The OCEM Journal of
Management, Technology & Social Sciences

Received: Aug. 08, 2023 | Revised: Aug. 21, 2023 | Accepted: Sept. 23, 2023 | Published: Jan. 2024

DOI: https://doi.org/10.3126/ocemjmtss.v3i1.62230 **Paper Type: Research Article**

Performance Analysis of Semi-Automatic Solar Panel Cleaning System

[1]Samir Raj Bhandari, [2]Aasish Chhetri, [2]Anil Rai, [2]Madan Rawal, [2]Rabin Deuba
[1]Department of Electrical and Electronics Engineering, Oxford College of Engineering and Management
[2]Student of Electrical and Electronics Engineering, Oxford College of Engineering and Management
*Corresponding email: bhandari.samirraj@gmail.com
*Orcid: https://orcid.org/0000-0003-2722-8008

Volume 3, Issue 1
ISSN Print:2705-4845
ISSN Online:2705-4845

Abstract

Solar energy has been one of the most promising energy sources since the 1990s. However, the efficiency of solar panels is reduced due to dust accumulation over modules, which blocks the incident light from the sun. The efficiency of a solar panel depends on various factors, such as the quality of the solar cells, the design of the panel, the temperature and intensity of the sunlight, and the presence of any shading or obstructions. High-efficiency solar panels can produce more electricity from the same amount of sunlight, resulting in higher energy production and cost savings over the system's lifetime. The study used a semi-automatic cleaning mechanism, which is one of the recent developments made on automated cleaning systems of solar photovoltaic modules. Aims of this study is to improve the efficiency of solar panels by designing and implementing a semi-automatic dust-cleaning mechanism. This study found that the experimental model shows improved efficiency by about 7 percent. The study's findings are consistent with previous research that emphasizes the importance of regular cleaning of solar panels to improve their efficiency and reliability. This research has important implications for improving the efficiency and reliability of solar energy systems. Solar panel owners can improve the profitability and sustainability of their system, leading to more widespread adoption of solar energy by optimizing the cleaning process and reducing maintenance costs.

Keywords: *renewable energy, solar panel cleaning system, solar photo voltaic, system improvement*

How to cite this paper:
Bhandari, S. R., Chhetri, A., Rai, A., Rawal, M., & Deuba, R. (2024). Performance Analysis of Semi-Automatic Solar Panel Cleaning System. *The OCEM Journal of Management, Technology and Social Sciences, 3(*1), 110-116.

Introduction

Solar energy is a promising and renewable source of power that can meet the world's energy needs. However, the efficiency of solar panels is influenced by atmospheric conditions like clouds, dust, and temperature. Regular cleaning of solar panels is necessary to maintain their performance. Dust and dirt accumulation on the panel's surface can obstruct sunlight and reduce the panel's efficiency. Studies have shown that the efficiency of solar panels increases significantly after cleaning, highlighting the importance of regular maintenance. Proper cleaning and maintenance enhance the overall performance of solar panels and optimize the utilization of solar energy (The Economic Times, 2019; ACS, 2022; Chandler, 2022; Patil et al., 2017).

Solar panels offer several advantages, including mitigating the environmental impact and combating climate change by generating electricity without emitting carbon dioxide. They also reduce reliance on fossil fuels and traditional power sources, promoting energy sustainability. Additionally, they have a long lifespan with minimal wear and tear. However, the initial cost of installing solar panels can be a limitation, as they can be expensive. Despite this, investing in solar energy is crucial for reducing carbon emissions, decreasing dependence on finite resources, and moving toward a cleaner and more sustainable energy future (ACS, 2022; Patil et al., 2017)

Solar cells, also known as photovoltaic cells, convert light energy directly into electrical energy. They consist of two types of semiconductors: p-type silicon and n-type silicon. The p-type layer has positively charged holes, while the n-type layer has an excess of electrons. When the two layers are combined, electrons from the n-type layer fill the holes in the p-type layer near the junction, creating a depletion zone (Myyas et al., 2022; Sedai et al., 2021). This process enables the solar cell to generate electricity

The efficiency of solar panels can be improved by designing and implementing a semi-automatic dust-cleaning mechanism. Studies have shown that such a mechanism can improve the efficiency of solar panels by about 7%. The research has important implications for improving the efficiency and reliability of solar energy systems. By optimizing the cleaning process and reducing maintenance costs, solar panel owners can improve the profitability and sustainability of their system, leading to more widespread adoption of solar energy.

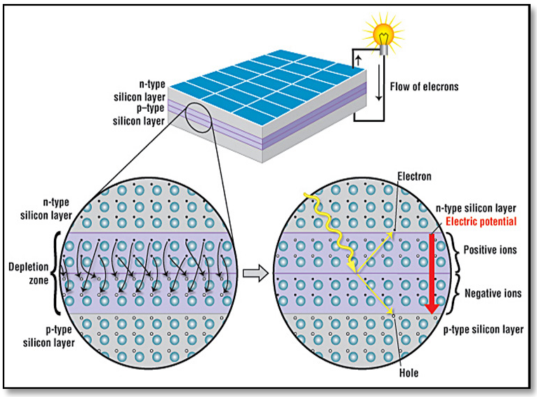

Figure 1: *Working Mechanism of Solar Panel* *(*ACS, 2022)

Cleaning solar panels can be challenging, especially when they are installed at a height. Dust particles obstruct sunlight and decrease the electricity generation capacity of solar panels by up to 50% if left unclean. However, cleaning solar panels requires manpower, time, and water, and can be dangerous for street light solar panels mounted on top of poles, often reaching heights of 15 to 20 feet (Maindad et al., 2020).

Photovoltaic (PV) cells, which convert sunlight into electricity, are primarily made of silicon. When photons from sunlight strike PV cells, electrons in the semiconductor material are excited, generating electric voltage and current. The efficiency of PV modules depends on the mass and size of the dust particles deposited on their surface. As the mass of dust increases, power output and module efficiency decrease. Smaller particles have a more significant impact as they block more radiation.Pollutants like red soil, ash, sand, calcium carbonate, and silica contribute to this deposition, and air pollution can further deteriorate the energy yield of PV panels, even over short periods. Currently, most solar panels are manually cleaned in many countries. However, this method requires additional manpower, time, and can pose safety risks. Urban areas are particularly affected, with a high density of airborne particles that adhere to panel surfaces, causing a drastic reduction in efficiency over time

(Hussain et al., 2017; Mishra, 2022; Rodríguez, 2024). The automatic dust-cleaning system for solar panels addresses the drawbacks of manual cleaning, ensuring effective and non-abrasive cleaning, minimizing accidents, panel damage, movement difficulties, and maintenance issues (B et al., 2018).

The objective of this research project is twofold: The first objective is to develop a semi-automatic Solar Panel Cleaner and investigate the performance of solar panels under varying conditions throughout the day, encompassing both dusty and dust-free scenarios; second, to meticulously record voltage and current measurements to facilitate the calculation of efficiency, subsequently comparing the obtained efficiencies of the solar photovoltaic (SPV) panel in the presence and absence of dust.

Literature Review

One major challenge with solar panels is the high cost associated with installation. However, by increasing the efficiency of each panel, fewer panels would be needed, resulting in cost savings and environmental benefits. Two key factors to improve efficiency are maximizing direct sunlight exposure and effectively converting light energy into power. Dust accumulation on solar panels, particularly in dusty regions like Saudi Arabia, significantly reduces their efficiency. To address this issue, an automated cleaning system is proposed to ensure optimal performance. The use of appropriate fabrication techniques and controllers will be essential for the success of this project. Dust settlement depends on various factors, including chemical properties, size, weight, shape, site location, tilt angle, surface characteristics, stickiness, and wind speed. Previous research has explored the impact of dust and impurities on solar panels, providing valuable insights for this project (Ghate et al., 2019).

Projects and Trends Solar Panel Cleaning Technology

Cleaning systems for photovoltaic cells have been developed to address the issues mentioned above. Extensive research and discussions on various cleaning technologies, with autonomous cleaning robots emerging as a leading solution. The earlier mentioned robots utilize soft brushes to clean the panels without causing any surface damage. The robots are equipped with motorized trolleys for horizontal movement, while the vertical motion is controlled by a belt-driven system. In a similar vein, many surveys on solar cleaning projects and technologies, including the solar brush UAV robot, Ecoppia E4, wash panels, and Nomad cleaning systems have been done. The solar brush robot, for instance, operates as a drone that hovers close to the panel surface and cleans it through air pressure pressure and gentle rubbing. This robot's design minimizes direct contact with the panel, significantly reducing the risk of damage. The solar brush UAV robot represents a promising advancement in solar panel cleaning technology (UT Pumps & Systems Pvt Ltd, 2020).

Current Technologies

In current situations various cleaning system are in practice for solar panel cleaning.

Manual Cleaning

Manual cleaning of solar panels can be done using cleaning kits that include extension poles, brushes, cloths, and hose connections. However, as the solar plant size increases, manual cleaning becomes impractical and costly due to the need for large manpower and increased O&M costs (Aljaghoub et al., 2022).

Piezoelectric Systems

Piezoelectric actuators, known for their high torque to volume ratio, flexible structure, and precise positioning, are utilized in various fields including optical adjustments, biomedical manipulation, and space explorations. In the cleaning of solar panels, piezoelectric systems are employed. An acoustic piezoelectric system uses water as a cleaning agent, creating a vacuum called an ultrasonic cavity during the rarefaction cycle of compression waves. This cavity effectively cleans the solar panel surface by suctioning the dust. For the air medium, the cleaning mechanism remains similar with a change in the cleaning medium. A linear piezoelectric actuator-based solar PV panel cleaning system ensures proper pressure force between the wiper and the solar panel, allowing the actuator to vibrate and effectively remove dust from the panel's surface (Khadka et al., 2020).

Water-Based Robotic Cleaning System

Water-based cleaning systems use water as their primary component as their cleaning agent. The water-based cleaning system is best suited in an urban and tropical climate where water is abundantly available. Water-based cleaning is the best cleaning system in terms of cleaning efficiency. It can remove hard stains and bird excrement from the surface of the panel (Bhandari et al., 2023).

Robotic Cleaning System

In dry regions where water is scarce and dust accumulation is the main issue on solar panels, water-less cleaning technology proves to be effective (Bhandari et al., 2023). This method involves the use of a dust-repellent brush that rotates or moves across the panel's surface to remove the dust. This approach is particularly efficient in arid areas. One example of a water-less robotic cleaning system is the Solar Brush, which is wireless, rechargeable, and capable of walking on solar panels with an inclination of up to 35 degrees (Haya Aljaghoub et al., 2022). As drone technology advances, companies are also introducing drone-based cleaning systems, which are suitable for streetlight solar panels and smart energy-efficient greenhouses (Hussein et al., 2021). Currently, manual cleaning is the predominant method in many countries, but it is not cost-effective. With the increasing demand for large-capacity solar power plants for higher energy demand, more efficient cleaning methods and energy alternatives like integrated micro hydropower plants will be required in the future (Fırat Ekinci et al., 2022).

Methodology

The current research is based on the experimental research design to enhance solar panel cleaning for improved efficiency.

Project Flow Diagram

Following the dimensions of the flat plate panel, the solar panel cleaning system consists of a brush driven by DC motors. The timing of the brush operation is controlled by a pre-set value. The frame carrying this cleaning brush is moved along the length of the solar panel in a horizontal direction and vice versa, resulting in a mopping action on the solar panel to clean it.

The working mechanism of our project starts with the DC power supply to the Arduino. The timing and intensity of the solar tradition value are primarily set and checked against the pre-set value. This motor drive provides power to the DC motors fitted on the two edges of the panel in the horizontal position. The motors initiate rotation, and their shafts are connected to the two metal frames. The shafts accelerate in the forward direction, and the cleaning brushes attached to them start cleaning the panel surface. After cleaning the panel, the brush and the entire system move in the forward and reverse directions. After the complete brushing of the panel, the output will be displayed on the LCD screen and compared with the output of the panel's dust condition with and without dust.

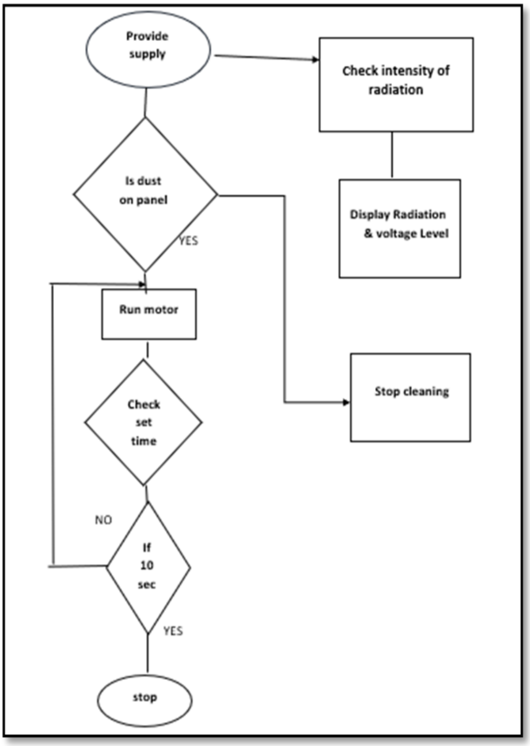

Figure 2: *Flow Chart of the Solar Panel Cleaning System*

Working Mechanism and Design of the Project

The diagram below shows the top view of our project, which consists of a solar panel with dimensions of 1.47m*0.67m. The rated capacity of the panel is 160W, with a maximum voltage and current output of around 18.67V and 8.63A, respectively. The panel's width is measured to determine the design of the connecting shaft.

Two motors are fitted with the help of four bearings to support and ensure smooth motion of the cleaning system. After measuring the dimensions, a rotor shaft is connected between the two motors using a metal motor cover structure to secure and fix the motors to the cleaner's shaft.

The outer structure of the cleaner is designed to accommodate a brush made up of five small shoe-polished brushes attached together, forming a complete single brush that covers the entire panel surface effectively. Connecting rods made of steel are used to attach the brushes and connect the two different motors. A single-phase 12V DC motor with a 100 RPM motor is utilized. A rubber terminal box is fixed on top of the rotor shaft in the middle part, housing the entire system's circuit and components. After assembling all the components, the cleaner system weighs approximately 2.5kg. The complete working mechanism is shown in Figure 3, involving a solar panel with a capacity of 160W. A 11.3V DC voltage supply is used to operate the motor and provide power to the entire system. An LDR sensor measures the voltage intensity at different time intervals, and the measured radiation intensity level is displayed on an LCD screen. An Arduino receives the radiation level from the LDR sensor. The motor continuously monitors the motor mechanism. The motor rotation time is predetermined based on the panel's length and the motor's RPM. If the motor receives the voltage, it starts rotating on the panel, and after the preset time period, it rotates back. Once the cleaning process is complete, the dust on the panel is manually removed. Finally, the LCD displays the initial voltage and final voltage.

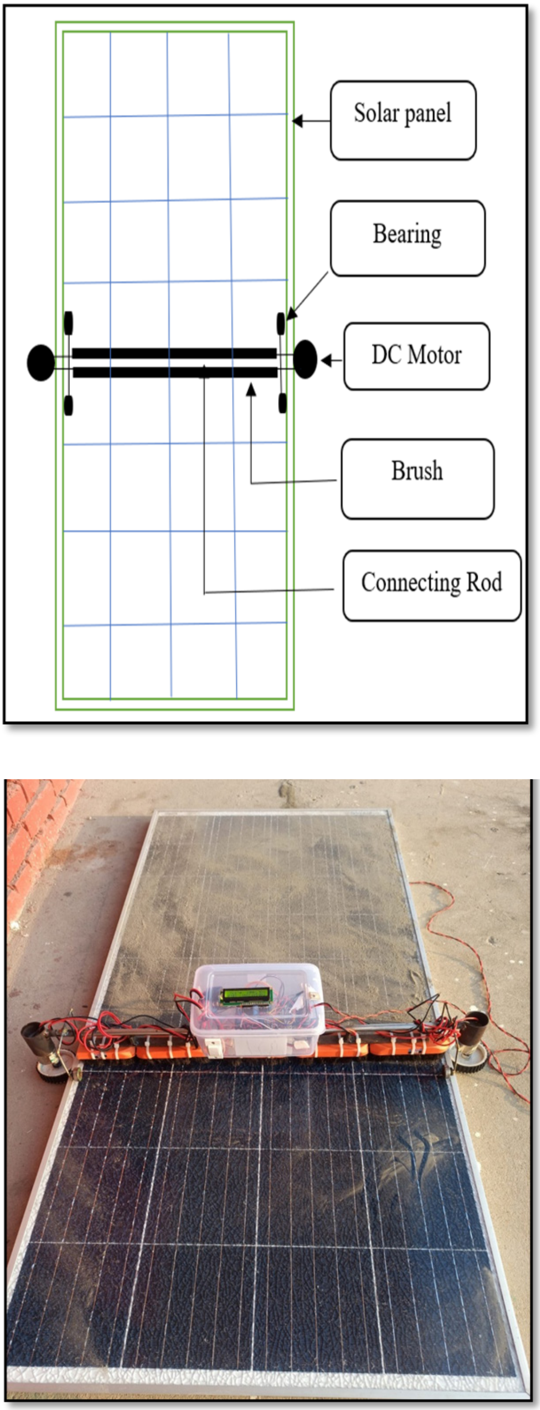

Figure 3: *Design of the (First Design, Second Practical Model as per the design)*

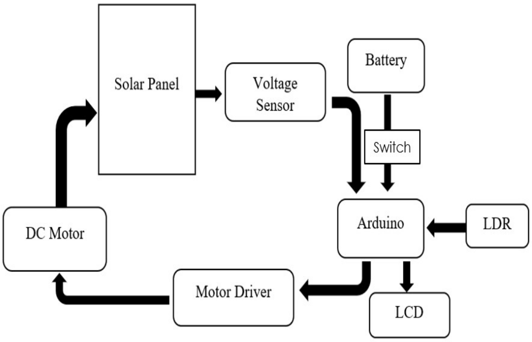

Figure 5: *Block Diagram of the Semi-Automatic Solar Panel Cleaning System(-PCS)*

Results and Discussion

The findings of the results are described after analysing the experimental data.

Output Voltage under Various Conditions

After collecting voltage readings at different times of the day from 8:00 AM to 4:00 PM, as shown in Table 2, it is observed that the voltage value decreases in the presence of dust compared to when the panel is cleaned by the Semi-Automatic Solar Panel Cleaning System. Therefore, it can be concluded that the dust on the panel surface is responsible for the decrease in voltage and also that the designed system can improve the system voltage significantly. Based on the voltage readings, the efficiency can be calculated. At 8:00 am, the voltage value with dust is recorded as 17.2 V, while without dust it is measured at 18.6 V. Similarly, at 12:00 pm, the voltage value with dust is 20 V, whereas without dust it is 21.5 V.

Table 2: *First Day Output Voltage with and Without Dust*

S.N	Time	Voltage (Voc) in Volts	
		With Dust (Before)	*Without Dust (After)*
1	8:00 AM	17.2	18.6
2	10:00 AM	18.57	20.3
3	12:00 PM	20	21.5
4	2:00 PM	19.6	20.55
5	4:00 PM	18.09	19.79

Table 3: *Efficiency Analysis before and after using the Semi-Automatic Solar Panel Cleaning Technology*

S.N	Time	Efficiency (in %)		Increase in Efficiency (%)
		With Dust(Before)	*Without Dust(After)*	
1	8 AM	73.7	80.88	7.18
2	10 AM	79.2	87	7.8
3	12 PM	85.7	92.1	6.4
4	2 PM	84	88	4
5	4 PM	77.7	84.8	7.1

Efficiency under Various Conditions

The results shown in table 3 reveals that at 8:00 AM, the efficiency of the solar panel without dust is measured at 80.88%, while in the presence of dust, the efficiency decreases to 73.7%. Similarly, during the middle of the day, the efficiency without dust is recorded at 92.1%, whereas with dust, it drops to 85.7% (See Table 3).

The results indicate that the presence of dust has a noticeable impact on the efficiency of the solar panel. The decrease in efficiency suggests a decline in the overall performance of the panel. It is evident that the accumulation of dust on the panel surface hinders the absorption and conversion of sunlight into electrical energy, resulting in reduced efficiency.

This difference in efficiency between the dusty and clean conditions is significant, highlighting the importance of regular cleaning and maintenance of solar panels to ensure optimal performance. This optimal performance can be achieved by using the proposed system. The decrease in efficiency observed at different times throughout the day further emphasizes the need for the semiautomatic system that can continuous monitoring and cleaning to minimize the negative effects of dust accumulation.

Conclusion

The results demonstrate that using a Semi-Automatic Cleaning System increases the efficiency of solar panels, while the presence of dust decreases efficiency, impacting overall performance. Regular cleaning and maintenance are crucial to maintain efficiency and maximize energy output. The experimental model showed a significant 7% improvement in efficiency with the use of the semi-automatic cleaning system. This study is important as it provides insights into enhancing the efficiency and reliability of solar energy systems. Optimizing the cleaning process and reducing maintenance costs are key factors in achieving improved efficiency, benefiting not only solar panel owners but also the profitability and sustainability of solar energy systems overall. Effective cleaning strategies and minimizing debris buildup enhance performance and energy output, contributing to the economic viability of solar energy. Improved cleaning practices increase confidence in the technology and promote wider adoption of solar energy as a clean alternative. This study emphasizes the significance of performance analysis and optimization of semi-automatic cleaning systems, highlighting the benefits of enhanced efficiency, reduced costs, improved profitability, and increased sustainability. These findings provide valuable guidance for industry practitioners and policymakers, supporting the widespread adoption of solar energy as a viable and environmentally friendly solution.

References

The Economic Times. (2019). *Definition of Solar Panel | What is Solar Panel ? Solar Panel Meaning - The Economic Times*. The Economic Times. https://economictimes.indiatimes.com/definition/solar-panel

ACS. (2022). How a Solar Cell Works. American Chemical Society. https://www.acs.org/education/resources/highschool/chemmatters/articles/how-a-solar-cell-works.html

Maindad, N., Gadhave, A., Satpute, S., & Nanda, B. (2020, April 25). Automatic Solar Panel Cleaning System. 2nd International Conference on Communication & Information Processing (ICCIP) 2020. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3646147

Hussain, A., Batra, A., & Pachauri, R. (2017). An experimental study on effect of dust on power loss in solar photovoltaic module. Renewables, 4(1). https://doi.org/10.1186/s40807-017-0043-y.

B, M., Bari, A., & C M, P. (2018). Automatic Solar Panel Cleaning System. International Journal of Advances in Scientific Research and Engineering, 4(7), 26–31. https://doi.org/10.31695/ijasre.2018.32778

Ghate, S. N., Sali, K. R., Yadav, A. S., Neman, N. S., & Chahande, J. (2019). Design and fabrication of Automatic Solar Panel Cleaning System. International Journal of Innovative Research in Science, Engineering and Technology, 8(3). https://doi.org/10.15680/IJIRSET.2019.0802096

UT Pumps & Systems Pvt Ltd. (2020). UTPumps is Screw Pump High Pressure Pump Cleaning System Manufacturer. Utpumps.com. https://www.utpumps.com

Aljaghoub, H., Abumadi, F., AlMallahi, M. N., Obaideen, K., & Al Alami, A. H. (2022). Solar Pv Cleaning Techniques Contribute to Sustainable Development Goals (Sdgs) Using Multi-Criteria Decision-Making (Mcdm): Assessment and Review. International Journal of Thermofluids, 16. https://doi.org/10.2139/ssrn.4166067

Khadka, N., Bista, A., Adhikari, B., Shrestha, A., Bista, D., & Adhikary, B. (2020). Current Practices of Solar Photovoltaic Panel Cleaning System and Future Prospects of Machine Learning Implementation. IEEE Access, 8(8), 135948–135962. https://doi.org/10.1109/access.2020.3011553

Bhandari, S. R., Khang, U. K., Yadav, A. K., Pradhan, D., Shrestha, M., & Adhikari, S. (2023). An Economic and Smart Greenhouse System using Microcontroller for Sustainable Agriculture: A Case Study. Indonesian Journal of Electrical Engineering and Renewable Energy, 3(1), 36–46. https://doi.org/10.57152/ijeere.v3i1.

Haya Aljaghoub, Abumadi, F., Maryam Nooman AlMallahi, Khaled Obaideen, & Abdul Hai Alami. (2022). Solar PV cleaning techniques contribute to Sustainable Development Goals (SDGs) using Multi-criteria decision-making (MCDM): Assessment and review. International Journal of Thermofluids, 16, 100233–100233. https://doi.org/10.1016/j.ijft.2022.100233

Hussein, M. F., Réda Nouacer, Corradi, F., Yassine Ouhammou, Villar, E., Tieri, C., & Castiñeira, R. (2021). Key technologies for safe and autonomous drones. Microprocessors and Microsystems, 87, 104348–104348. https://doi.org/10.1016/j.micpro.2021.104348

Fırat Ekinci, Abdurrahman Yavuzdeğer, Hüseyin Nazlıgül, Burak Esenboğa, Başak Doğru Mert, & Tuğçe Demirdelen. (2022). Experimental investigation on solar PV panel dust cleaning with solution method. Solar Energy, 237, 1–10. https://doi.org/10.1016/j.solener.2022.03.066

Chandler, D. L. (2022, March). How to clean solar panels without water. MIT News | Massachusetts Institute of Technology. https://news.mit.edu/2022/solar-panels-dust-magnets-0311

Patil, P., Bagi, J. S., & Wagh, M. (2017). A review on cleaning mechanism of solar photovoltaic panel. 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS), 250–256. https://www.semanticscholar.org/paper/A-review-on-cleaning-mechanism-of-solar-panel-Patil-Bagi/d7b7aef50d1f7f7dc5d1a77d5cbbade66a1f28ce

Myyas, R. N., Al-Dabbasa, M., Tostado-Véliz, M., & Jurado, F. (2022). A novel solar panel cleaning mechanism to improve performance and harvesting rainwater. Solar Energy, 237, 19–28. https://doi.org/10.1016/j.solener.2022.03.068

Ashish Sedai, Singh, G., Rabin Dhakal, & Anjay Kumar Mishra. (2021, November 13). Technical and economic feasibility of a fully solar powered Airport in Nepal. https://www.researchgate.net/publication/359176334_Technical_and_economic_feasibility_of_a_fully_solar_powered_Airport_in_Nepal

Mishra, A. K. (2022). Assessment Of Grid Electric Powered Transformation Into Solar Powered Pumping Water Supply Projects. Zenodo (CERN European Organization for Nuclear Research), 8(6), 1533–1546. https://doi.org/10.5281/zenodo.6538072.

Rodríguez, L. (2024, July 21). How to clean solar panels: 5 tried and tested ways. Ratedpower.com; RatedPower. https://ratedpower.com/blog/clean-solar-panels/