Review of Self-Cleaning Method for Solar Cell Array

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Abstract

The self-cleaning technology for solar cell array can promote efficiency of electricity produced and protect the solar cell. The methods of dust-removal, such as natural means, mechanical means, self-cleaning nano-film, and electrostatic means are presented in this paper. It is intended to help readers to gain a more comprehensive view on self-cleaning method for solar panels or other optical devices.

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1. Introduction

Photovoltaic (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of cells containing a photovoltaic material. Because it is safe, renewable and pollution-free, PV has advanced considerably in recent years [1, 2].

Large-scale solar installations already exist in China, Europe, the Middle East, Australia, and USA. These installations usually are located in sun-drenched desert areas where dry weather and winds sweep dust into the air and deposit it onto the surface of solar panel. Just like grime on a household window, that dust reduces the amount of light that can enter the business part of the solar panel, decreasing the amount of electricity produced. Clean water tends to be scarce in these areas, making it expensive to clean the solar panels. It is reported that a dust layer of 4 gram per square meter decreases solar power conversion by 40 percent [3, 4]. In many areas, like Xinjiang, Gansu, and Ningxia in China, dust is deposited each
month at about several times that amount. For improving the efficiency of the PV and protecting the solar cell, the research of the cleaning method is vital.

Now, no research about the self-cleaning for solar cell array has been motioned in China, and more researching works focus on Lunar or Martian exploration missions on abroad. The cleaning method is summarized as natural means, mechanical means, self-cleaning nano-film, and electrostatic means.

2. Natural removal of dusts

The natural powers are employed to remove the dusts, such as wind power, gravitation and the scour of the rainwater. The effect of this method is not very well. Gaier J, Davis P and Marabito M [5, 6] reported that they had studied the validity of this method. It is viable that the solar cell array can be turned to vertical or oblique position to remove the dusts easily when early morning, late evening, night and a rainy day. However, the rotation of the large solar cell array is very difficult.

3. Mechanical removal of dusts

The mechanical methods remove the dusts by brushing, blowing, vibrating and ultrasonic driving. The brushing methods clean the solar cell with something like the broom or brush that were driven by the machine was designed just like windscreen-wiper. However, firstly, because of the small size and the strong adhesivity of the dusts, the cleaning method is inefficient. Secondly, the abominable working environment of the solar cell makes the maintenance of the machine difficult. Then, due to the large area of the solar cell array, the cleaning machine is powerful. Lastly, the surfaces of the solar cell maybe were damaged by the brush when wiping.

The blowing method cleaning the solar cell with wind power is an effective cleaning one except the low efficiency, high energy-consumption and the unsatisfactory maintainability of the blower.

Removing the dusts with vibrating and ultrasonic is also a valid mechanical cleaning method. The key of this strategy consist of the driving method, the frequency and the amplitude of the solar cell. Williams R. Brett [7] and his team have studied the vibration characterization of the self-cleaning solar panels with piezoceramic actuation. Their research work is yet at the initial stage of exploration.

4. Self-cleaning nano-film

If the surfaces of the solar cell array were covered with a pellucid self-cleaning nano-film, it will keep clean. The self-cleaning nano-film is made of super-hydrophilicity material or super-hydrophobic material. That is means the self-cleaning mechanism of the nano-film involve two strategies.

4.1. Super-hydrophilicity film

The popular super hydrophilicity film is TiO2, which has hydrophilicity and photocatalytic activity. The self-cleaning method consists of two stages. The first one is photocatalytic process which TiO2 film reacts under the ultraviolet light, and split the organics dirt. Then, because of the hydrophilicity, the rainwater will diffuse to the whole surface instead of get together and rinse the dust. Now, most researchers focused on the preparation, doping and modification of this material. This self-cleaning method can not be used in solar cell array because they worked mostly in desert region with seldom rain.

4.2. Super-hydrophobic film
Superhydrophobic surfaces such as the leaves of the lotus plant show high hydrophobicity and extremely low wettability. Various studies have been conducted to realize superhydrophobic surfaces by forming microstructures or nanostructures. The nanostructures of this surface can enhance the contact angle (CA) to higher than 150°, so the water droplets that hit the surface would quickly roll off, carrying dust and other particles with them. Nevertheless, most studies regarding superhydrophobic surfaces have focused mostly on enhancing the non-wetting property itself. It is still a question of whether such a superhydrophobic surface can be practically applicable in areas such as self-cleaning surfaces on solar cells. Further studies are needed to verify the feasibility of superhydrophobic surfaces in real-world applications [8-10].

5. Electrostatic removal of dusts

Electrostatic dust-removing is a sample electric method. When Clark P E, Minetto F A and Keller J [11] studied the dust mitigation strategy that works on the lunar surface, they suggested that there are possibly two mechanisms of particles charging on moon: 1. triboelectric charging, 2. photoemission of electrons from the surface of the particles by UV radiation. So, if there are a high potential on the surface of the solar panels, the charged and uncharged dusts will be attracted to the panels because of the electrostatic forces. Then, the dust particles will be charged by the solar panels finally, so they have the same electric charge and the electrostatic forces between them are repulsion. At last, the dust particles will float away the solar panels. However, this strategy cannot be used in PV systems, because of the effect of the rain on earth.

The most popular electro dust removal technology is based on the electric curtain concept developed by F.B. Tatom and collaborators at NASA in 1967 and further developed by Masuda at the University of Tokyo in the 1970s [13]. This technique has been shown to lift and transport charged and uncharged particles using electrostatic and dielectrophoretic forces [14]. In recent years, many researchers have focused on how this technology can be applied for space applications on the moon and Mars[15-19]. Electric curtains consist of a series of parallel electrodes embedded in a dielectric surface, across which are transmitted oscillations in the electrode potentials (fig 1).

When the electrodes connect to a single-phase AC voltage, it generates a standing-wave field (shown as fig 2). Until quite recently it was believed that standing-wave fields could only levitate particles on the curtain, but not cause a net transport [20].
When the electrodes connect to a multi-phase AC voltage, a traveling-wave electric curtain be excited (shown as fig 3). Under the right frequency and amplitude conditions, the charged particles will not be allowed to deposit, but will be entrained to move along the surface following the electric field. In this way, the surface will stay clean of particle deposition [19].
For solving the problem that the dust particles affect the lunar explorer, Calle, McFall and Buhler [14,15] had studied the effecting of dusts-removal under the action of the electrostatic and electrophoretic force produced by travel-wave electric curtain. Atten P. [16] had studied the technology of the standing-wave electric curtain and its application on Martian exploration. Mazumder[4,17,18] and his colleagues designed a flexible electrodynamic screen to protect the solar cell on Martian explorer based on travel-wave field technology.

At present, less research of the dust-removal based on electric curtain technology has been performed in domestic. Some reports show that Yuan Yafei [21] at Beijing orient institute of measurement and test has surveyed the application of this technology on the lunar and Martian exploration.

6. Conclusions

Although some methods for self-cleaning have been mentioned by many researchers, especially, the application for lunar and Martian exploration, less research about self-cleaning for the solar cell array has been performed. Synthesizing the above-mentioned method, the best strategy of removal-dusts for solar cell array is electric curtain.

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