International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 8 Issue 4, Jul-Aug 2024 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Appraisal on An Automatic Solar Cleaning Robot

Abubakar Ibrahim[1], Baba Abdullahi Alhaji[2], Makinde Kayode[3], Mohammed Mahmood Katun[4], Ibraheem Abimbola Ganiyu[5], Owolabi Bilikisu Oluwabunmi[6]

[1,2,3,4]Department of Electrical Engineering, Federal Polytechnic Bida, Niger State, Nigeria
[5]Federal Airport Authority of Nigeria, Electrical Department Dugbe Ibadan, Oyo State, Nigeria
[6]Department of Electrical and Computer Engineering Kwara State University Malete, Kwara State, Nigeria

ABSTRACT

The efficiency of photovoltaic (PV) systems can be significantly compromised by the accumulation of dust, dirt, and other pollutants on solar panels. Traditional manual cleaning methods are labour-intensive, time-consuming, and often pose safety risks. This appraisal evaluates the implementation and effectiveness of automatic solar cleaning robots as a solution to these challenges. Automatic cleaning robots are designed to autonomously maintain the cleanliness of solar panels, utilizing advanced sensors, mobility mechanisms, and various cleaning technologies such as brushes, water jets, and air blowers. This study examines the advantages of these robots, including enhanced efficiency, cost-effectiveness, safety improvements, and consistent cleaning performance. Additionally, it addresses the challenges and limitations, such as high initial investment, maintenance requirements, compatibility issues, energy consumption, and the impact of weather conditions on performance. The appraisal concludes that automatic solar cleaning robots offer a sustainable and efficient solution for maintaining solar panel performance, particularly in large-scale installations. Recommendations include conducting a cost-benefit analysis, ensuring regular maintenance, performing pilot testing, integrating with monitoring systems, and considering environmental factors. Overall, the adoption of automatic solar cleaning robots can lead to significant long-term benefits in terms of energy yield and operational efficiency of PV systems.

KEYWORDS: *Photovoltaic system, sensors, microcontroller, solar panel, cleaning robot, rail, software development board*

How to cite this paper: Abubakar Ibrahim | Baba Abdullahi Alhaji | Makinde Kayode | Mohammed Mahmood Katun | Ibraheem Abimbola Ganiyu | Owolabi Bilikisu Oluwabunmi "Appraisal on An Automatic Solar Cleaning Robot" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-8 | Issue-4, August 2024, pp.437-444, URL: www.ijtsrd.com/papers/ijtsrd67171.pdf

IJTSRD67171

1. INTRODUCTION

Solar panels are essential for harnessing renewable energy from the sun. However, their efficiency can significantly drop due to dust, dirt, bird droppings, and other pollutants accumulating on their surface. Traditional manual cleaning methods are labour-intensive, time-consuming, and sometimes unsafe. An automatic solar cleaning robot offers a promising solution to maintain the efficiency of solar panels through regular and automated cleaning.

As climate changes and global warming threaten the future of our planet, it is becoming increasingly crucial to find sustainable ways to fulfil our energy requirements (Babu *et al*., 2018). One of the most reliable ways of moving towards sustainable and green energy sources is to provide electrical powerby the means of photovoltaic panels (Ravikumar *et al*., 2020).

Since they have no moving parts, solar panels are one of the most cost-effective and low-maintenance ways of generating electricity. Despite the advantages of PVs, unclean panels' surfaces hinder the efficiency of their output. In order to maintain the efficiency, panel surfaces should be kept clean. However, manual cleaning of solar panels is hazardous and time-consuming (Omur *et al*. 2019).

The implementation of solar panel cleaning robot is to maintain the panel's efficiency and avoid associated risks. The robot consists of roller brush and water sprayer. The sprayer is supplied with water through a water tank. A caterpillar track was used to drive the robot on the surface of the panel. All cleanings of dirt on the surface of the panel are achieved through the roller brush and water sprayer. This robot operates wirelessly and automatically. This designed robot is not restricted to large solar farm; it can also find application on rooftop mounted panels.

2. RELATED WORKS

Several works have been carried out on this topic, the summary of some of these are as follows:

Babu K., Dinesh K. P, Kamala P. S, and Kathirvel P. (2018) developed a robot cleaning device that travels the entire length of the panel. A peripheral interface controller (PIC) was used to implement robots control system. The proposed systemconsists of two main parts, the first is the cleaning robot and the second is the carrier robot. The carrier robot, along with the cleaning robot moves towards the solar panel and stops its movement by sensing the solar panel. A signal is then sent to the cleaning by the carrier robot. By receiving the signal, the cleaning robot travels to the entire length of the solar panel in both forward and backward directions and cleans thepanel for the specified time duration. After each cleaning, the cleaning robot then returns to the carrier robot, and the process will be repeated for the next panel. The devicewas used toremove the dirt and dust deposited on the solar panel as proposed thushelping the solar panelto absorb the maximum quantity of energy. However, the device lacks auto inspection, communication and self-diagnostic features and has only two wheels. These set back was taken care of in the new design. The new design has 6 wheels and itself automation.

Omur A., Erdinc S., Timur O., and Mehmet A. (2019) designed a solar panel cleaning robot (SPCR). The design is a dual-motor and crawler robot type which moves horizontally and the cleaning brush runs on the vertical axis. To keep the cleaning robot in the working area, position switches were installed to detect the length of the solar panel array. The design lacks light detection circuit and takes a longer time for cleaning; its response time is delayed because it uses Bluetooth connectivity. These limitations are taken care of in the Automatic Solar Cleaning Robot**.**

Rutvij P. K., Mandar A. K., Tushar T. S., Nitin B. S., and Atul D. A. (2018) published a paper on Automatic Solar Panel Cleaning System. Its automation system was implemented using ATMEGA 328 microcontroller which controls the DC gear motor. The mechanism consists of a sensor light dependent resistor (LDR). For cleaning the solar panel modules, slide brushes ware used. The design was a complete prototype.

Shilpa B., Shagufta A. S., Manjusha, Prajwal S. S., 2018) developed Automatic Cleaning of Solar Panel. In the automatic cleaning system, when the dust accumulates on the solar panel, Arduino sends a signal to activate the system. A DC motor was used in the project to move the brush back anf forth while another was dedicated for pumping water. The horizontal movement of the brush cleans the panel. Two sensors (LDR and voltage sensors) were used, and their sensitivity was dependent upon on sunlight incident on the panels. This design cannot be used for a large solar farm.

Ravikumar P., Abirami K, Anushiya R., Elakkiya M., and Harshidha P. R. (2020) designed a Solar Powered Unmanned Cleaning Robot (SPUCR). The aim of the work is to develop solar powered unmanned cleaning robot without human guidance. The SPUCR consists of Microcontroller, obstacle sensor, DC motors, LDR, IR sensor, vacuum cleaner and a GSM module. An Arduino mega microcontroller was used to control the SPUCR. The system was integrated with a dry cleaner. The SPUCR navigates in all direction with the help of motors connected to the wheel. Obstacle sensor was used to detect the obstacles and helps the SPUCR in self-navigation. The LDR was incorporated in the device, fixed with solar panel to sense the solar light and convert it to battery voltage. The charging level of the battery is usually on the LCD.

Nasib K., Aayush B., Binamra A., Ashish S. and Diwakar B. (2019) presented a paper on smart solar photovoltaic panel cleaning system. The prototype of this system comprises of a cleaning robot and a cloud interface: the cleaning robot is mobile and able to clean the entire solar array back and forth, with its separately driven cleaning rotatory brush; whereas, the cloud interface is a human-machine interface featuring the distant monitoring and control of the robot. Furthermore, toadd an automatic cleaning feature, a month-long data of totally clean and dusty panel was processed with regression analysis, and the developed regressionmodel was programmed into the sensing unit. The sensing unit and the regression model predicts the suitable time for the cleaning. Based on the system evaluation done on a demonstration PV module, it was found that the designed system can clean dry dust accumulated over the panel's surface. This system can be used for a large solar farm because of the ray tracks attached. One major disadvantage of this design is the chain sprocket design of the wheel mechanism as it may get rusted over time with rain water. Plastic wheel is better in this case.

(Vamsi K. P. and Svav P., 2017) worked on Project V Star Solar Panel Cleaning Robot. It was designed to self-charge it's battery and clean the dust on the solar panel only during the night time. This method is not 100% efficient, because it does its cleaning at night.

Mohammad S., Sakibkhan P., Hrithik N., Bobby P., Awaiz Q, Zaid S, and Khandelwal K. K., (2022) developed a Fabrication of Semi-Automatic Solar Panel Cleaning System and its Analysis. The cleaning unit moves on the central spine in a to and fro motion. A cylindrical brush is mounted on the cleaning unit which rotates in the clockwise direction. The cleaning unit along with the rotating brush moves along the central spine towards the bottom of the panel. Along the entire path, it forces the dust to move in the direction of the motion of the cleaning unit and finally blows sit a way at the edge of the panel. The cleaning unit refreshes its operation by returning to starting point. Once it reaches the top of the spine, the cleaning unit stops there. Then the wheels move in the directionparallel to the edge of the solar panel until it reaches the part of the panel that is not cleaned. After this, thecleaning unit again comes in to action and the process keeps on going until the entire array is cleaned. Once the array of the solar panel is cleaned, it is moves on another array.

3. OVERVIEW OF AUTOMATIC SOLAR CLEANING ROBOTS

Automatic solar cleaning robots are designed to autonomously clean the surface of solar panels. They can be programmed to clean at specific intervals or based on sensor data indicating a drop in panel efficiency due to dirt accumulation. These robots typically use brushes, microfiber cloths, water jets, or air blowers to remove dirt and debris without damaging the panels.

4. A TYPICAL ROBOT CONTROL PV CLEANING SYSTEM

The block diagram of the solar panel cleaning robot is shown in figure 1. It comprises of microcontroller unit, RF sensor, four-wheel-drive (WD) robot with DC motors, waterpump, water tank, reservoir and brushes. The major heart of this review is the microcontroller unit. The microcontroller unit controls the movement of the DC motor based on the input given by the RF sensor. The time pump water to the brushes is also determined by the sensor.

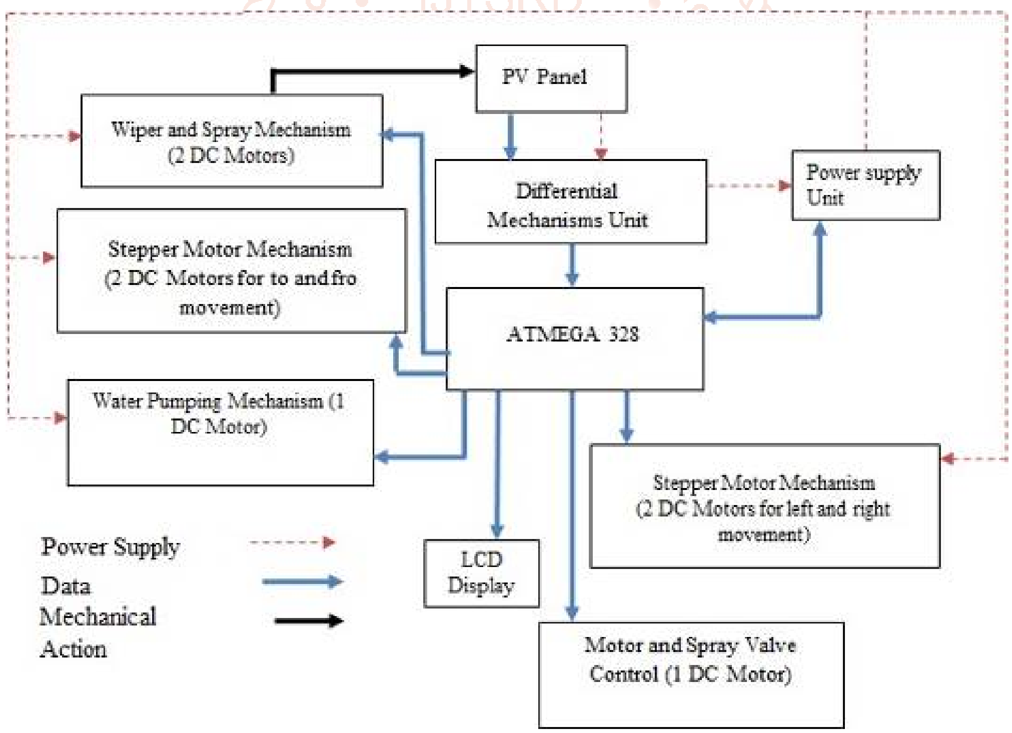

Figure 1: A block diagram illustrating a typical automatic PV panel cleaning system.

4.1. Description of Units that make-up a typical Robot Control PV Cleaning System

A. Photovoltaic Panel (PV Panel)

The top of the PV panels is the area where the cleaning is required. This unit also provide the power supply to the microcontroller through the differential measurement unit. This means that the cleaning is meant to be done in the day time.

B. Differential Measurement Unit (DMU)

It is a decision making component of this device. DMU makes decision from the microcontroller unit either to clean the panel with wiper and spray mechanism or to continue the conversion. DMU consists of adjustable timer which automatically allocates time for cleaning of the PV panels. As the time elapses and timer reaches its count value, then, DMU activates the wiper and spray mechanism and start the cleaning of PV panel.

C. Wiper and Spray Mechanism

It is a mechanism used to clean the PV panel. It consists of brush mounted on PV panel. When timer activate this mechanism then the mechanism will start moving from one end of PV panel to clean it and it will move towards the other end of a PV panel. This mechanism is controlled by motor and spray valve control block.

D. Microcontroller

This controls the whole system. The Microcontroller control various blocks of this robot that is DMU, Wiper and Spray Mechanism and Motor etc.

E. Motor and Spray Valve Control

This block is used to control the motor assembly and spray valve. It will pump the water from water tank to the wiper and spray mechanism. The motor assembly will move the wiper and spray mechanism across the PV panel.

F. Water Pumping Mechanism

This block is used to pump water from the reservoir once the motor and spray valve control tank is empty. It will pump water from the reservoir to the wiper tank.

G. Power Supply:

This block supplies the power required for operation of the whole system. A 12 V DC supply will be required to operate the motors for rotating the PV panel and to move the robot on the PV panel. Another power supply of 5 V DC supply will also be required to operate the ICs in the circuit e.g. Microcontroller.

H. Liquid Crystal Display (LCD):

The LCD display is used to display the current state of the system. It displays when the panels are dirty as well as when the cleaning process is ongoing.

I. Stepper Motor Mechanism

These are theDC Motors responsible to control the movement of the robot for to and fro movement and also for left and right movement.

4.2. Working principle

A remote controller was used to wirelessly control the movement of data to the robotic vehicle. The sensor communicates the controller, the data received are then processed and in turn operates the wheel of the motor in a desired direction. A brush is fixed to the main DC motor. The front panel is integrated with a water pipe. The pipe is then used to channel water to the front brush with the aid of the DC pump. The followings are components that make up a typical solar cleaning robot as shown in figure 2.

4.3. Components:

1. DC Motor
2. Depth Meter
3. Tracks
4. Pump Motor
5. Filter
6. Water Tank
7. Water connections
8. Controller Circuitry
9. Shafts
10. Water Gutter
11. Screws & Bolts
12. Supporting Frame

4.4. Functions of Components in Solar Cleaning Robots

1. **DC Motor**: The DC motor is responsible for driving the mechanical movements of the robot. It powers various components such as the tracks for mobility, brushes for cleaning, and other moving parts. The speed and direction of the motor are controlled by the robot's control system, allowing precise movements and operations.

2. **Depth Meter**: The depth meter measures the distance between the cleaning apparatus and the surface of the solar panels. It ensures that the cleaning brushes or nozzles maintain an optimal distance from the panels, preventing damage while ensuring effective cleaning. This sensor helps in adjusting the cleaning mechanism dynamically to accommodate variations in panel surface levels.
3. **Tracks**: Tracks provide the mobility needed for the robot to move across the surface of the solar panels. They allow the robot to navigate different sections of the solar array, ensuring comprehensive cleaning coverage. Tracks are designed to grip the panel surface securely, even at inclined angles, and move smoothly without causing scratches or damage.
4. **Pump Motor**: The pump motor is used to drive the water pump, which supplies water to the cleaning nozzles. This motor ensures a consistent and adequate flow of water needed for cleaning, particularly for systems that use water jets or sprays to remove dirt and debris from the panels.
5. **Filter**: The filter is used to remove impurities from the water before it is sprayed onto the solar panels. This prevents contaminants from scratching or damaging the panel surfaces during cleaning. Clean, filtered water enhances the effectiveness of the cleaning process and extends the life of the cleaning equipment.
6. **Water Tank:** The water tank stores the water used by the cleaning system. It ensures that the robot has an adequate supply of water to perform cleaning operations over extended periods. The size and capacity of the tank are designed to match the operational requirements of the robot, balancing weight and cleaning efficiency.
7. **Water Connections**: Water connections, including hoses and nozzles, distribute water from the tank to the cleaning mechanism. They ensure a controlled and directed flow of water, facilitating effective cleaning action. These connections are designed to withstand pressure and prevent leaks.
8. **Controller Circuitry**: The controller circuitry acts as the brain of the cleaning robot. It processes inputs from various sensors, controls the motors and actuators, and coordinates the overall operation of the robot. The circuitry ensures that the cleaning operations are performed efficiently and responds to real-time conditions such as dirt levels and obstacles.
9. **Shafts**: Shafts are mechanical components that transfer rotational motion from the motors to the cleaning brushes or other moving parts. They are critical in ensuring the smooth operation of these components, providing the necessary mechanical linkage to perform cleaning tasks.
10. **Water Gutter**: The water gutter collects and channels runoff water away from the cleaned panels. This component prevents water from pooling on the panel surfaces or dripping down onto other parts of the installation. It helps manage water flow, keeping the panels dry after cleaning and preventing water damage to surrounding equipment.
11. **Screws & Bolts**: Screws and bolts are used to assemble and secure various components of the robot. They provide structural integrity and stability, ensuring that all parts are firmly held together. Proper fastening is crucial for the durability and reliability of the robot, especially under operational stresses.
12. **Supporting Frame**: The supporting frame provides the structural foundation for the robot. It holds all the components together, ensuring they are aligned and securely mounted. The frame is designed to withstand operational loads and environmental conditions, maintaining the robot's functionality and robustness during cleaning operations.

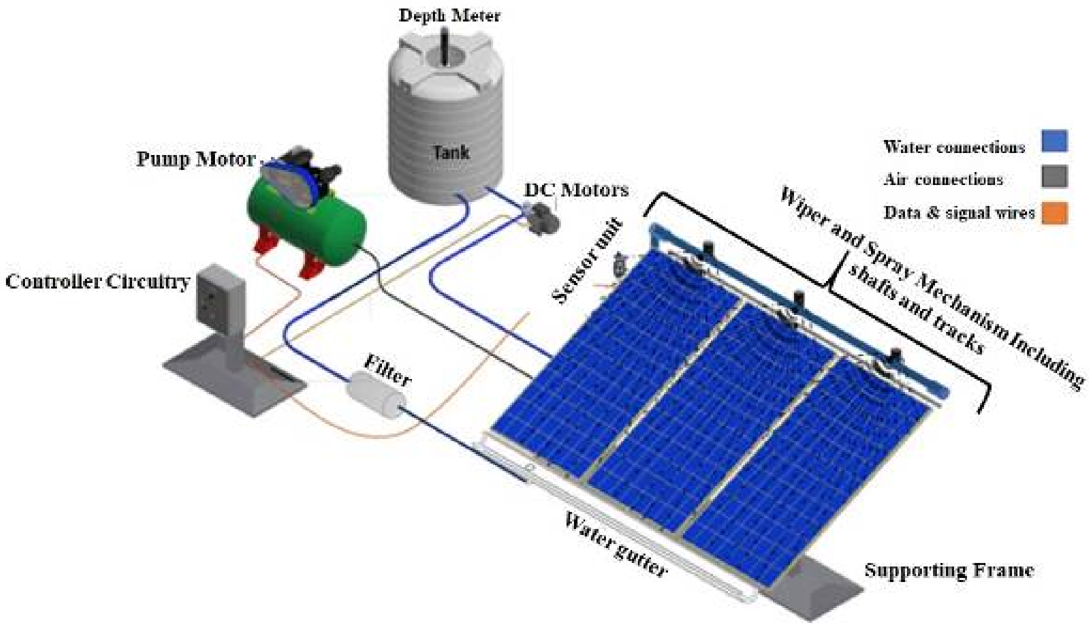

Figure 2: A typical implemented solar robot cleaning system (Ra'ed, 2022).

4.5. Factors Influencing Dust Settlement on PVs and Advantages of Solar Panel Cleaning Robot System

Dust on PVs are usually influenced by certain environmental factors. The variables differ according to geographical location. Some of the common factor highlighted in the literature are the rainfall, temperature, wind speed, humidity et cetera. These factors reduce the efficiency of the PV output(Mustafa et al., 2022). Whilst the impact of dust settlement on PVs are experience globally, is effect are more in dry climates with dusty wind (Bubnova, 2016). Figure 3 shows the factors that influence dust accumulation on PVs. The advantages and drawback of different methods of PV cleaning system are presented on table 1.

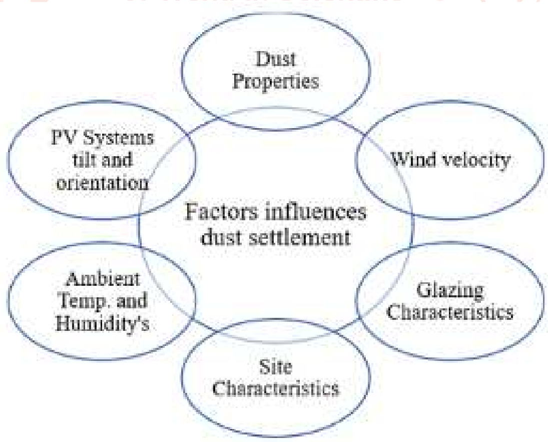

Figure 3: Factors influencing dust accumulation on PVs (Mustafa et al., 2022).

Table 1: Advantages and shortfalls of different PV cleaning system (Pickerel, 2017).

	Cleaned Surface Quality	Labours Injuries Risk	Electric Shock Risk	Panel Damage Risk	Water Wasting	Electricity Consumption	Cleaning Cost
Intelligent Cleaning	High	-	-	-	-	-	Low
Manual Cleaning	Visual method	High	High	High	High	Low	High
Vacuum Cleaning	Visual method	High	Low	High	Low	High	Low
Electrostatic Precipitator	Low	-	-	-	-	Low	High
Automatic Wiper Cleaning	Low	Low	Low	High	Low	Low	High

Coatings With Nanoparticles	Low	-	-	-	Low	-	High
Robotic Cleaning Solutions:	High	Low	Low	High	Low	Low	High

Observing the analysis on table 1, it can be concluded that the cleaning quality, labour risk, panel damage risk, water and electricity consumption, and the cost influence the existing cleaning technologies. However, the robotic technique presented in the paper shows superior performance with little energy demand.

5. ADVANTAGES

A. Improved Efficiency: Regular cleaning helps maintain optimal performance and efficiency of solar panels.

B. Cost-Effective: Reduces the need for manual labour and associated costs over the long term.

C. Safety: Minimizes the risks associated with manual cleaning, especially in large-scale solar farms or difficult-to-reach areas.

D. Consistent Cleaning: Ensures consistent and thorough cleaning, which can be difficult to achieve manually.

E. Water Conservation: Some robots are designed to use minimal water, which is beneficial in arid regions.

6. CHALLENGES AND LIMITATIONS

A. Initial Cost: High initial investment for purchasing and installing the robots.

B. Maintenance: Requires regular maintenance to ensure proper functioning.

C. Compatibility: May need customization to fit different types of solar panel installations.

D. Energy Consumption: Power requirements for operation, though mitigated if the robot is solar-powered.

E. Weather Conditions: Performance can be affected by extreme weather conditions such as heavy rain, snow, or high winds.

7. CONCLUSION AND RECOMMENDATION

A. Conclusion

The efficiency of the solar panels can either be maintained or retarded by the concentration of dirt on its surface. Therefore keeping the surface clean is a major concern for maintaining its efficiency. Automatic solar cleaning robots represent a significant advancement in the maintenance of solar panels. They offer a sustainable, efficient, and safe solution to the problem of dirt accumulation, ensuring that solar panels operate at their maximum efficiency. The technology is especially beneficial for large-scale solar farms where manual cleaning is impractical.

B. Recommendations

A. Investment Justification: Conduct a cost-benefit analysis to justify the initial investment based on long-term savings in maintenance costs and improved energy efficiency.

B. Customization: Select a robot model that can be customized or is compatible with the specific type of solar panels and installation layout.

C. Regular Maintenance: Establish a regular maintenance schedule for the cleaning robots to ensure they operate efficiently and have a long service life.

D. Pilot Testing: Implement a pilot test before full-scale deployment to identify any potential issues and ensure the robot meets the specific needs of the installation.

E. Integration with Monitoring Systems: Integrate the cleaning robots with existing solar panel monitoring systems to automate cleaning based on performance data.

F. Consider Environmental Factors: Choose robots that are designed to operate effectively under the specific environmental conditions of the installation site.

REFERENCES

[1] Babu K., Dinesh K. P, Kamala P. S, and Kathirvel P. (2018). Solar Panel Cleaning Robot.

[2] Published tt International Journal of Innovative Science and Research Technology ISSN No: -2456-2165. Volume 3, Issue 3.

[3] Bubnova, O., 2016. Photovoltaics: self-cleaning solar cells. Nat. Nanotech. https://doi.org/10.1038/nnano.2015.327.

[4] Mohammad S., Sakibkhan P., Hrithik N., Bobby P., Awaiz Q, Zaid S, and Khandelwal K. K. (2022).Fabrication of Semi-Automatic Solar Panel Cleaning System and Its Analysis International Research Journal of Modernization in Engineering Technology and Science(Peer-Reviewed, Open Access, Fully Refereed International Journal) Volume:04/Issue:05. www.irjmets.com

@International Research Journal of Modernization in Engineering, Technology and Science

[5] Mustafa, R., Gomaa, M., Al-Dhaifallah, M. and Rezk, H., 2022. Environmental Impacts on the Performance of Solar Photovoltaic Systems.

[6] Nasib K., Aayush B., Binamra A., Ashish S. and Diwakar B. (2019**).** Smart solar photovoltaic panel cleaning system: International Conference on Sustainable Energy and Green Technology. IOP Conf. Series: Earth and Environmental Science. IOP Publishing

[7] Omur A., Erdinc S., Timur O., and Mehmet A. (2019). A Solar Panel Cleaning Robot Design and Application. Published at European Journal of Science and Technology Special Issue, pp. 343-348,www.ejosat.com ISSN:2148-2683.

[8] Pickerel, K., 2017. Different types of solar mounting systems for roofs, "13 February 2017. [Online]. Available: https://www.solarpowerworldonline.com/2017/02/different-types-solar-mounting-systems-roofs/.

[9] Ra'ed N. M., Mohammad A., Marcos T., & Francisco J. (2022). A Novel Solar Panel Cleaning Mechanism to Improve Performance and Harvesting Rainwater. Elsevier, Solar Energy 237 (2022) 19–28. https://doi.org/10.1016/j.solener.2022.03.068.

[10] Ravikumar P., Abirami K, Anushiya R., Elakkiya M., and Harshidha P. R. (2020).

[11] Solar Powered Unmanned Cleaning Robot at International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249-8958 (Online), Volume-9 Issue-6. Published by: Blue Eyes Intelligence Engineering and Sciences Publication © Copyright: All rights reserved. Retrieval Number: F1539089620/2020©BEIESPDOI: 10.35940/ijeat. F1539.089620. Journal Website: www.ijeat.org.

[12] Rutvij P. K., Mandar A. K., Tushar T. S., Nitin B. S., and Atul D. A. (2018) Automatic SolarPanel Cleaning System. Published at Internal Journal of Advanced Research in Science and Engineering Vol. (07), I(07), www.ijarse.com.

[13] Shilpa B., Shagufta A. S., Manjusha, Prajwal S. S. (2018) Automatic Cleaning of Solar Panel. Published at International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 ICRTT-2018 Conference Proceedings.

[14] Vamsi K. P. and Svav P. (2017). Project V Star Solar Panel Cleaning Robot: International Journal of Engineering Trends and Technology (IJETT) – Volume 46 Number 9.