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Original Article

Automatic Cleaning and Coating for Photovoltaic Panel

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Abstract: *Recently, transparent self-cleaning coatings have been developed specifically for the building glass, automobile and photovoltaic (PV) panel industries with an emphasis on glass panels. The wettability study's discovery changed the course of the self-cleaning property's development and raised industrial demand. Because robotic and mechanical cleaners shatter glass, use less electricity during heavy rainstorms, and need expensive equipment, their usage for cleaning tasks appears to be impractical.*

Keywords: *Photovoltaic, Self-Cleaning, Shatter Glass, Heavy Rainstorms.*

INTRODUCTION

The amount of energy consumed worldwide is rising right now, and it is expected to keep rising in the future decades. About 80% of the world's energy comes from nonrenewable sources like fossil fuels, which causes the natural resources to be rapidly depleted. The rate of resource extraction is only expected to rise, which could result in an unavoidable energy crisis. In addition, the exploitation and burning of fossil fuels releases greenhouse gases into the atmosphere, which causes global warming and its catastrophic, unexpected impacts [1]. As a result, environmental concerns are growing. Thus, it is vitally important to practise energy conservation and make the most efficient use of the energy supplies that are now available. For instance, the Middle East has over half of the world's known oil reserves; as a result, economic instability spreads globally and impacts the entire geopolitical system. These resources are running out because to overuse of these fuels. As a result, no more than two generations can be supported by the current energy system.

It is crucial to move away from conventional nonrenewable energy sources and towards renewable energy on a large scale in order to prevent an energy crisis and lessen the consequences of climate change. Furthermore, with the world population growing and living standards rising, it is becoming more and more important to quickly adopt cleaner and renewable energy sources as the primary energy sources, as well as to increase energy efficiency and the incentives for utilising new technology, in order to establish a sustainable global development. The most hopeful answer to the above listed issues is renewable energy, since its rising global popularity has made a significant contribution to somewhat narrowing the energy gap. Investment in renewable energy-based power plants is being propelled by a confluence of factors such as pollution, global warming, and unstable costs for conventional fuels, particularly in Sunbelt nations.

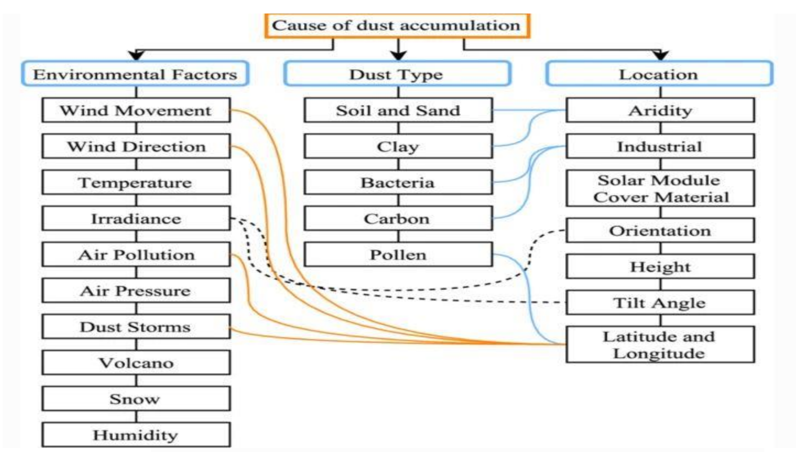

Figure 1: Detailed View of the Causes for Dust Accumulation

SOILING MITIGATION TECHNIQUES

It is widely acknowledged that the soiling effect poses a serious risk to solar PV efficiency. As a result, cleaning PV panels is important to prevent power and efficiency losses. For solar PV panels, dust collection is a constant problem, especially in desert regions. Due to their sheer size, Mega Solar Parks and Ultra Mega Solar Parks are typically located in desert-prone areas, where they are more likely to accumulate dust than those in metropolitan areas. There are two categories of cleaning strategies for PV panel soiling mitigation: manual cleaning and self-cleaning..

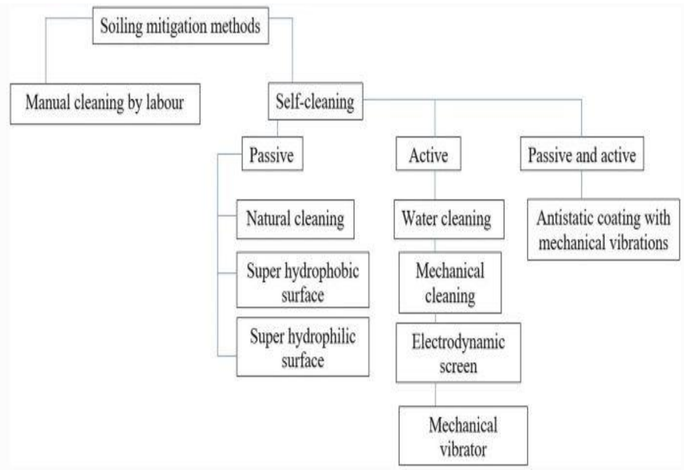

Figure 2: Different Soiling Mitigation Techniques

SELF-CLEANING OF PV PANELS

Generally speaking, self-cleaning solar panel solutions fall into three categories: active, passive, and hybrid approaches, as shown in Fig. 8. An active technique is a restorative cleaning approach that works with external energy. Examples of active techniques are electrodynamics screens, water cleaning, and mechanical cleaning. Conversely, a passive cleaning method doesn't require outside energy. Natural cleaning, which employs rainfall to remove dust buildup on PV panel surfaces, is an illustration of passive cleaning. Nevertheless, two further passive techniques were created that alter the surface morphology of PV modules by applying super hydrophilic or super hydrophobic coatings, in response to the lack of rainfall in many areas. The antistatic coating is a different kind of coating that keeps dust from adhering to the PV panel's surface and being repelled off it. To capitalise on the benefits of both active and passive approaches, a hybrid approach has been devised, such as the use of mechanical vibrations and an antistatic coating. The mechanical vibrator shakes the PV panel, causing the dust to fall off the surface due to gravity, while the antistatic coating keeps dust from adhering to the panel.

Active cleaning methods:

Mechanical cleaning

The majority of mechanical cleaning methods make use of brushes and wipers. Depending on where in the dirt they are, they can move either vertically or horizontally. The mechanical cleaning systems (such as robotic cleaners that use electrical or electronic technologies) can be turned on manually or automatically. The robot in Fig. 10a employs suction bots to clear dust from the PV panel's surface, while the robot in Fig. 10b uses brushes similar to car windscreen wipers. The autonomous cleaning robot in Figure 10c uses tiny photovoltaic panels to recharge its battery.

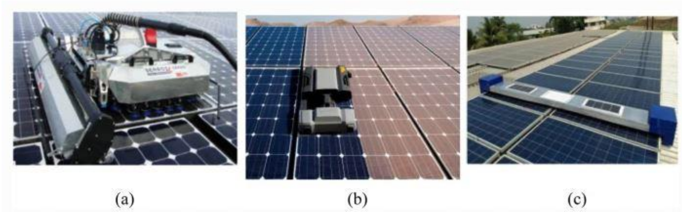

Figure 3:PV panel dry cleaning using robot with a brushes [103], b suction bots [26], and c small solar cells for charging its batteries and self-running

Compared to standard manual cleaning methods, robotic solar panel cleaning offers more integrated characteristics including high stability, quick response times, and dependability. They can be applied whenever fixing labour issues is not enough, and when strong autonomous and unmanned control is needed. However, because the robot requires multiple mechanical parts and additional costs for system installation, the cost of acquiring the robot itself is significant, particularly for big PV plants. When determining the cost of the robotic cleaning system, maintenance costs for the hardware system, such as gears and chains, must be included. The system must function well if the maintenance schedule is followed on time. As was already discussed, the PV panel may sustain significant surface damage during cleaning because wipers and brushes are the cleaning instruments utilised in the great majority of mechanical cleaning systems. As a result, if maintenance is neglected, dirt and dust will build up on the cleaning instruments and other components that come into direct contact with the PV panel surface, reducing the panel's efficiency. The fact that the active cleaning systems are electrically powered—either by the PV system itself or an additional battery that is regularly changed for charging—is another crucial factor to take into account. Nevertheless, the latter circumstance will cause the PV system's output power to drop during the cleaning procedure, resulting in high power consumption rates, particularly in big PV systems.

Electro Dynamic Cleaning:

The primary idea behind the development of the electrodynamics screen cleaning method, or electrodynamic screening (EDS), was the dust electrostatic property. Masuda et al. used the electric curtain concept to further enhance the electrodynamics screen cleaning approach. This idea is based on how dust electrostatic interactions cause oppositely charged particles to travel in different directions. As a result, once the dust has settled on the panel's surface, it continues to migrate, as seen in the illustration, from one edge to the next. This process continues until the dust is completely cleaned from the panel's surface. Experimental evidence has demonstrated that the EDS technique needs a low energy consumption rate of less than 1 Wh/m2 to remove the dust layer during each cleaning cycle. This energy output is comparable to 0.1% of the energy generated by a 1 m2 photovoltaic panel. Furthermore, it has been demonstrated that the EDS method can clean solar panels quickly; in dry environments, the dust layer can be eliminated in a matter of minutes, yielding extremely high efficiency. Moreover, this method has great adaptability because it doesn't require any extra cleaning agents or an external power source. By using a minimal amount of energy, the EDS approach may return the PV panel's surface to its original, pristine state while reaching high efficiencies of over 90%. It was discovered that the EDS approach performs better on dust particles larger than 20 µm, however it is less efficient on small dust particles between 0 and 5 µm.

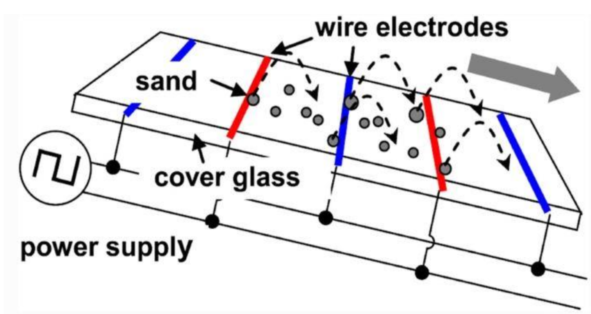

Figure 4: Schematic design of the electrostatic cleaning system that cleans a solar panel by using gravity and a standing wave to remove sand.

However, it was discovered that applying an additional layer of the EDS cleaning method to the PV panel lowers the amount of sunlight that reaches its transparent screen. This lowers the panel's efficiency because ultraviolet radiations have an uncertain durability. The output power consequently drops by 15%. EDS can be combined with super hydrophobic coatings to improve the cleaning of the panels in rainy situations, although it is unreliable in wet conditions or with cemented dust.

EFFECT OF THE CLEANING FREQUENCY ON THE EFFICIENCY OF THE PANELS

The right timing for solar panel cleaning depends on striking a balance between the total cost of cleaning the panels and the maximum amount of efficiency loss that can be accepted. In light of the UAE's environment, Shah et al. investigated the ideal interval for PV cleaning. According to this study, when compared to panels that were cleaned every day, the output power of the panels left unclean for three months dropped by 13%. However, the output power achieved decreased by 3% when the panel was exposed to a dusty atmosphere for a duration of 10 days. In the meantime, the PV panels produced 5% and 7% less electricity after being left uncleaned for 20 and 30 days, respectively. Nevertheless, it was discovered that washing the panels every 15 days is the most practical cleaning interval; this resulted in a 4% reduction in losses. A predicted cleaning frequency of 12–15 days was suggested by Hammad et al. for PV panels in Jordan. In addition, Mohamed et al. tracked soiling losses throughout a range of time periods, from three days to a month. Based on cleaning and energy loss costs, they discovered that an 8-day cleaning frequency is ideal. The impact of fluctuating daily soiling rates resulting from different weather patterns in Zimbabwe was taken into account in order to reduce the number of days between cleaning intervals. It was shown that the ideal cleaning interval to reduce the losses from both regular and infrequent cleaning is 15 days.

RESULTS AND DISCUSSION

Numerous researches suggested cleaning schedules for PV modules based on factors such as location, energy loss from soiling, PV integration design, and size of PV power plant, and cleaning costs, which varies significantly between the two nations. Additionally, the choice of cleaning technique is contingent upon whether the modules are situated in an area with low levels of dust and a lot of rain, or in an area that is dry and extremely contaminated.

The safest way to clean the PV panel's glass surface is using water and detergents, although this option isn't suitable in areas with limited water supplies. Consequently, it is necessary to create new cleaning techniques that do not require water (i.e., dry cleaning) and do not alter the panel's glass surface's surface texture (i.e., do not scratch the surface). In the end, whether or not to clean a photovoltaic system comes down to economics. The cleaning system must be financially viable if the cleaning expenses are offset by the increased productivity brought about by the cleaning procedure. Two factors need to be taken into account in order to determine whether a cleaning method is economically viable: the number of kilowatt hours that a photovoltaic plant needs to produce as additional yield in order to recover the cost of cleaning, and the percentage of additional yield for the plant's overall production.

In order to make the system even more intelligent and efficient, self-cleaning systems incorporate cloud-based man-machine interfaces, autonomous cleaning units, and IOT-based models. For a huge solar farm situated in semiarid areas—where frequent cleaning is necessary owing to sand deposition—this clever self-cleaning system proved to be quite successful. Additionally, soiling prediction can benefit greatly from the application of artificial intelligence (AI) tools. Based on the most recent environmental data, these methods forecast the daily and cumulative PV soiling loss using artificial neural network (ANN) models.Additionally, ANN models can be used to forecast output power, study the impact of soiling on energy production, estimate soiling losses based on dust density and particle size composition under artificial soiling conditions, and model how dust deposition affects the transmittance of photovoltaic modules. Unmanned aerial vehicles (UAVs) are thought to be one of the main components that are being utilised more and more in place of the traditional, costly, and time-consuming soiling inspection methods. Unmanned Aerial Vehicles (UAVs) are utilised for efficient examination of solar modules to precisely forecast losses due to filth and dust buildup. It is also very adaptable, capable of operating in tough environments, and enables fast data collection—particularly for big regions. It also broadens the measuring coverage and inspects hard-to-reach installations. This lowers the workload in power plant operations, saves time, and requires less human intervention. Although dust sensors are more accurate than UAVs in soiling detection, UAVs are more cost-effective due to their topography detection method rather than spot detection. More work needs to be done to increase the precision of UAVs so they can identify soiling at centimetric or millimetric levels. Additionally, they should be able to correlate the detection of soiling with a decrease in panel efficiency, enabling precise cleaning decisions to be made.

CONCLUSION

The current study gave a thorough overview of the literature and a critical analysis of the issue of dust deposition, highlighting the detrimental effects it has on PV panel surfaces as well as the different cleaning methods, difficulties, and solutions that have been suggested. A number of factors, including the climate and environmental conditions—which include wind direction and strength, ambient temperature, precipitation totals, humidity, seasonal fluctuations, and the size, shape, and mass of the dust—as well as the solar plant's placement and installation, can influence the percentage reduction in efficiency caused by dust accumulation on the PV panels over time.

The water gap may be closed by combining supply and demand management strategies; in the agricultural sector, where it has the greatest influence, water demand management should be prioritised above all others. However, even with all demand management methods in place, the water gap will not be filled. It ought to be supported by new alternatives for the provision of water that come from unconventional sources like treated wastewater and seawater desalination.

It is imperative that researchers do additional thorough investigations to reduce the dependability of traditional water-based cleaning techniques for photovoltaic (PV) panels. Consequently, ongoing initiatives in this area appear to be a step in the right way towards preserving the PV panels' efficiency. Further study should be done in this direction. It is strongly advised to develop artificial intelligence models and smart cleaning systems that can identify the optimal and most advantageous cleaning time and frequency depending on the dust pattern.

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