of atmosphere. These conditions are easily recreated in a factory but the situation is different for outdoor. With the increasing use of PV systems it is vital to know what effect active meteorological parameters such as humidity, dust, temperature, wind speed; etc has on its efficiency. This paper investigates the effect of dust on PV system performance .

Several worldwide companies compete to produce PV cells that are efficient, low-cost, and durable. Solar cells are the building blocks of PV systems. Typically, a PV cell generates 1.5 to 3 W of power. PV modules or panels are made up of multiple cells. PV arrays are made up of multiple modules. Typical PV panel I-V values are usually with current = 7.95A and voltage=30.2V with different types being manufactured. Polycrystalline cells are less expensive to make than single-crystalline modules but are also slightly less efficient than the single-crystalline (12% - 15%). Also, it has been found that amorphous silicon cells dominate in warm, sunny conditions due to their lower power-loss temperature coefficient. In general, PV panels are not too sensitive to dust when compared to concentrated solar power (CSP), where a few dust particles can reduce power to 80% and could even become completely ineffective, if left unattended for a month.

Over the last thirty years, extensive work has been carried out to study the effect of dust accumulation on the performance of PV panels. It was found that PV panels lose their power from 40W (when cleaned) to 13 W (during dust storms), i.e. a loss of nearly 68%. Dust reduces the efficiency of PV panels in humid air at certain times of the year, leading to the fusing of dirt to the surface of the collectors making it hard to remove. The dust accumulation considerably deteriorates the performance of PV systems and emphasized that the physical characteristics of dust must be determined and correlated to the observed effects. They showed that the drop in power output from a PV system with dust density (in g/m2) falls by 80% when the dust density increases discretely from 0 to 300 g/m2 when the dust grain diameter is 80 µm and the solar intensity is about 700W/m2. It reported a 32% reduction, after 8 months, due to dust accumulation on a PV system in Riyadh City, Saudi Arabia, when compared to an identical PV system tilted at 24.68 ° and cleaned daily, and it reported a reduction in PV power output by 17% due to sand accumulation on panels, in Kuwait city, Kuwait, after a period of 6 days and also found that the influence of dust on PV performance was higher in

spring and summer (20% in 6 months) than in autumn and winter.

2. LITERATURE REVIEW

In the literature review, it was discovered that mono crystalline solar panel is the best with the highest output power efficiency. It was found from the study that the accumulated dust on the surface of photovoltaic solar panel reduces the system efficiency up to 35% in one month. Katz, (2008) carried out a research on the effect of accumulated dust on solar panel and it was reported that the dirt on solar photovoltaic panels caused a 2% of current reduction relative to that of clean panels . Khoshaim*et al.,* (2003), on their experiment, it was discovered that there are two primary ways which dusts affect the performance of photovoltaic panel. First, dust settles directly on the solar photovoltaic panel, blocking the cells from the sun's rays. Second, the tracing sensor may be covered by dust, inhibiting the panels from following the sun's direction.

Mizanur Rahman, (2010), University of Asia Pacific, Dhaka, Bangladesh experimented on the effects of Natural Dust on the Performance of PV Panels in Bangladesh stating that Dust has an effect on the performance of solar PV panel. The reduction in the peak power generated can be up to 20%. It was also shown that under greater irradiation, the effect of dust became slightly reduced but not negligible. Hence, in practice, dust must be removed from the surface of solar PV panel in order to ensure highest performance, given the fact that it is still a costly form of energy source and the short lifespan it has.

Aliand Abdulazez Hasan, (2012), on their experiment on Effect of Dust Accumulation on Performance of Photovoltaic Solar Modules in Sahara Environment, showed that PV installation in desert region necessitates a regular cleanings to maintain an optimum performance. However, the accumulations of dirt objects on solar module have a significant, impact on output power and overall system efficiency. Periodically weekly cleaning maintained performance losses between 2 – 2.5%. In framework once a week cleaning intervals and rinse every three days from (February to May), then follows by once a month cleaning in other months, that help to reduce the dirt's and debris build up. The cleaning intervals is different from site to another, it is important before schedule such agenda to have a fully knowledge of region environment pollution type and it is occur period.

Bouchalkha (2009), worked on Modeling of Dust Effect on Solar Panels in Abu Dhabi and was reported they performed light scattering calculations using the T-matrix approach to estimate the effect of dust deposition on the photocell performance in the Abu Dhabi region. Due to the very limited rain fall and the high level of dust present in this region, one would expect this effect to be larger and to require more attention in this region than in other parts of the world with regular rain falls. Our results show that we can reach up to 10% reduction in the photocell short-circuit current density in just 10 to 15 days. Based on our calculations, solar cell surface cleaning is necessary to maintain close to 100% performance. From our model we have estimated that the cleaning process should take place on a regular basis every 10 to 15 days on average to keep the photocell performance as high as 90% of its maximum performance under normal conditions. Regular solar panel cleaning is recommended, especially in the Abu Dhabi region where rain is rare and dust is often present.

3. Factors influencing dust settlement

Dust is a term which is applied to solid particle with less than 500µm. The main sources of dust are; dust laden winds, volcanic eruptions etc. It also includes micro pollens, microfiber, which are scatter with atmosphere. The factors influence the dust settlements are shown in figure 1. Dust promotes dust. It settles in region of low vapor pressure induced by the high pressure movements on inclined /vertical surface. The PV system is affected by several environmental factors as shown in figure 1.

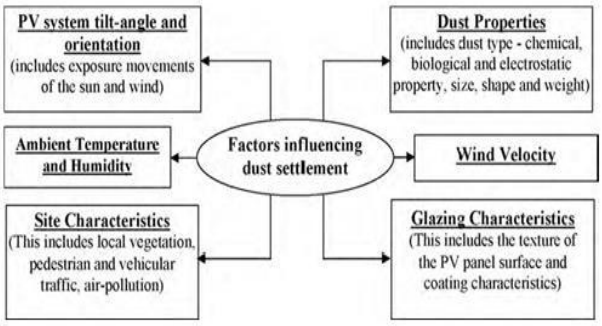

Fig – 1: shows Factors influencing the dust settlement

3.1. Effect of Dust Properties

The first point to be investigated is the effect of dust properties on the PV performance. This section separated into two main points: dust accumulation, and dust pollutant.

i. Dust Accumulation

The accumulation of sand particles on horizontal glass surface is found to exponentially reduce the available area for transmission of incident photons. Initially all sand particles are distant from each other and subsequent particles landing on them cannot be supported and fall onto the glass. In this regime the free surface area decreases linearly with sand mass. As more particles arrive on the surface, clusters are gradually formed and there is an increasing probability that subsequent particles will land on a cluster rather than on the glass. This causes the evolution of the free surface area.

Fig – 2 : Shows dust collected on PV panels

ii. Dust Pollutant

The air pollution is degradation of PV performance as a result to accumulation of solid particles varying in type, composition and shape. It was found that depending on the type of pollutant the percentage of area coverage increased which decrease the power generation.

3.2. Effect of Tilt Angle on dust accumulation

It was studied that, gather of dust on a glass plate decreases transmittance by average of 8% after an exposure period of 10 days., and dust deposition on glass plate with different tilt angles . It was found that degradation in solar transmittance depend on the tilt angle.

3.3. Effect of PV Technology

PV module is classified into two categories which are silicon crystalline and thin film. Each category of PV modules (solar cells) contain of different types. The types of silicon crystalline are mono crystalline, polycrystalline, hybrid silicon, emitter wrap through cell and silicon crystalline investment while amorphous silicon, cadmium sulphide or telluride and copper indium disellenide or copper gallium are the types of thin film. The investigations found that a- Si performs best in dusty environment.

3.4. Effect of Cleaning Methods

Dust is probable to stick on to the array by Van der Waals adhesive forces. These forces are very strong at the dust particle sizes expected. Cleaning method must be overcome these forces. There are four ways classified to remove dust the surface of solar panel namely natural, mechanical, electromechanical and electrostatic. More investigation and ideas are important to reduce the effect of dust.

3.5. Effect of Humidity PV panel

To study the effect of humidity on PV cell, two cases must take into account. The first case is the effect of water vapor particles on the irradiance level of sunlight and the second case is humidity ingression to the solar cell enclosure. Three phenomena occur when light hits water droplets. It may be refracted, reflected or diffracted. These effects deteriorate the reception level of direct component of solar radiation

3.6. Effect of Temperature

The efficiency of PV cell usually decreases with high ambient temperature on the cell. That means the electric power generated from the cell decreases. A more significant effect is dependence of the voltage which decreases with increasing the temperature. The investigations found that PV output power affected by ambient temperature. The more clean and cool PV the high power generated and more efficiency .

4. Different cleaning methods used to remove dust Accumulated on PV panels

Solar Photovoltaic panels are constantly exposed to various types of weather conditions throughout the year and are thus the target for dirt, dust, industrial residues, atmospheric pollution, algae, mosses, bird droppings etc. The agents and chemicals used during cleaning of the surfaces attract dirt and accelerate the deterioration process with negative repercussions on the appearance and mainly on the function of the PV panel.

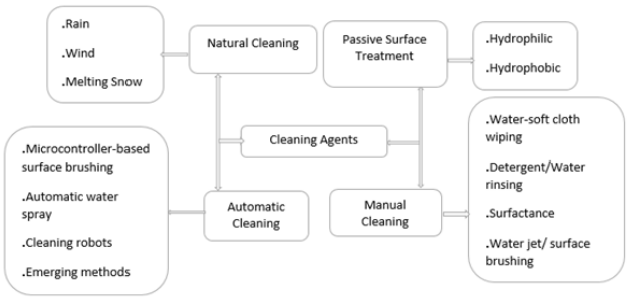

Fig - 3: shows different dust removal method used to clean the PV panels

The presence of these elements on the panel's surface prevents the sun's rays from filtering onto the panel's photovoltaic cells completely, reducing the solar performance and therefore efficiency

i . Manual Cleaning

This method require human operator to clean manually with the help of mop or any wipers with suitable support structures as shown in Figure 2. The quality of cleaned surface is judged by visual method by the operator himself for the satisfactory level or till the dust particles get wiped out completely. The process is found to be very tedious and challenging as the solar power plants consists of numbers of panels installed at a height of 12 to 20 feet or more from the ground. The time required and safety of the person and panel is in threat. To clean the panels manually the fluids like cleansers or gels has to be used which act upon the panel and reduces the surface transparency if cleaning is not proper. There are quite chances of physical damages to the PV panels which cannot be avoided.

Fig - 4: shows manual cleaning methods

ii . Vacuum Suction Cleaning

A vacuum suction cleaner is a device that uses an air pump to create a partial vacuum to suck up dust and dirt, usually from floors, window panes etc. In general the electrical supply is given to the vacuum cleaner motor which creates the suction pressure. The power consumption of the vacuum cleaner is in watts and it does not justify the effectiveness of the cleaner. The input power is converted into airflow at the end and is measured in air watts. The vacuum cleaner can clean the panel properly only on the surfaces other than the corners and this has to be handled manually

Fig – 5: shows suction cleaning

iii. Automatic suction Based Cleaning

The automatic wiper based cleaning incorporate a rubber wiper and water pot for the spray of water with additives and cleaning. The process is exactly like vehicle glass cleaning and require a automatic mechanism to operate and complete the task. Mechanism is battery operated as shown in Figure 4. This method is similar to earlier one and operated automatically by the suitable control mechanism but the impacts are similar to those earlier ones.

Fig- 6 : *Automatic cleaner robot.*

iv. Electrostatic Precipitator

Considering the impacts of different cleaning methods for solar PV panels the mechanical damages, scratches and scars like marks the electrostatic precipitator work with non-contact mechanism. It cleans efficiently and protects the top surface of the panel without any physical contact. An electrostatic precipitator (ESP) is a filtration device that removes fine dust particles from the surface of the solar PV panel using the force of an induced electrostatic charge. The mechanism consists of the electrodes which 27 are charged suitably as shown in Figure 7. The electrodes of the ESP obtain power through relay when the Arduino controller signals after obtaining weight of the PV panel after the comparison with preset value. The negative electrodes of the electrostatic precipitator induces the negative charge on the dust particles which are present on the surface of the panel. The dust particles are accumulated at the positive electrode after being attracted. In this way, a non-contact dust cleaning technique helps in improving the efficiency of solar panel.

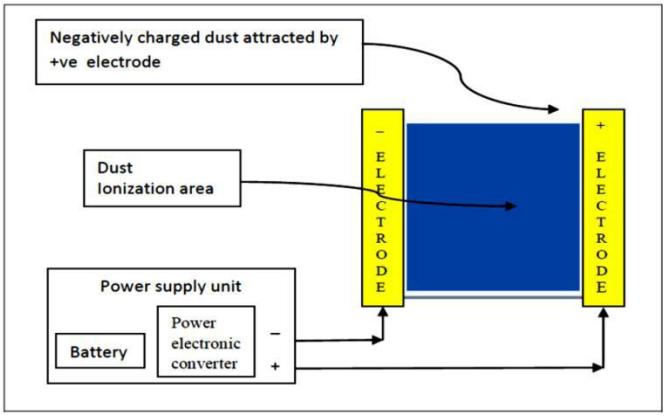

Fig- 7 : shows ESP layout

Conclusion

This paper reviews the effect of dust accumulation on the PV system performance .The status of research has been discussed based on various factors influencing dust accumulation and carious cleaning methods used to remove dust. PV panels are not sensitive to dust when compared to concentrated solar power (CSP) where a few dust particles

can reduce power upto 80% and could be ineffective if left unattended for a month.

As the scarcity of energy is increasing and decline of energy resource result an opportunity to incorporate new and renewable energy systems in practice. In this regard use of solar PV system is becoming promising as availability of PV solar based devices is increasing in the market. Many factors determine the ideal output or optimum yield in a photovoltaic module. The environment is one of the contributing factors which directly affect photovoltaic performance. In this paper various factors which increase the soil accumulation is studied and various cleaning methods to reduce the soiling has been studied. It is analysed that the cleaning by ESP is better than manual and vaccum type cleaning.

With the use of nanotechnology the percentage in loss can be avoided, by nano coating the surface of the PV panels the accumulation of dust and water droplets can be avoided. There are various research going on in various nano coating material such as aluminium oxide, silicon oxide, zirconium oxide which can be used as a nano coating material which avoids the accumulation of dust and water droplets.

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