



FABRICATION OF SOLAR PANEL CLEANING ROBOT

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Abstract: Photovoltaic (PV) panels, which are grouped in several arrays inside a solar farm or solar energy system, are the primary source of solar power. Many nations with high levels of insolation favor solar as a possible source of clean energy, despite the variable efficiency of power generation from solar photovoltaic (PV) panels. However, even on a single panel in an array, the buildup of pollutants and dust reduces the level of energy produced by PV panels. Because of this condition, PV panels' surfaces need to be cleaned on a regular basis. The labor-intensive, time-, water-, and energy-intensive cleaning techniques used for photovoltaic arrays today lack automation. A completely automated system that may be used with or without water is suggested as a solution to this issue. Therefore, the development of a machine for automatic PV panel surface cleaning is discussed in this study. To regulate the robot's mobility while cleaning, the design makes use of an Arduino controlling system. Furthermore, it has a system for pumping water and two rough sponges that will be used to remove dust or dirt from PV panel surfaces. Prior to and following the cleaning procedure, the PV panels' efficiency is also noted. The outcome demonstrates that, once the dust of the photovoltaic panel is removed, the designed solar panel washing robot can efficiently clean the panel and restore 50% of the panel's maximum power and output current.

Keywords— Solar Panel Cleaning Robot, Photovoltaic (PV) Efficiency, Automated Cleaning System, Arduino-Based Control, Dust and Debris Removal etc.

I. INTRODUCTION

The primary source of electricity for all life on Earth is solar energy, which is also the foundation for all other energy sources except nuclear energy. However, solar electricity has not advanced to the level of conventional energy sources, and it faces numerous obstacles like high cost, unpredictable and erratic nature, low efficiency, and the need for storage. The goal of this project is to increase the efficiency of renewable energy sources by resolving the issue of dust accumulation on the surface regarding solar panels, which lowers the generated electricity and overall efficiency of the facility. It suggests creating a solar panel washing system that could regularly clear the dust buildup on the panel's surface and preserve the output of the solar power plant. Given the limited water supply in the areas where these plants are primarily found, the robotic system could move on its own across the tops of solar arrays using pneumatic equipment suction cups and clean them using dry techniques like a rotating cylindrical touch cleaning system. Because cleaning solar panels exposes people to dangerous conditions in the blazing sun, this project also attempts to minimize the amount of human involvement involved in the process.

A robot is an instrument that can perform a sequence of tasks automatically based on input from its surroundings and an internal program. According to these guidelines, an autonomous robot can perform tasks and instructions with a high degree of precision on its own.

• Capable of obtaining concrete inputs from the surroundings; • Capable of carrying out tasks for extended periods of time without human intervention.

• Capable of moving around its workstation without assistance from humans.

• Unless specifically trained to do so, it is capable of avoiding circumstances that could endanger both humans and itself.

The robot that cleans.

Although cleaning is considered to be among the least desirable tasks, it is nevertheless a vital activity in human life. Cleaning can also be dangerous for people in some situations. Machines have thus been developed repeatedly to help us with this essential evil of cleaning. The newest trend that has emerged in recent years is robotic cleaning. An autonomous robot that can turn around to disinfect surfaces using a variety of methods, including vacuuming, mopping, or just scouring with a rotating brush, is called a robotic cleaner.

Although it is intended for industrial cleaning in large-scale solar power facilities, the suggested solar panel clean system is classified as a cleaning robot. It is a robot with autonomy that uses vacuum suction cups to move across the sloped coating of the solar cells and a revolving cylindrical brush to clean the panels' surface. Every cycle begins with the robot traveling a certain distance parallel to the solar panel's base, after which the revolving brush moves from top to bottom perpendicular to the base. In order to

maximize solar irradiance, the solar cells are attached at an angle toward the ground, depending on the latitudinal position of the photovoltaic plants. However, because robotic cleaning systems must travel over a sloped surface, this benefit turns into a drawback. A typical wheel-based robot can't move on the sloping surface because it will slip and tumble to the ground. As a result, we have a pneumatic system with suction cups on the bottom. When these suction cups are activated by vacuum pumps, a suction force is produced that aids in the robot's attachment to and movement on its surface.

II. PROBLEM IDENTIFICATION

- **Solar Technology Advancements:** Solar panels, derived from solar cells, convert solar energy into electrical energy and are widely used in industries and households.
- **Challenge in Maintenance:** Maintaining solar panels is crucial to preserve efficiency, requiring effective cleaning methods.
- **Impact of Dust:** Dust accumulation is the primary factor reducing panel efficiency, with losses of up to 50%, depending on environmental conditions.
- **Other Factors Affecting Efficiency:** Shadow, snow, high temperatures, pollen, bird droppings, and sea salt also contribute to efficiency reduction.

Manual Cleaning Limitations:

- Commercial detergents are costly, time-consuming, and potentially hazardous to the environment.
- Frequent cleaning every few weeks is required, especially challenging for large arrays.
- **Automated Cleaning Solutions:**
- Robotics offers an economical, autonomous solution for cleaning large ground-based arrays.
- Eliminates human labor and supports efficient maintenance for systems with up to 22,000 panels.



Fig.1. solar panel cleaning

Existing System

The traditional method for cleaning solar panels involves manual labor, which is time-consuming, inefficient, and costly. Commercial cleaning detergents, although effective, pose environmental hazards and require frequent use to maintain panel efficiency. Large solar farms, consisting of thousands of panels, demand substantial human resources and water for regular maintenance. Additionally, factors like dust, bird droppings, and environmental pollutants accumulate on panel surfaces, reducing efficiency by up to 50%. Manual cleaning methods also expose workers to hazardous conditions, such as extreme heat and difficult terrain. Some semi-automated systems, such as water-based cleaning robots, exist but are limited by high water consumption and the inability to navigate slanted panel surfaces effectively. As solar farms expand, the inefficiencies of manual or semi-automated cleaning become more apparent, necessitating an advanced solution that enhances efficiency while reducing operational costs and human involvement.

B. Drawbacks

Despite its advantages, the automated solar panel cleaning system has several drawbacks. The initial investment for robotic cleaning systems is high, making it less accessible for small-scale solar farms. The reliance on vacuum suction cups may lead to wear and tear over time, requiring regular maintenance. Additionally, the system may struggle with extremely rough or uneven panel surfaces. In regions with severe soiling, such as bird droppings or hardened debris, the dry cleaning method may not be as effective as water-based cleaning. Moreover, power consumption by the robot reduces the net energy gain, and extreme weather conditions may impact operational efficiency.

III. AIM AND OBJECTIVES

The main objectives of the project are comprehended as follows:

Aim: This Solar Panel Cleaning Robot aims to maintain the efficiency of Solar power production by making sure the Solar panels are kept clean without putting humans at risk.

Objectives:

- To develop smart cleaning robot for solar panels.
- To make wireless smartphone operation for cleaning robot using Bluetooth technology.
- To effectively clean dirt from solar panels using a roller brush and water sprayer.
- To enhance solar panel efficiency for both industrial and small-scale applications, including solar plants and rooftop panels.

IV. LITERATURE SURVEY

Maghami et al. (2016) examine the effects of soiling on solar panels, analyzing how dust accumulation reduces sunlight absorption and subsequently lowers power output. Their study reviews various pollutants, such as soil, ash, and calcium carbonate, showing how each affects panel efficiency differently. They highlight the importance of regular maintenance and propose potential

cleaning techniques to counteract dust impact on PV systems. The authors argue that managing soiling is crucial to sustaining optimal energy output, as daily energy loss due to dust can reach significant levels, especially in areas with prolonged dry spells.

Sayyah et al. (2014) explore how dust deposition on solar panels diminishes energy yield. They document how dust density and deposition rate correlate directly with power losses, noting variations based on geographic location and environmental conditions. The study evaluates multiple cleaning strategies, from manual to automated methods, highlighting the economic and operational impacts of each. Findings suggest that high-dust regions experience more frequent and severe energy yield losses, emphasizing the need for effective dust mitigation techniques to preserve energy efficiency, particularly for large-scale solar power systems.

Ilse et al. (2018) present an extensive review of techniques to mitigate soiling losses in PV systems, focusing on both preventive and active cleaning solutions. They assess passive coatings, robotic cleaners, and electrostatic methods, comparing their cost-effectiveness and suitability for different environments. The study shows that automated robotic systems provide efficient and scalable cleaning for commercial solar installations, reducing operational disruptions. By identifying the best strategies for soiling mitigation, this research provides valuable insights for developers and operators to improve PV panel longevity and output.

Bhushan et al. (2020) discuss power loss minimization by adopting various solar panel cleaning techniques. Their research evaluates manual, semi-automatic, and robotic cleaning options, analyzing each for cost, efficiency, and long-term effectiveness. They emphasize that automated systems, although costly upfront, offer consistent cleaning quality, enhancing panel performance and reducing maintenance intervals. Their findings support the integration of robotics in solar energy management, especially in areas with frequent dust accumulation, where they estimate power loss could reach up to 20% without regular cleaning.

Mani and Pillai (2012) investigate the influence of dust on PV performance, covering research developments and the challenges associated with dust accumulation. The authors review the varying degrees of power loss caused by different dust types and recommend targeted cleaning solutions based on environmental conditions. They also highlight a need for economical, region-specific cleaning technologies to maintain PV efficiency, especially in arid and semi-arid climates. Their recommendations advocate for more research into automated cleaning solutions and coatings that prevent dust adherence, thereby preserving PV output and reducing operational costs.

Our research aims to construct a solar panel cleaning robot using Arduino and wireless technology. The objectives of the project are to design and implement a microcontroller-based dust cleaning system by using Arduino UNO as the main system, to optimise the performance of PV panel operation under dusty environment, and to improve the efficiency of the solar panel by keeping them clean.

V. PROPOSED SYSTEM

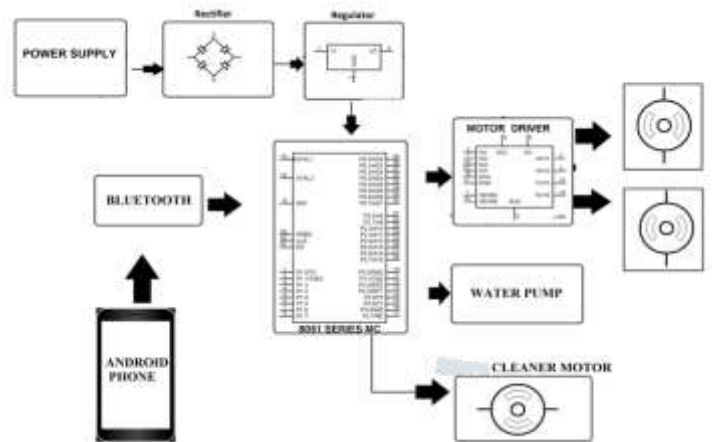


Fig. 1. Block Diagram of system

Their electric energy is stored in a battery when the adaptor is used. The machine's electrical switch board is powered by a 12V DC battery. SMPS and the air dryer receive their primary power from the electrical board, while the sipping process and SMPS receive DC power when they are operating. The DC motors, which are essential to the cleaning process, are operated by the moping process. One of the single D.C. motors rotates the mop to clean the central surface that the chassis covers. Compared to the brush motor, the DC motor that is used to rotate the mop has a higher torque. The front portion of the solar array is cleaned by another two DC motors with high RPM. The brushes are rotated by the DC motor via the shaft, which is fastened to the motor shaft by a nut and bolt. The arc on the left side of the chassis allows you to adjust the front mopping mechanism, which cleans the uneven particles that accumulate on the Solar's surface during the summer.

A spinning mop brings moisture as well as dust or dirt fragments into the central region of the chassis during the wet season, which slightly alters how the solar cleaning equipment operates. In order to gather more water in the center portion, the mopping heads rotate in the opposite directions, collecting the water and dirt mixture. For efficient cleanup, the mop is rotated by the third motor. A water sprayer pump is installed at the bottom for the water tank to supply fresh water for effective cleaning; the control valve sets the fresh water flow.

VI. COMPONENT USED

The manually operated Solar cleaning machine consist of various elements such as, DC motors, fresh water sprayer pump, mope, LED lights, chassis and fresh water tank. For converting the AC supply into DC the Switched mode power supply (SMPS) is used. The fresh water tank is used to stores the water in it. While doing wet cleaning it provides water as per the requirement. The switch board is fixed onto the handle. It is used to start and stop the machine as per operator's wish different buttons are

provided to operate the different component. Chassis is a Main part of machine which holds all other parts on it. It is made up of mild steel because it satisfies all the required conditions. Water is stored in a chamber that has a opening controlled by a motor. By putting this motor to ON position water or cleaning liquid starts flowing from the tank. A connecting pipe connects it to a shower-style setup. There are several manually adjustable holes in the sprinkler system that are positioned in a consecutive fashion. When a mop is not needed, an arc is supplied to allow for positional adjustment.

- Battery
- Adapter
- Arduino Controller
- Motor Driver controller
- Relay Board
- Bluetooth Module
- Mop for cleaning
- DC Pump
- LCD Display
- Wheels

Software Required:

- Arduino Compiler
- MC Programming Language: Embedded C.

VII. ADVANTAGES

1. Manual effort is reduced:

This solar cleaning machine has the electric work system that reduces the manual effort in the cleaning of surface.

2. Operating time is less:

As we are using the motorized brushes and mop in this machine this will reduce the operating time and cleaning work can be done faster.

3. It is possible to accomplish both cleaning and polishing simultaneously:

By using mop we can clean the dirt and dust and as well as at the same time solar polishing is also done with the help of mop.

4. Power consumption is less:

The power usage is lower because we are employing a low voltage electrical DC motor.

5. This machine requires low Maintenance cost.

6. In this machine Easy control of cleaning solution supply by controlling valve.

7. Other than rough surfaces, it can be employed in a variety of settings.

8. By further modification the drive or movement can be made automatic.

VIII. APPLICATION

Applications of Solar Panel Cleaning Robot:

- Industrial Solar Power Plants: Maintains efficiency of large-scale solar panels in dedicated solar power plants.
- Residential Rooftop Solar Panels: Cleans solar panels in homes, boosting power generation efficiency.
- Commercial Buildings: Enhances the performance of solar panels installed on office rooftops.
- Solar Farms: Regularly cleans solar arrays in vast solar farms to ensure maximum energy output.
- Hazardous Locations: Operates in areas where manual cleaning is risky or time-consuming, ensuring worker safety.
- Remote Solar Installations: Ideal for cleaning panels in isolated or difficult-to-reach areas.

The methodology section outline the plan and method that how the study is conducted. This includes Universe of the study, sample of the study, Data and Sources of Data, study's variables and analytical framework. The details are as follows;

IX. RESULTS AND DISCUSSION

Present work is aimed at working of smartphone controlled multifunction Solar cleaning robot that could clean the Solar of normal Indian house-hold as well as public places. Proper cleaning is achieved by motion of the mopping which is relatively rotational in manner. The cleaning process is carried out by making the Solar wet and mopping it and again making the Solar dry. The Solar should be dry after the process is complete because wet Solar leads to different sort of problems as discussed above. For this purpose, water pumps are to be used. The cleaning also meets challenges like which type of debris it will meet. This leads to proper cleaning when heavier particles are there as debris particle. Thus, leading to proper cleaning of the surface. There may be oily surfaces in some cases. To counter act this situation necessary disinfectants are to be used. wheel drive mechanism should be used for proper control of the machine. To control all the motors and water pumps basically Arduino control board with Bluetooth communication is used. Robot can move to any direction and perform all necessary function of cleaning. Basically, we are to design a portable Solar cleaning machine that could move smart way all over the Solar surface and cleaning the Solar.

Solar panel characteristics

To test the effectiveness of the developed solar panel cleaning robot, several experiments on cleaning a dusty solar panel were conducted. In these experiments, flour was used to imitate dust on a solar panel. The tests were done by measuring voltage and current of the tested solar panel at initial condition (without dust), at dusty condition, and after the dust cleaning process. Figure 4 illustrates the condition applied to the solar panel for the experimental setup.

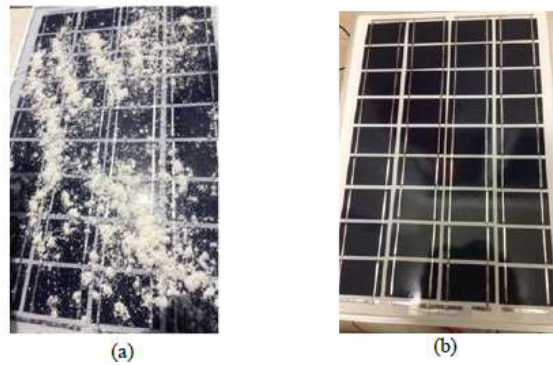


Fig. 2. Experimental setup, (a) When the solar panel is covered with dust (using flour),
(b) When the solar panel is cleaned using the developed robot

For the experimental procedure, the current and voltage of undusted, dusty and cleaned solar panel were measured every one hour, start from 11.00 a.m. until 2.00 p.m. Then the real power of the solar panel was calculated using the following equation:

$$P = V * I$$

The measured data is tabulated in Table 1. The calculated real power obtained from the measured voltage and current is provided in Table 2. Figure 5 provides the current versus voltage (I-V) characteristic of the undusted, dusty and cleaned solar panel. From the data given in Table 1, the current decreased by almost 50% when the solar panel was covered by dust. The real power provided by the solar panel also decreased linearly with the reduction of the current. Then the cleaning process was done by using the developed robot. After the dust cleaning process, the current increased back almost by 50%. These conditions can be seen from the data provided in Table 1 and Table 2.

Table 1. Measured voltage and current of tested solar panel

Time	Before Dust		During Dust		After Dust	
	Volt(V)	Current(mA)	Volt(V)	Current(mA)	Volt(V)	Current(mA)
10:00 AM	20.06	314	18.3	180	20.12	312
11:00 AM	20.32	340	19.1	250	20.28	344
12:00 PM	20.46	368	19.22	290	20.48	374

Table 2. Calculated real power of tested solar panel

Time	Before Dust	During Dust	After Dust
	Power(Watt)	Power(Watt)	Power(Watt)
10:00 AM	6.31	3.25	6.22
11:00 AM	6.92	4.75	6.97
12:00 PM	7.52	5.57	7.65

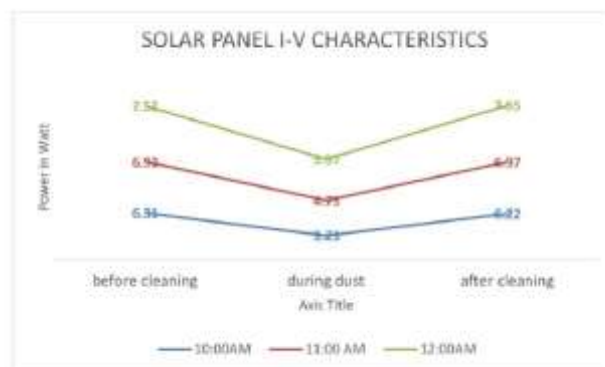


Fig. 3. Solar panel I-V characteristic

In this project, a fully assembled solar panel cleaning robot has been developed. The control algorithm and cleaning sequence are established with the Arduino platform. The robot is designed to be fully powered by rechargeable batteries. The experiment and verification results demonstrated the functionality of the cleaning robot to performed its duty. The solar photovoltaic output power is successfully restored to its maximum power capacity after the cleaning process, even though there are slight losses due to some

glitch error in the system. The 50% improvement at the output current as well as the maximum power before and after cleaning reveals that the robot guarantees the effectiveness of the developed robot.

X. CONCLUSION

Dust, dirt, pollen, sea salt, and bird droppings significantly impact solar panel efficiency, reducing peak power generation by 10-30%. Robotic cleaning methods effectively address this issue, enhancing power generation capacity while offering easy maintenance, low cost, and minimal power usage. The lightweight device, primarily made of aluminum, ensures affordability and efficiency, especially for large solar systems. Automatic cleaning proves more economical and less labor-intensive than manual methods, enabling frequent and consistent cleaning to maintain optimal panel transmittance. Innovative technology reduces human effort, encourages regular cleaning, and improves system performance. This advancement promotes sustainable energy solutions and supports India's progress by increasing solar efficiency, reducing costs, and fostering a cleaner, healthier environment for future generations.

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