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Dust effect on flat surfaces – A review paper

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ABSTRACT

Dust accumulation is one of the natural phenomena that adversely affects the performance of solar systems. Since 1942, many efforts have been made to address the severity of deposited particles like dust, water stains, carbon from smoke, pollen in agricultural regions, etc. on the efficiency reduction of solar devices, which results in additional costs either from oversizing the system or from cleaning it. Although various innovative methods have been employed to clean the surface of grimy PVs, a holistic approach needs to show the cleaning mechanism under different climate conditions. This review highlights the findings from several references in three time periods and focusing on their similarities. For scaling up the appropriate mitigation method, four different global zones are explored based on suspended particles in the air. Consequently, the pattern of dust distribution in different parts of the world is assessed and it was found that the Middle East and North Africa have the worst dust accumulation zones in the world. Finally, a set of recommendations and guidelines with regard to the different climatic zones and their characteristics are presented especially for the installers of PV or other solar devices to implement a suitable cleaning system.

Contents

1. Introduction

The use of solar energy increased by 50% from 2003 to 2008 and is estimated it will continue at a growth rate of at least 25% annually [1]. Large scale solar power plants already have been installed in many parts of the world including the United States, Spain, Germany, the Middle East, Australia and India. These installations are usually located at high solar radiation intensity zones such as in desert areas where it has a dry and windy weather. The wind normally sweeps the dust from the solar devices but stays suspended into the air, which can result in an adverse effect resulting in less solar radiation reaching the solar devices. Also, suspended dust, whether fine or large, in the atmosphere eventually will settle on the solar panels and cover their surfaces and therefore reduce their efficiencies. Another disadvantage of having suspended dust particles is they reflect solar radiation and hence reduce the solar gain reaching the devices to generate power or electricity such as photovoltaic, flat plate solar collectors and concentrating solar power devices (CSP). In arid, semi-arid zones, and desert regions dust storms and suspended micro-particles in the air often occur and need to be

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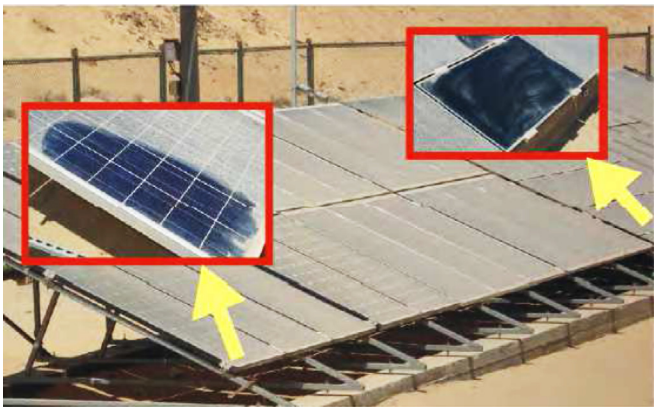

Fig. 1. Dust layer accumulation on PV modules in Egypt [3].

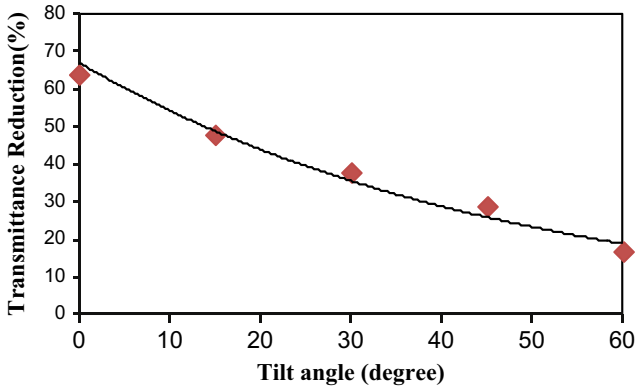

Fig. 2. Variation of transmissivity decrease percentage versus title angle for dust accumulation on a flat glass at Riyadh, Saudi Arabia in 1977.

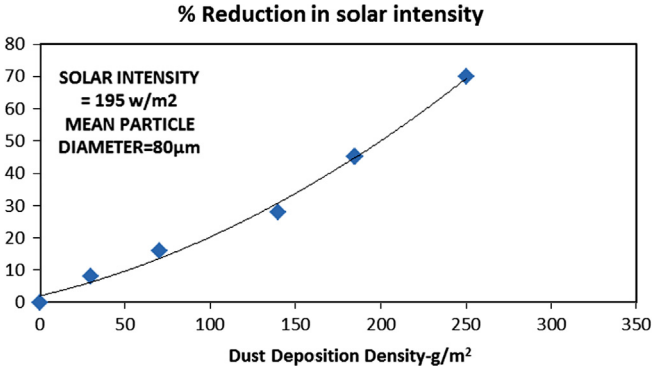

Fig. 3. Solar intensity reduction versus amount of dust deposition density [7].

managed in planning the site or through the use of cleaning mechanisms. For example, in just one hour, a desert sand storm can plaster even the toughest solar panels with a thick layer of residue, reducing their efficiency by upwards of 70–80%. If the panels are not cleaned regularly or almost daily, they become practically useless. Moreover, these areas suffer from water shortage, which leads to a relatively expensive cleaning mechanism. Fig. 1 shows the soiling accumulation after a period of one year for the systems installed in Egypt. The energy production results showed a dusty module produced 25 and 35% lower energy compared to a clean module after a period of three months and one year, respectively[2,3].

From 1942 to the present a number of research has been conducted on the adverse effect of dust on solar PVs and solar thermal devices. Moreover, several reviews have been published recently, which cover a wide range of studies dealing with dust impact on solar systems, mitigation approach and cleaning mechanisms. In this review, examination of the state of the art by presenting the results of some experiments and studies in different periods of time and different places will be analysed. Also, it emphasises, the importance of different climate conditions, as a significant factor for accumulating of dust and particles on solar systems and a framework needs to be provided for the cleaning mechanism of PV panels or exposed solar devices all over the world.

2. The state of the art

Early research on dust and deposition effect on PV panels and solar thermal devices dates back to more than seventy years ago. Initial studies were focused mainly on the thermal cells and dust effect on the mirror reflectance [4]. For instance, Sayigh [5] conducted a detailed investigation on the effect of dust on solar flat-plate collectors. The experiment comprised seven flat plate collectors, with six arranged in pairs and subjected to various inclinations of 0°, 30°, and 60°, with the seventh collector inclined vertically at 90°. In each pair one collector was cleaned regularly while the other was kept undisturbed. The amount of absorbed solar energy of the unclean plates was computed and compared to that of the cleaned ones. It indicated a dust collection of about 2.5 g/m^2/day between April and June 1978. Sayigh et al. [6] also investigated the effect of dust accumulation on tilted glass plates located in Kuwait and found a reduction in plate-transmittance by an amount ranging from 64% to 17% for tilt angles ranging from 0° to 60°, respectively, after 38 days of exposure in 1985. In addition, a reduction of 30% in useful energy gain was observed by the horizontal collector after 3 days of dust accumulation. The influence of tilt angle on dust-covered glass reduction in solar transmittance is illustrated in Fig. 2.

Fig. 3 shows the percentage of solar intensity reduction versus the amount of dust deposition (g/m^2) under a constant solar intensity of 196 W/m^{2}and dust particles size 80 μm, [7].

The work of Sayigh [5,6] in the 1970s and the 1980s highlighted a major problem regarding dust in the Gulf Region. Figs. 4 and 5 show collectors and glass samples under environmental conditions in Riyadh and Kuwait during different tests in the period 1977–1985.

Fig. 6 shows two collectors subjected to two weeks' weather conditions during the summer period. A – was inclined at 45° in Riyadh, Saudi Arabia, the dust accumulation is clearly more at the lower parts of the collector, B – a different collector which was in Kuwait close to the sea, the dust was mixed with the humidity and cemented itself onto the glass cover.

In 1978, research has updated information that deals with solar photovoltaic panels. A study by Salim et al. [8] discusses the long-term dust accumulation on a solar-village PV system near Riyadh, Saudi Arabia, which indicated a 32% reduction, after 8 months, in performance of the solar array due to dust accumulation. This was in comparison with an identical PV system tilted at 24.6° that was cleaned daily. On similar lines, a study carried out by Wakim [9] in Kuwait city showed a reduction in PV power by 17% due to sand accumulation on panels after 6 days. Further, the study also highlighted that the influence of dust on PV performance was higher in spring and summer (20% in 6 months) than in autumn and winter.

In this context, after 1990 many experiments have been conducted to test the effect of dust on the solar panels in terms of the collected power, the effect of particle size, the effect of wind on the accumulated dust, and the effect of different types of dust,