International Scientific Journal of Engineering and Management (ISJEM) ISSN: 2583-6129
Volume: 04 Issue: 04 | April – 2025 DOI: 10.55041/ISJEM02986
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

Automated Solar Panel Cleaning Mechanism

Priti V. Gadgil, Mansi A. Suryavanshi, Rohan N. Rawal, Sanjog S. Waghmare
Prof. A. R. Nadaf
Diploma Student, Department of Mechanical Engineering, Dr. Bapuji Salunkhe Institute of Engineering and Technology, Kolhapur, Maharashtra, India.
Head of Department, Department of Mechanical Engineering, Dr. Bapuji Salunkhe Institute of Engineering and Technology, Kolhapur, Maharashtra, India.

Abstract - As solar energy becomes a key alternative to traditional power sources, maintaining panel efficiency is essential. Dirt buildup on photovoltaic panels reduces their output by blocking sunlight, making regular cleaning crucial yet often challenging. This project aims to develop a compact, portable, and cost-effective solar panel cleaning system suitable for mobile use. Using Unigraphics for design and Analysis Workbench for performance evaluation, a prototype for a 2-watt panel will be created and tested. The system's effectiveness will be compared to existing cleaning methods to assess improvements in efficiency and practicality.

***Key Words*:** photovoltaic panels, solar energy, dirt and dust, 2-watt power panel.

1. Introduction

Solar energy has abundant energy, but natural processes, such as clouds, dust, and temperature, affect its conversion to a usable form of energy. Solar energy can provide us with a clean, renewable source of energy, and provides us electricity through solar energy produced through photovoltaic panels. The electricity produced through photovoltaic panels does not produce carbon emissions, which is beneficial to the environment. The efficiency of the solar panels is obstructed by dust, moisture, and panel temperature. A microcontroller-based automatic dust cleaning system has been designed to replace the labor-intensive cleaning of solar panels, and help limit the risk of accidents and damage to solar panels that can occur while cleaning the panels manually. This microcontroller-based system can clean the solar panel without abrasives, and is an efficient cleaning solution that helps improve the efficiency of solar panels by limiting dust related inefficiencies. Studies also showed that cleaning the panels after dust had settled over one day, one week, and one month can effectively improve efficiency of the panels. This microcontroller system definitely improves the efficiency of solar energy panels when compared to other methods of cleaning the panels. With the depletion of fossil fuels as a source of energy, including coal, gas, and nuclear energy, it is important to try to improve solar energy productivity through microcontroller systems like this and other technologies to meet our growing energy consumption demands.

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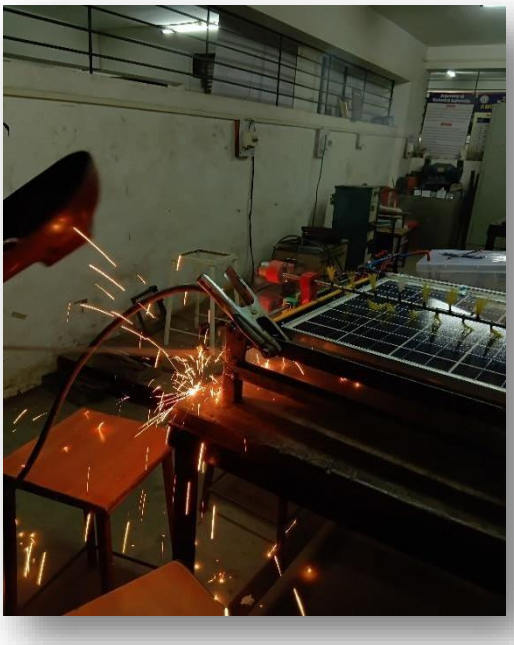
- **Impact on Efficiency:**
  Before cleaning the panel, energy output showed a 15–20% reduction compared to a clean panel. After cleaning the panel, energy output showed consistent increases in energy output. At times, energy output would increase by as much as 18% immediately after cleaning demonstrating that dust accumulation had such an impact on improving solar panel efficiency. Daily automated cleaning also sustained a similar energy output over several days compared to a similar uncleaned panel which continued to produce decreasing amounts of energy output. This indicates that even light daily cleaning of a solar panel is better than infrequent manual cleaning.

2. Problem Statement

The performance of solar panels, which convert renewable solar energy into usable electricity, can suffer significantly from the effects of dust, dirt, and other debris from the environment. This can be a serious issue in arid and semi-arid areas prone to dust build-up, where we have observed a significant impact on the performance of solar panels. Manual cleaning of solar panels is still the most common way to clean panels, but it can be slow, expensive, labor-intensive, and can damage panels, personnel and sometimes both. In cases like solar farms, where frequent cleaning is desirable or even necessary, manual cleaning on a large scale is not practical. Additionally, the range of cleaning options available, when considering alternatives to manual cleaning, generally either use large amounts of water, use a lot of energy, or are very complicated, expensive systems that are hard to keep running. As a result, we see a critical need for an automated cleaning system that eliminates the need for human cleaning of solar panels, doesn't require human maintenance during operation, doesn't sacrifice performance or durability of the panels, and also is energy-efficient, cost-effective, and conserves water. This is the purpose of this research project: to develop an automated cleaning system that uses a rotating brush cleaning system controlled with a micro controller that can control the movement, and operating speed of the brush, on a small scale while also being functional on a larger scale.



3. Overview of proposed system

To improve the efficiency of solar panels, the automated solar panel cleaning system proposed in this research is developed to combat the collection of dirt and debris commonly found on the surface of the panel. The proposed automated solar panel cleaning system aims to be less expensive, more energy efficient, and low maintenance, for cleaning solar panels, in both small-scale domestic and larger commercial solar installations. Solar energy is a renewable,

eco-friendly resource and provides an alternative to conventional energy (Bal, L. M. et al., 2010). Although, dust and debris accumulate on the surface of the photovoltaic panels, especially in arid and semi-arid areas, significantly reducing the amount of energy the panels output, by obstructing sunlight and rendering the panels inefficient and less effective (Chena, Y et al., 2019).

The automated cleaning system proposed is a rotary brush operation employing a DC gear motor, with movement from the process controlled by a microcontroller. The brush moves across the surface of the solar panel in both a linear and rotating brushing method that sweeps the dust and debris from the surface of the solar panels. The proposed cleaning system is good for residential and commercial solar panel installation, where manual cleaning methods are less effective and issues of practicality become prevalent with larger installations (Bena, B., and Fuller, R. J., 2002). The proposed cleaning does not consume water which would be functional in areas deficient in water or areas who advocate for conservation of water (Condori, M., et al. 2001).

4. Key Features of the Proposed System:

1. Rotary brush mechanism: The application of a rotating brush to clean the surface of solar panels issued to clean the surface in a gentle manner. The soft rotating brush will remove dust and dirt without destructing the surface of the panels, maintaining the veracity of the surface. The approach removes any potential for scratching the panel surface that may occur with traditional methods of damaging the panel's surface due to all the abrasive cleaning (Bena, B., and Fuller, R. J., 2002).
2. Microcontroller Control: A microcontroller commands the cleaning system by controlling the brush's forward and backward motion and activating and deactivating the motor. The system can be programmed to operate on a periodic basis or based on real time data (if sensors are added), as done with other automatic systems (Bal, L. M. et al., 2010). Compact Design: The entire cleaning mechanism is designed to be compact, ensuring that it can be installed without taking up too much space on rooftops or solar panel farms. This design is especially important for small-scale solar panel installations such as those on residential buildings (Condori, M., et al., 2001).
3. Energy Efficiency: The system uses a small amount of energy, usually from the solar panel directly, so it can overall be said to be sustainable and energy efficient to the point that it does not extract energy from the grid at any extreme rate (Bena, B., and Fuller, R. J., 2002).
4. No use of Water: This technology is designed to be "water-less," with a sustained, water-less operation; changing the way we traditionally clean. For example, this is of particular value in arid regions, where water supplies may be limited or the loads on water resources may be prioritized for potable use. And of course, the water-less operational aspect of this system maintains a significant level of eco-friendliness (Bal, L. M. et al., 2010)
5. Low Maintenance: The system has no maintenance. Most of the maintenance consists of replacing the brushes occasionally or simply inspecting the mechanical components of the

system. The system does not require frequent human involvement so it can be used in large solar farms or for remote installations (Condori, M., et al., 2001).

6. Scalability: The system's modularity and scalability make it applicable to a number of solar panel setups, including domestic solar lights, street lights, commercial solar power plants, and solar vehicles. The cleaning mechanism is configurable to different sizes and arrangements of solar panels (Bena, B. and Fuller, R. J., 2002).
7. Enhance Efficiency: By routinely cleaning the solar panels, the system will keep the highest operating efficiency. During the cleaning process, the panels can generate up to 18 percent more energy when compared to dirty panels (Chena, Y et al., 2019).
8. Safety Functions: The system is designed for air cautious and relies on the fact it automatically powers on, and has no human involvement in its daily operation, therefore minimizing danger to accidents and harm to the panels.

5. Operation Principles

The intended operation of the proposed technology follows the sequence below:

1. Panel Identification: The system is fixed to the solar panel array, and the cleaning mechanism is aligned to the panel surface.
2. Movement Control: The microcontroller controls the movement of the brush across the solar panel, ensuring that the panels' surface is fully covered during sweeping.
3. Brush Activation: The brush is switched "on", and it sweeps across the panel and removes dirt and dust.
4. Energy generation improvement: After the brushing operation, the efficiency of the solar panel improves because the debris blocking sunlight is removed and the solar panel produces a more consistent energy generation rate.

The system is set to run on a timer or can be sensor-based and triggered to operate when dirt or dust has accumulated on the panel surface.

6. Benefits of the Proposed System:

- Sustainability: There is low energy consumption and no water consumption in the cleaning process, which advances the sustainability of solar energy production.
- Low cost: The system abstains from human labor and water consumption while contributing to lower operational cost.
- Environmental safety: The system doesn't involve any chemicals or detergents. No damaging agents would be added to the cleaning process allowing the environment to retain its integrity.
- Dependability: Automated cleaning ensures regular and consistent cleaning of the solar panel improving the long-term energy production and performance output capacity.

7. Literature Survey

Automated solar panel cleaning systems assist in keeping your solar panels running efficiently by easily wiping away dirt and debris. They are a better option than manual cleaning which can take a significant amount of time and risk damage to the panels. All automated systems can be grouped into the following categories:

1. Brush-based: Rotating brushes to scrape the dirt off the panels; they are effective in dusty regions;

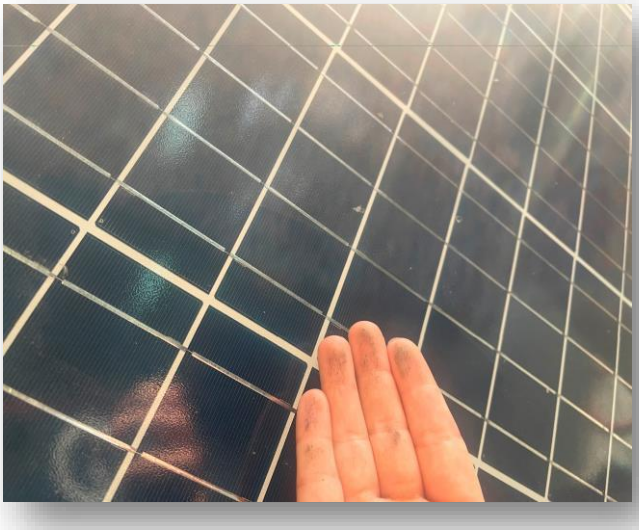
however, special care should be taken as the brushes can cause damage to the panels.

2. Air-based: High-pressure air that has an ecological benefit; for water-scarce areas; not very effective for heavy dirt.
3. Robot-based: More advanced, good for larger solar farms, and costly; not easy to maintain.
4. Ultrasonic: Uses vibrations to remove fine dust; good to remove even the lightest dirt but high energy usage; generally safe for solar panels that are delicate.
5. Waterless: Either air or brushes; good for areas where there is a lot of water shortage. These systems assist in increasing the efficiency of solar energy through panel cleaning. As technology continues to advance there may be a hybrid automated cleaning and with artificial intelligence for increased efficiency.

8. The Impact of Dust on Solar Panel Production:

The impacts of dust and accumulations of other pollutants on solar panels have a range of notable consequences. The dirty accumulation of contaminants and dirt affects the cells by blocking the path of sunlight that can enter into them, shading them, and in turn raising the temperature on the cells which lowers the total efficiency of the solar system. One study addressed the problem of contamination of solar panels by testing the impact of adding 4 g and 8 g of dirt to solar panels orientated at a 35° angle to assess the effects on power, current and voltage collected from 9:30 am to 4:30 pm. The study showed that the voltage displayed a large difference from the dirty panels to clean panels, which decreases as the day progressed until about 2:00 pm. The 8 g of dirt relative to 4 g of dirt did show slightly higher results for volts on the solar panels. Chena, Y et al., also confirmed that at least for the orientation studied, solar collector performance decreased as the dirt charge increased. The conclusion of this study, would show that with an average accumulation of dust of 10 g/m², would reduce the power of solar panels by 34%.

In the general sense, the deposition of dust particle, dirt, and accumulations of other pollutants, will have a number of effects to solar panels. The accumulation of dirt on the solar panels, see figure:1 just indicates one clean panel and also the restriction of sunlight the cells are able to receive, which they require to allow them to become charged.



9. Concept of solar panel cleaning mechanism.

The motor will drive the rotary mechanical brush which will clean the solar panel. The motor connected to the rack and pinion will move the brush mechanism forward and backward, the water spraying system will wet the solar panel to enhance the cleaning process.

10. Future scope:

An independent self-cleaning mechanism that can be integrated into solar panels and performed without the need for human action. Is simple to build, low cost and low maintenance.

11. Conclusions

The automated cleaning system for solar panels is an efficient and sustainable solution for the dust build-up to allow the panels to operate more efficiently with the potential for increased energy output. The system reduces the manual cleaning time saving both time and costs associated with it, as well as conserving the water used to clean. The system is capable of cleaning approximately 95% of the dust with an up to 18% increase in energy generation potential. The restrictive minor aspects of the system, clearly demonstrate a good ability to move onto a variety of potential solar applications. When measured against possible future developments or one-off developments, this system would take-on an enhanced gravity as the principal tool to help better the efficiency of solar panels and aid the progression of sustainable clean energy.

12. ACKNOWLEDGEMENT

Many thanks to my colleagues, friends and family for their continued support, encouragement and helpful suggestions with all stages of this project. Lastly, we would like to admit the project team members who took part in the project. All the team members made vital contributions to the project together with design, development and execution of an automated solar panel cleaning system. The project has been a valuable learning experience for us, and we are proud to take a small step towards sustainable energy in this automation project.

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