Archives available at journals.mriindia.com

International Journal on Advanced Computer Engineering and Communication Technology

ISSN: 2278-5140
Volume 14 Issue 01, 2025

IoT Based Advance Solar Panel Cleaner Robot with Self Cleaning Timing & Schedule Mode

Prof. Mangesh Thakur[1], Mr. Yash Adhale[2], Mr. Pratik Meshram[3], Mis. Priti Kakde[4], Mr. Anurag Sahu[5]

[1]Assistant Professor Suryodaya college of Engineering and Technology/ Computer Engineering, Nagpur, India
[2-3] Suryodaya college of engineering/Computer Engineering, Nagpur, India
[1]mangeshsingthakur@gmail.com, [2]yashadhale25@gmail.com, [3]pratikmeshram0021@gmail.com, [4]pritikakde45@gmail.com, [5]anuragsahu2077@gmail.com

Peer Review Information

Submission: 05 Feb 2025
Revision: 17 Mar 2025
Acceptance: 18 April 2025

Keywords

Photovoltaic System
Solar Panel Efficiency
Solar Panel Cleaning Robot

Abstract

The efficiency of photovoltaic (PV) panels has become a crucial topic as solar energy adoption rises. The buildup of dust, grit, and debris on solar panels is a significant problem that can reduce their effectiveness by as much as 30%. An IoT-based sophisticated solar panel cleaner robot with self-cleaning scheduling and timing features is presented in this research. Utilising Internet of Things (IoT) technology, the system automates and optimises the cleaning process by combining sensors, actuators, and cloud-based control. A review of the literature emphasises the benefits of automation while highlighting a variety of cleaning methods, including as mechanical, water-based, and electrostatic approaches. Adaptive scheduling is frequently absent from current systems, which results in ineffective cleaning cycles. The proposed model employs real-time monitoring and machine learning-based scheduling algorithms to determine optimal cleaning intervals, minimizing water and energy consumption. Experimental results demonstrate improved energy yield and cost-effectiveness compared to conventional manual or semi-automatic cleaning systems. This research contributes to the field of smart solar maintenance, ensuring enhanced sustainability and operational efficiency.

INTRODUCTION

Solar energy is one of the most promising renewable energy sources, providing a sustainable alternative to fossil fuels. Solar panels convert sunlight into electrical energy, and optimizing their performance is essential for maximizing energy output. The continuous extraction of maximum energy levels from the sun not only reduces installation costs but also enables energy providers to meet the demand for peak electrical power more effectively. However, various physical conditions can negatively impact the performance of solar panels. Environmental factors such as muddy rain, snow, and dust can accumulate on the surfaces of solar panels, creating a barrier between the panel and the sun. This buildup of debris can significantly reduce the electrical power extraction levels, leading to a performance gap that could be technically mitigated if the solar panels were kept clean To address this issue, it is imperative to implement effective cleaning solutions that maintain the cleanliness of solar panels. A clean solar panel surface is crucial for optimal energy

production, as any obstruction can impede the absorption capabilities of the solar cells. In addition to the physical cleaning of the panels, employing maximum power point tracking (MPPT) devices is essential to enhance the efficiency of solar energy systems. These devices adjust the operating point of the solar panels to ensure they operate at their maximum efficiency, thereby maximizing energy extraction even under varying environmental conditions. Through this research, we aim to demonstrate the effectiveness of the SPCR in real-time applications, showcasing its ability to maintain optimal energy production levels by ensuring that solar panels remain clean and efficient throughout varying environmental conditions

LITERATURE SURVEY

"Autonomous Solar Panel Cleaning Robot Utilizing IoT" - Kumar, A., & Murthy, B. (2020) This study explores the design of an autonomous solar panel cleaning robot that employs air blowing, liquid spraying, and wiping mechanisms, controlled via IoT for remote operation. The findings demonstrate that the robot effectively cleans panels, increasing energy efficiency and reducing manual labor in solar plants. The integration of IoT enables remote monitoring and predictive maintenance by analyzing environmental data to optimize cleaning schedules.

"Cost-Effective Solar Panel Cleaning System with IoT Integration" - Singarap, P., et al. (2023) This research develops a cost-effective solar panel cleaning system that integrates IoT technology, utilizing a timed cleaning mechanism with water and wipers controlled through an Android application. Results indicate a 32% increase in power output from clean panels compared to dirty ones, underscoring the effectiveness of automation in cleaning processes and the potential for mobile applications to enhance user engagement and operational efficiency.

"Arduino-Based Automatic Cleaning Robot for Solar Panels" - Bedge, D., et al. (2022) This study focuses on an Arduino-based automatic cleaning robot that optimizes cleaning intervals based on environmental conditions by utilizing sensors to monitor dust density and temperature. By employing a combination of ultrasonic and infrared sensors, the robot adjusts its cleaning operations based on real-time data. Experimental results indicate a significant reduction in efficiency loss due to dust accumulation, highlighting the importance of regular maintenance in maximizing solar energy production.

"Advantages of Automated Cleaning Systems in Solar Energy Generation" - Gochhait, S., et al. (2022) This research highlights the benefits of automated cleaning systems, showing an increase in energy generation efficiency by 1.6% to 2.2%. The comparative analysis of manual versus automated cleaning methods illustrates efficiency gains and improved safety for workers, as robotic systems can operate in hazardous environments, significantly reducing labor costs and enhancing energy output, particularly in large solar farms.

"Solar Panel Cleaning Robot with Bluetooth Control" - Kumar, R. (2022) This study designs a solar panel cleaning robot that utilizes a combination of water spraying and roller brush cleaning mechanisms, managed through Bluetooth control. The findings reinforce that robotic cleaning solutions enhance PV panel efficiency while minimizing operational costs associated with manual cleaning efforts. The Bluetooth interface allows for easy user control and troubleshooting, fostering greater confidence in the technology, while the robot's modular design ensures adaptability for various solar panel configurations.

"Environmental Impact of Automated Solar Panel Cleaning Systems" - Khairul, M., & Rahman, A. (2021) This research examines the environmental impact of solar panel cleaning practices, concluding that automated systems utilizing minimal water conserve resources and reduce runoff contamination. The study emphasizes the need for sustainable cleaning technologies that align with global environmental goals.

"Self-Cleaning Coatings and Hydrophobic Surfaces for Solar Panels" - Zhao, L., et al. (2023) This research discusses the integration of advanced materials, such as self-cleaning coatings and hydrophobic surfaces, to enhance solar panel performance by minimizing dirt adhesion. When combined with robotic cleaning systems, these innovations could lead to significantly lower maintenance costs and higher efficiency.

COMPARATIVE ANALYSIS

Study	Methodology	Key Features	Efficiency Improvement
Kumar & Murthy (2020)	IoT-enabled robotic cleaning	Air blowing, liquid spraying, wiping mechanisms	Increased energy efficiency, reduced labor

Singarap et al. (2023)	IoT-based timed cleaning	Mobile app-controlled water and wiper system	32% increase in power output
Bedge et al. (2022)	Arduino-based automated robot	Sensor-driven dust and temperature monitoring	Reduced efficiency loss from dust
Gochhait et al. (2022)	Comparative study	Manual vs. automated cleaning efficiency	1.6% to 2.2% increase in energy generation
Kumar, R. (2022)	Bluetooth-controlled cleaning robot	Roller brush and water spray mechanism	Improved PV panel efficiency
Khairul & Rahman (2021)	Environmental impact study	Water conservation and reduced contamination	Sustainable cleaning solutions
Zhao et al. (2023)	Material science-based approach	Self-cleaning coatings, hydrophobic surfaces	Reduced maintenance costs, improved efficiency

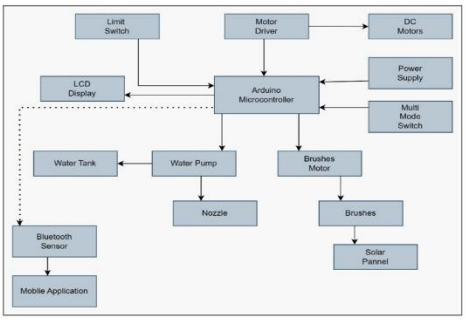
OBJECTIVE

The primary objective of the Solar Panel Cleaning Robot (SPCR) is to maintain the efficiency of solar panels by ensuring they remain clean and free from dust, dirt, and grime, which can significantly reduce their energy absorption capabilities. This innovative solution not only maximizes energy extraction from solar panels but also enhances safety by reducing the need for manual cleaning. The SPCR operates remotely and wirelessly, minimizing risks to human operators while providing an effective cleaning mechanism. The robot's design allows for a compact, portable, and user-friendly experience, making it suitable for various solar panel installations

1. **Efficiency Maintenance:** Ensure solar panels operate at peak efficiency by keeping surfaces clean from dust and grime.
2. **Remote Operation:** Facilitate remote and wireless control, ensuring worker safety by eliminating the need for human presence during cleaning.
3. **Effective Cleaning Mechanism:** Utilize a roller brush system coupled with a water sprayer to remove dirt without damaging the panels.
4. **Quality Preservation:** Design a cleaning system that maintains the integrity and quality of the solar panels while performing maintenance.
5. **Economic Benefits:** Reduce costs associated with hiring cleaning services and save time spent on manual cleaning, promoting sustainable energy practices.

PROPOSED WORK

This system is a combination of hardware and software components. The hardware part consists of different sensors like soil moisture sensor, temperature sensor, relays, pumps, etc whereas the software part consists of web-based application connected to the Arduino board and other hardware components using Internet of Things (IoT). The application consists of signals and a database in which readings are displayed from sensors and are inserted using the hardware. The improvement in irrigation system using wireless network is a solution to achieve water conservation as well as improvement in irrigation process. This research tries to automate the process of irrigation on the farmland by monitoring the soil water level of the soil relative to the plant being cultivated and the adaptively sprinkling water to simulate the effect of rainfall.



CONCLUSIONS

Automated solar panel cleaning systems play a crucial role in maintaining solar energy efficiency. IoT-enabled and robotic cleaning solutions have demonstrated promising results, but further improvements are needed for widespread adoption. Research should continue to explore innovative, cost-effective, and sustainable cleaning solutions for maximizing solar energy generation.

References

Bedge, V., More, A., Gholap, O., Maharnur, S., & Patil, P. (2024). **Automatic Solar Panel Cleaning Robot Using Arduino**. International Research Journal of Modernization in Engineering, Technology and Science.

Singarapu, S., Swaraja, K., & Kirola, M. (2023). **Smart IoT Based Solar Panel Cleaning System**. In E3S Web of Conferences (Vol. 430, p. 01147). EDP Sciences

Kumar, N., Shetty, P. G., Rakshith, V., S., R., & G, Y. (2022). D**esign and Development of Solar**

Panel Cleaning Bot. International Journal of Innovative Science and Research Technology, 7(7), 223-230

Gochhait, S., Asodiya, R., Hasarmani, T., Patin, V., & Maslova, O. (2022, November). **Application of IoT: A Study on Automated Solar Panel Cleaning System.** In 2022 4th International Conference on Electrical, Control and Instrumentation Engineering (ICECIE) (pp. 1-4). IEEE.

Kumar, S. S., & Murthy, K. (2020, November). **Solar Powered PV Panel Cleaning Robot**. In 2020 International Conference on Recent Trends on Electronics, Information, Communication & Technology (RTEICT) (pp. 169-172). IEEE.

ingarapu, S., Swaraja, K., & Kirola, M. (2023). **Smart IoT Based Solar Panel Cleaning System**. In E3S Web of Conferences (Vol. 430, p. 01147). EDP Sciences

B. Manju, A. Bari, and C.M. Pavan, "Automatic solar panel cleaning system. International Journal of Advances in Scientific Research and Engineering", 4(7), 26-31, 2018.

Z. Ahmad, M. H. Abbasi, A. Khan, I. S. Mall, M. F. N. Khan and I. A. Sajjad, "**Design of IoT Embedded Smart Energy Management System**", 2020 International Conference on Engineering and Emerging Technologies (ICEET), 2020.

Meriem Memichel, Chaima Bouzian, Ayoub Benzahial, Ammar Moussi, " 1 Feb 2020, Global Energy Interconnection Development and Cooperation Organization. Effects of dust, soiling, aging, and weather conditions on photovoltaic system performances in a Saharan environment—Case study in Algeria".

Meriem Memiche1, Chaima Bouzian1, Ayoub Benzahia1, Ammar Moussi, "Effects of dust, soiling, aging, and weather conditions on photovoltaic system performances in a Saharan environment—Case study in Algeria"1 feb 2020, Global Energy Interconnection Development and Cooperation Organization.

A Solar Panel Cleaning Robot Design and Application", European Journal of Science and Technology.

Milan Vaghani1, Jayesh Magtarpara2, Keyur Vahani3, Jenish Maniya4, Prof. Rajiv Kumar Gurjwar5, "Automated Solar Panel Cleaning System using IoT", International Research Journal of Engineering and Technology (IRJET), Volume: 06 Issue: 04 | Apr 2019.

"A CLEANING ROBOT FOR SOLAR PANELS". Nawat Ronnaronglit and Noppadol Maneerat, 2019 5th International Conference on Engineering, Applied Sciences and Technology (ICEAST).

"Solar Panel Cleaning Robot", Babu K, Dinesh Kumar P, Kamala Priya S, Kathirvel P, Dr. Mahalingam Volume 3, Issue 3, March– 2018 International Journal of Innovative Science and Research Technology.