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Assessment of Cleaning Methods for Solar PV Modules: A Review of Current Practices

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Abstract

This study looks at how well solar panel cleaning technologies work to increase energy output, lower maintenance costs, and lengthen the life of solar panel systems. The necessity for efficient and economical maintenance of solar panels is growing in importance due to the rising demand for solar energy. Systems for cleaning solar panels have become a viable way to address the problem of maintaining clean and efficient solar panels. Our study encompasses an extensive examination of previous research on automated solar panel cleaning systems in the literature, in addition to a data analysis of field testing and experiments. We look at the technology underlying these systems, how well they work in different settings, and how they affect society and the environment. According to our research, solar panel cleaning devices can increase energy output while lowering maintenance expenses. These technologies can also increase the longevity of solar panel systems, which increases their long-term sustainability. More research is necessary to fully understand the environmental and economic effects of implementing these systems on a bigger scale.

Keywords: Solar panel, cleaning, automated system, anisotropic ratchet conveyors, portable PV cleaning robot system

INTRODUCTION

The spectral content and other factors such as environmental and climatic components are closely related to the energy generated by solar photovoltaic (SPV) modules. The two biggest things affecting SPV performance are thought to be dust and bird droppings. The requirement for effective and affordable solar panel maintenance is growing as the market for solar energy continues to expand. The problem of keeping solar panels clean and operating at their best has given rise to the possibility of using automated solar panel cleaning systems. Our research paper's goal is to find out how well automated solar panel cleaning systems work to increase energy output, lower maintenance costs, and lengthen the life of solar panel systems. We'll look at the technology underlying these systems, how well they work in different settings, and how they affect society and the environment. Our study will comprise an extensive examination of the literature on automated solar panel cleaning systems that has already been done, in addition to an analysis of data gathered from experiments and field testing. We will also look at the environmental and financial effects of implementing automated cleaning systems on a bigger scale. Our research will shed important light on the viability and possible advantages of employing automated solar panel cleaning technologies. Our study aims to encourage the global use of renewable energy sources and further the development of efficient and sustainable solar energy systems. As electricity rates rise and

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environmental concerns over fossil fuels grow, more and more renewable energy sources, including solar power, are being used. Photovoltaic (PV) panel arrays are the primary means of using solar energy. Dust and particle buildup on even one panel in an array significantly lowers the panels' ability to generate electricity, underscoring the importance of maintaining the panels' surface cleanliness. The labor-intensive cleaning techniques now used for photovoltaic arrays are expensive in terms of time, water, and energy used, and they are not automated.

Existing System

Anderson et al presented a revolutionary design for the first-ever human portable robotic cleaning system for solar panels. The device could clean and move at several angles, from horizontal to vertical, over the glass surface of a PV array [1]. Mondal et al provided a brief background on mechanical, electrical, chemical, and electrostatic cleaning procedures to address dust-related difficulties and improved advances made to the automated cleaning system [2].

COMPONENT SPECIFICATION

1. *Cleaning brushes:* To remove dirt and debris from the solar panels, these mechanical parts come into direct contact with the panels. Materials like nylon, polypropylene, or natural fibres can be used to make them.
2. *Water Delivery System:* To moisten the solar panels and supply the required cleaning fluid, a water delivery system is required. There could be nozzles, hoses, and pumps in this system.
3. *Control System:* To manage how the cleaning system operates, a control system is required. This might have sensors to gauge the amount of dirt on the solar panels and modify the frequency of cleaning accordingly.
4. *Power Supply:* For the cleaning system to function, a power supply is needed. This could be an external power source, a solar panel, or a battery, depending on the design.
5. *Mounting System:* The cleaning system can travel along the solar panel array and is held in place by the mounting system. Rails, brackets, and other mounting hardware might be examples of this.
6. *Safety measures:* To safeguard employees and avert mishaps, safety measures including motion sensors, emergency stop buttons, and safety barriers may be installed.

The size and kind of solar panel array, the surrounding environment, and the cleaning system design are just a few examples of the variables that will affect the precise component specifications.

PROCEDURES OF SOLAR PANEL CLEANING

Mechanical Method

1. *Manual Cleaning:* Operators that use this cleaning procedure run the risk of having to climb staircases and rooftops. Given the typically high expenses associated with performing this kind of cleaning, hiring a specialised technical expert to complete this service may need a significant financial commitment. As seen in Figure 1, the cleaning is done with a brush that doesn't scratch the panel and a handle that has a connected water hose. If there isn't an overhang, running soapy water or water from the rooftop can discolour a house's sides. The soap and water still need to drain, even with a well-designed overhang. Certain cleaning solutions can injure pets and animals and harm plants, trees, and vegetation in addition to causing damage to solar panels [5, 6].
2. *Sprinlders:* Initial generation Regular washing is necessary for photovoltaic (PV) systems to prevent efficiency degradation. Surface dust deposition reduces solar energy absorption by photovoltaics and, as a result, PV output. If the modules are not cleaned for a month, efficiency could drop by fifty percent. This impact is very location-dependent, with desert conditions posing greater challenges due to the accumulation of dust particles and the potential for high wind speeds. Using a self-cleaning mechanism, temperature control to prevent solar cell overheating, water recycling, and rainwater harvesting, this research seeks to demonstrate the concept of an innovative, intelligent device with numerous applications and benefits. This study investigated the purification of solar cells at the energy production facility above the Najashi Mosque in the city of Salt (Jordan). An automated cleaner was installed to clean the dust on a regular basis. It

recognises the dust on the solar panel and cleans the module automatically. The following cleaning techniques were compared: pressurised air, manual injection water, automatic cleaning, and manual cleaning. The new proposal has certain excellent properties that make it the perfect tool to solve issues with cleaning, high temperatures, and improving the efficiency of solar cells. It can also be used to collect rainfall by utilising the large regions of solar cells that are dispersed over the globe [7].

Figure 1. Manual cleaning of solar panel module.

Chemical Method

1. *Electrostatic biasing:* It uses electrical current in a non-contact way to clean the panels. We gave an example of effectively clearing the panel surface of dust. Low frequency high voltage is used to achieve good cleaning performance; low initial dust loading and high panel inclination are preferred. Even if residual dust still builds up after several cleaning sessions, it does so in considerably lesser amounts than it would have in the absence of cleaning. Technology uses a very small amount of power. It is anticipated that this technology will greatly improve the efficiency of large solar power plants built in desert regions. The particles close to the parallel screen electrodes on a solar panel are subjected to an electrostatic force when a high AC voltage is supplied to them. The alternating electrostatic field causes the particles to move in the reciprocator between the electrodes, with some particles falling along the inclined panel due to gravity and others passing through the upper screen electrode's holes [3].
2. *Biomimetic:* Natural surfaces like moth eyes and lotuses provide inspiration for many surface designs. This allows for the creation of unique surface capabilities like self-cleaning or antireflection qualities that are achieved using lasers. Based on its DLIP technology, Fusion Bionic has recently created a proprietary laser technique that enables bio-inspired micro- and nanostructures to greatly minimise the soiling behaviour of dust and dirt on glass surfaces. Anisotropic ratchet conveyors (ARCs) are microscale hydrophilic curved rung structures that Böhringer et al constructed on a hydrophobic background [11]. Michele et al examined a few biomimetic techniques that can be applied to enhance the performance and stability of transparent and semi-transparent solar cells [12]. In order to reduce the surface stress created between the coated facet and the water, a unique hydrophobic silicon dioxide (SiO_2)-based nanoparticle coating proposed by Aljdaeh et al [13].

Automation Methods

1. *Dry Cleaning:* Debris accumulation on solar panels directly affects their efficiency. Consequently, to maintain the panels' optimal level of efficiency, routine cleaning is required. Since this is a groundbreaking advancement in the field of solar panel cleaning technologies, a variety of cleaning solutions for different kinds of dirt are available on the market. The most popular method is dry cleaning, which is best suited for solar parks where the primary source of photon obstruction is sand and dust. Other cleaning techniques involve using water to remove stubborn dirt and dust, as well as some other types of dirt that are more difficult to remove. Through the development and manufacturing of a dry-cleaning robot based on the dust accumulation monitoring system, colour analysis of the PV panel surfaces, and an image

processing system, Amin et al provide a workable approach to automate both monitoring and cleaning of the PV panel's surfaces [14]. To clean solar panels as cheaply as possible, a robot that can work autonomously, is water-free, generates its own energy, takes in dusty air instead of blowing, and is unique from other robots by possessing all these qualities together has been developed in study by Olmez et al. Other than replacing the microfiber glands on a regular basis, the designed robot operates without human intervention [9].

2. *Cleaning with help of Water:* The bulk of cleaning techniques involve using a set of driven brushes to wipe the panels in various ways. However, effective cleaning techniques were also demonstrated in Figure 2, such as the use of water jets to remove dust from the panel surface. Additionally, it was noted that most patents and solutions available on the market employ solar panels' tracks to move the cleaning system. While smaller cleaning systems also use a vertical rail to allow the system to move both horizontally and vertically on the panel surface, larger cleaning systems the size of a frame only require one rail for horizontal movement [4]. Thomas et al present an automation system for solar panel cleaning which include two squeegees on either side of the brush to remove water, and it clean the panels using gentle yet strong nylon brushes. The system can be directly retrofitted onto the panels in solar power plants, businesses, and homes. This technology allows for multiple row cleaning, vibration-free operation, and water reuse [10].

Figure 2. Two main categories of cleaning robot for solar panel.
Source: https://image.baidu.com

3. *Cleaning Robots:* The design and execution of a novel Portable PV Cleaning Robot System (PPVCRS) proposed by Baloushi et al. [8].

Design Consideration

1. *Cleaning Mechanism:* An automated solar panel cleaning system must take the cleaning mechanism into account. A revolving brush, a wiper blade, or a water-based cleaning system can all be used as the cleaning mechanism. Every cleaning method has pros and cons, so choosing the right one for your solar panels will depend on several factors like the kind of panels, the level of soiling, and the surrounding environment.
2. *Sensors:* An automated solar panel cleaning system cannot function without sensors. The sensors can be used to determine the sun's position, the weather, and the degree of soil on the solar panels. To make sure that the solar panels are cleaned only when required and with the right amount of cleaning solution, the sensors can be linked with the cleaning mechanism.
3. *Power Supply:* An automated solar panel cleaning system needs a dependable and effective power source. The grid, batteries, or solar panels can all power the system. The cleaning mechanism and the sensors should be able to function with an adequate power supply.
4. *Control System:* An automated solar panel cleaning system needs a reliable and easy-to-use control system. The cleaning mechanism, sensors, and power supply should all be able to be

monitored and controlled in real time by the control system, which can be distributed or centralised.

5. *Maintenance:* An automated solar panel cleaning system should be inexpensive and simple to maintain. The sensors, control system, and cleaning mechanism should all be made for simple replacement and maintenance.
6. *Safety:* An automated solar panel cleaning system must take safety into account. To protect the public and operators alike, the system should be built with safety measures such safety guards and emergency stop buttons.

Technical Specification

1. *Size and Weight:* To enable simple installation and maintenance, the automated solar panel cleaning system's size and weight should be small and light. The system shouldn't significantly increase the weight of the solar panels or require a lot of room.
2. *Cleaning Efficiency:* The solar panels should be cleaned effectively by the automated solar panel cleaning system. The solar panels' ability to produce energy can be decreased by dust, grime, and other debris, so the system needs to be able to remove it from them efficiently.
3. *Cleaning Frequency:* To make sure that the solar panels are cleaned only, when necessary, the automated solar panel cleaning system's cleaning frequency should be optimised. The amount of soiling on the solar panels, the type of weather, and the sun's position can all influence how often they need to be cleaned.
4. *Power Consumption:* To save energy expenses, the automated solar panel cleaning system should have a low power consumption. The system ought to be fueled by renewable energy sources, such solar or wind turbines, and should be engineered to use the least amount of energy possible when cleaning the solar panels.
5. *Durability:* Materials for the automated solar panel cleaning system should be strong enough to endure adverse weather, including strong winds, cold temperatures, and heavy downpours. Long-term system performance should be possible without the need for frequent maintenance or replacements.
6. *Cost:* The automated solar panel cleaning system must be reasonably priced and economically efficient. In addition to offering a respectable return on investment, the system should boost energy production over time and save maintenance expenses.

DISCUSSION

Our study's findings on the automated solar panel cleaning project demonstrate that using an automated cleaning system can enhance the effectiveness and performance of solar panels. The automatic cleaning system can efficiently clear the solar panels of dirt, dust, and other debris, which can lower their ability to produce energy. The automatic cleaning system can help to lower maintenance costs and enhance energy production by keeping the solar panels clean. We have also demonstrated how the automated cleaning system may be programmed to run automatically in response to changes in the sun's position, soil level, and weather. As a result, less manual cleaning is required, which can be expensive, time-consuming, and labor-intensive.

CONCLUSION

In conclusion, automated solar panel cleaning systems have gained popularity in recent years due to their ability to reduce labour costs and improve cleaning efficiency. Different cleaning techniques, such as dry cleaning, wet cleaning, and robotic cleaning, have been developed to remove dirt and other contaminants from solar panels. However, the impact of cleaning on solar panel performance and the economic feasibility of automated cleaning systems depends on variousfactors, such as the size of the installation, the cost of labour, and the frequency of cleaning. Therefore, it is important to choose appropriate cleaning techniques and to consider the economicfeasibility of automated cleaning systems before investing in them.

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