

# IoT-Based Automated Solar Panel Cleaning and Grass Cutting System for Solar Farm Maintenance

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**Abstract:** Solar energy is one of the most important renewable energy sources for sustainable power generation. However, the efficiency of photovoltaic (PV) panels is significantly affected by dust accumulation and environmental particles that block sunlight from reaching the solar cells, leading to reduced power output. Several studies have proposed automated cleaning techniques such as brush mechanisms, water spraying systems, and microcontroller-based cleaning devices to overcome this issue and improve the performance of solar panels [1]– [3]. Recent developments also focus on integrating automation and monitoring technologies to reduce manual maintenance and improve system reliability [4].

This paper proposes an automated solar panel maintenance system that combines water sprinkling and a mopping mechanism for effective panel cleaning. The system is controlled using a microcontroller and supports IoT-based monitoring and remote operation. In addition, a high-RPM grass cutting mechanism is incorporated to remove vegetation around solar installations. The proposed system improves energy efficiency, reduces maintenance effort, and enhances the overall reliability of solar power systems.

**Keywords:** Solar Panel Cleaning System; Photovoltaic (PV) Systems; Internet of Things (IoT); Automated Maintenance; Grass Cutting Mechanism; Renewable Energy Monitoring

## I. INTRODUCTION

The increasing demand for clean and sustainable energy has led to the rapid adoption of solar power systems worldwide. Solar energy is one of the most promising renewable energy sources because it is environmentally friendly, abundant, and capable of generating electricity without producing harmful emissions. Photovoltaic (PV) systems convert sunlight directly into electrical energy and are widely used in residential, commercial, and large-scale solar farm applications. However, the performance and efficiency of photovoltaic panels is significantly influenced by environmental conditions such as dust, dirt, bird droppings, and other airborne particles that accumulate on the surface of the panels <sup>[1]</sup>.

Dust accumulation on solar panels is one of the major factors that reduces the efficiency of PV systems. When dust particles settle on the panel surface, they block sunlight from reaching the photovoltaic cells, which leads to a decrease in power generation. Studies have shown that dust deposition can cause significant energy losses, especially in dry and dusty regions where solar farms are commonly installed <sup>[2]</sup>. Regular cleaning of solar panels is therefore essential to maintain optimal performance and ensure maximum energy output from solar power systems. Traditional cleaning methods usually involve manual labour, which can be time-consuming, costly, and sometimes unsafe, particularly in large solar installations. To overcome these challenges, several automated solar panel cleaning systems have been developed. These systems use mechanical brushes, water spraying mechanisms, and automated wiper systems to



remove dust and dirt from the panel surface. Microcontroller-based control systems are often used to automate the cleaning process and improve the overall efficiency of solar panel maintenance [3]. In recent years, the integration of Internet of Things (IoT) technology has further enhanced the capabilities of solar energy systems. IoT-based monitoring allows real-time tracking of system performance, remote control of devices, and efficient management of solar installations. Sensors and microcontrollers can be used to monitor parameters such as voltage, power output, and system status, enabling operators to detect performance issues and schedule maintenance activities more effectively [4]. Another practical challenge faced in large solar farms is the growth of vegetation or grass around the solar panels. Excessive vegetation can obstruct maintenance operations, create shading effects, and reduce accessibility to solar installations. Therefore, maintaining vegetation around solar farms is an important aspect of solar power system management. To address these issues, this research proposes an IoT-based automated solar panel maintenance system that integrates a water sprinkling and mopping mechanism for cleaning the panel surface. In addition, the system incorporates a high-RPM grass cutting mechanism to remove vegetation around solar installations. The proposed system aims to improve solar panel efficiency, reduce manual maintenance effort, and provide a smart and cost-effective solution for solar farm maintenance.

## II. METHODOLOGY AND DESIGN

The proposed solar panel cleaning system uses two step mopping mechanism. The specification and motive of some major component used in proposed cleaning method are presented in Table I.

TABLE I PROPERTIES OF MAJOR COMPONENT

Name	Purpose and Rating
<b>Solar panel</b>	A 55W Solar panel is used in the system. Its Voc is 22V and Isc is 3.10. Vmp is 18V Imp is 2.78A.
<b>DC gear motor</b>	It is used for mopper. Rated voltage is 12V DC with 60 RPM. Its load current is 7.5A.
<b>Water pump</b>	Brushed DC motor with gear head is used with a rated voltage of 12V
<b>Grass Cutter</b>	To cut dry grasses that causes shade and has a risk of fire. With 2000 RPM it has a rated voltage of 12V.

Some other components are used in this system as supporting components The complete wiring diagram is shown in figure I.

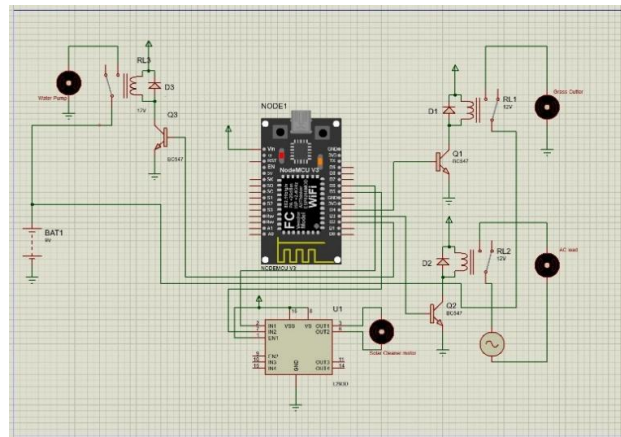


FIGURE 1 WIRING DIAGRAM OF THE PROPOSED SYSTEM



Inverter circuit contains transformer and MOSFET. Two relays are used one for grass cutting and one for water pump that decides when grass cutting and when water pump will operate. Motor driver will control the Johnson motor that is used for running sweeper. Microcontroller circuit will tell the motor driver when the sweeper will move forward and backward. Solar charge controller used to limit down the charge coming from the solar panel so that it will be safe for the battery and after the full charge, it will cut off power going to battery. Limit switches are used to stop the sweeper at a point and then move towards the 2<sup>nd</sup> step of mopping. When the solar charge controller will be ON, it will be connected to the Wi-Fi. After turning ON the sweeper will come to its initial position. Then Blynk IoT application will be used to control the cleaning, cutting and water sprinkling mechanism. The grass cutter is fixed at down side of the panel that will run according to the Blynk application and it will glide with the help of linear slider along with the sweeper. Along with the sweeper the sprinkling of the water will be done to loosen the dust particles that is stuck on the panel and birds waste too. A pump is used to pull the water from the tank and a nozzle will be used to sprinkle it on the panel.

### III. POWER REQUIREMENTS OF ELECTRICAL COMPONENTS

TABLE II POWER REQUIREMENTS OF COMPONENTS

Components	Power requirements
Solar panel	55W, 12V
Charge Controller	PWM 10-20A
Battery	12V, 7Ah- Le
Inverter	100W
Relay Module	5V
DC Motor (For grass cutter)	12V, 60RPM
DC Motor	12V

#### HARDWARE IMPLEMENTATION AND RESULT

The hardware implementation of the system involves integrating sensors, microcontroller (Node MCU), motor drivers, DC motors, and a water pump to automate the cleaning of solar panel and grass cutting.

TABLE III MAJOR COMPONENTS AND WORKING

Component	Working
Node MCU (ESP 8266)	Main controller (IoT control)
L298N motor driver	Drives DC motor
DC motor	For Cleaning mechanism
12V water pump	Sprays water
Relay module	Controls device such as motor, pump
Battery (12V)	Power supply
Grass cutter	Used for cutting grass

The Node MCU ESP8266 is connected to user through WIFI and is also connected to L298N motor driver to control the direction and speed of the DC motor. Main microcontroller is used to instruct the driver of the motor to operate the motor whether the motor must rotate clockwise or anticlockwise.



Two relay modules are used to control the water pump and second relay is used to operate grass cutter. The system is powered using a 12 V battery, and a solar charge controller is used in off-grid systems to maintain batteries at their highest state of charge without overcharging them to avoid gassing and battery damage. This helps to prolong battery life. Charge controllers also deliver proper current and voltage that meets the rated capacity of electrical loads voltage regulation is controlled using the solar charge controller.

A **100W inverter circuit** is used to power the load by converting DC input from the battery into AC output using a Transformer, two MOSFET and IC. The working of each component is explained as follows:

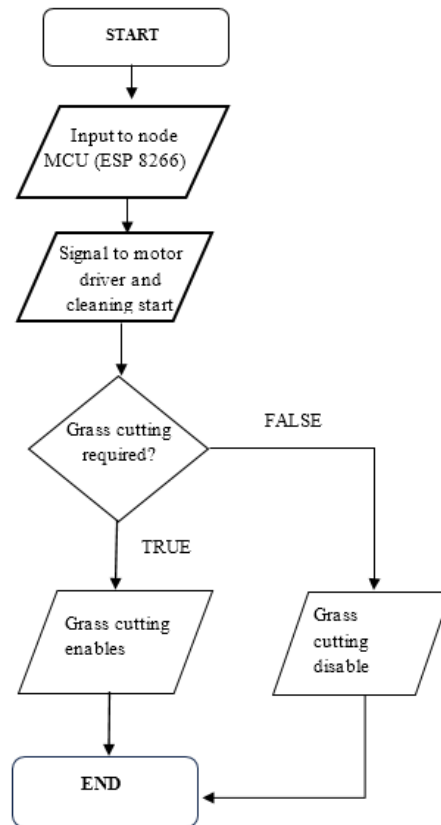
**Pulse generator:** Used to generate pulse. It defines the inverter's operating frequency, shapes the output waveform, and enables voltage regulation by switching the DC input on and off at precise intervals to produce AC output and drive the MOSFET.

**MOSFET:** Metal oxide semiconductor field effect transistor is a high-speed electronic switch used to rapidly alternate the flow of direct current through a transformer to create an AC waveform. They are driven by PWM signal to regulate the output voltage and frequency. The Input DC is fed into the MOSFET and converted into AC and fed into the transformer to supply AC to the load.

**Transformer:** A transformer is a static electrical device which is used to transfer electrical energy on the principle of electromagnetic induction. The primary function is to step up and step down the voltage. The alternating pulse from MOSFET is fed into the transformer to Boost the signal which is ready to fed to the load.

This whole inverter circuit is mounted on a frame which is fixed below the solar panel. The cleaning mechanism is mounted on the solar panel that moves through the frame of the solar panel connected with the pipes to spray water evenly. The grass cutter is used when needed in the solar farm on a regular interval.

The flow chart of the model is given below for reference:



The system was tested under different conditions to evaluate performance in cleaning solar panels and cutting grass effectively. Experimental results validate that the proposed solar panel cleaning system works efficiently at desired level.

TABLE IV SOLAR PANEL PERFORMANCE BEFORE AND AFTER CLEANING

Condition	Voltage (V)	Current (A)	Power (W)
Dust Accumulated	9.81	1.45	14.22
After Cleaning	13.16	2.6	34.216

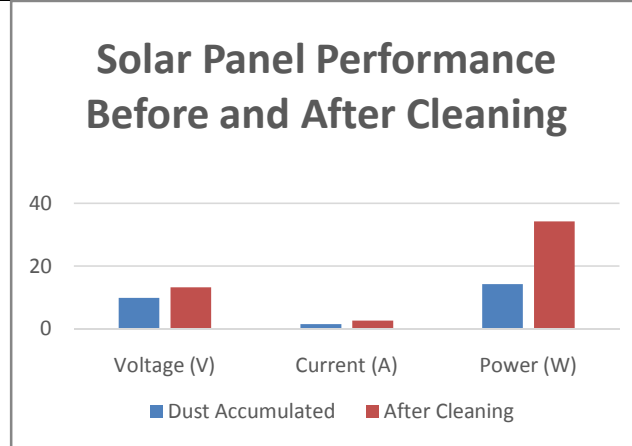


FIGURE II SOLAR PANEL PERFORMANCE BEFORE AND AFTER CLEANING

Parameter	Before Cleaning	After Cleaning	Improvement
Voltage	9.81	13.16	18.6%
Power Output	14.22	34.216	36.35%
Panel Efficiency	Low	High	Improved

TABLE V EFFICIENCY COMPARISON:

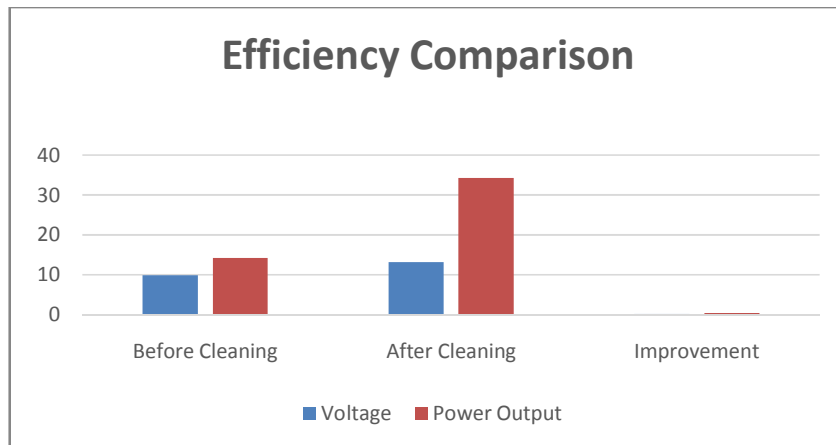


FIGURE III EFFICIENCY COMPARISON



TABLE VI EFFECT OF GRASS CUTTING:

Condition	Shading Effect	Efficiency
With Grass	High	Reduced
After Cutting	Low	Improved



FIGURE IV SOLAR PANEL COVERED BY DUST AT 30%

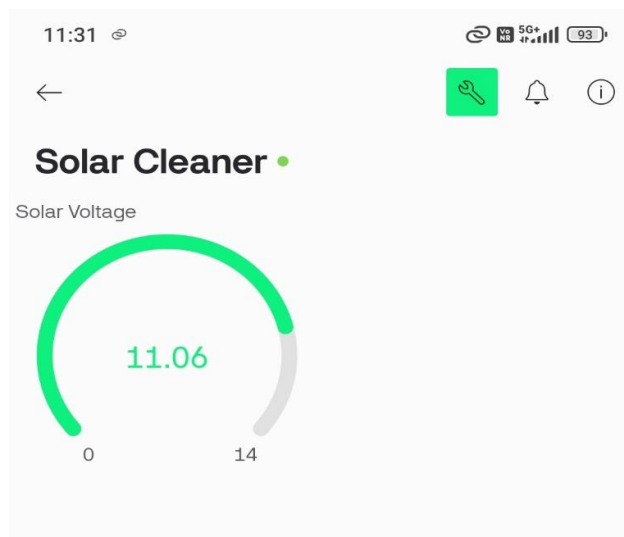


FIGURE V SOLAR VOLTAGE WHEN SOLAR PANEL COVERED BY DUST AT 30%



FIGURE VI SOLAR PANEL COVERED BY DUST AT 60%





FIGURE VII SOLAR VOLTAGE WHEN SOLAR PANEL COVERED BY DUST AT 60%



FIGURE VIII SOLAR PANEL COVERED BY DUST AT 90%

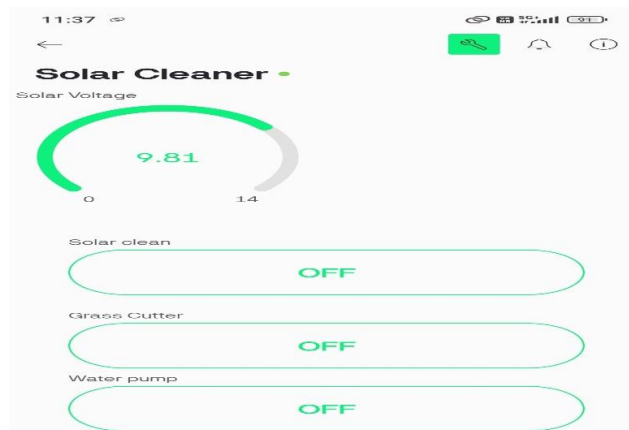


FIGURE IX SOLAR VOLTAGE WHEN SOLAR PANEL COVERED BY DUST AT 90%





FIGURE X AFTER CLEANING DUST I.E., 0 % DUST

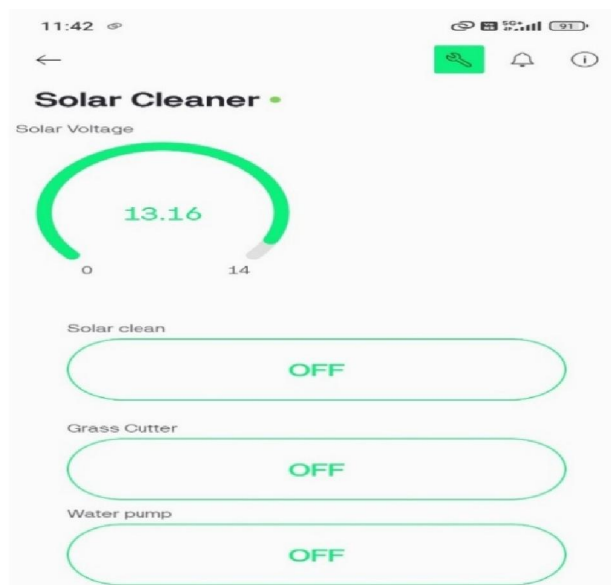


FIGURE XI SOLAR VOLTAGE AFTER CLEANING DUST I.E., 0 % DUST

**Experimental Analysis of Dust Impact on PV Output:**

To evaluate the impact of dust accumulation on photovoltaic (PV) panel performance, controlled experiments were conducted by artificially covering the solar panel surface with sand at varying levels. The output voltage was monitored in real time using the Blynk IoT application.

Initially, approximately 30% of the panel surface was covered with sand, resulting in a measured output voltage of 11.06 V. As the coverage was increased to 60%, the voltage dropped to 10.0 V. At approximately 90% coverage, the output voltage further decreased to 9.81 V, indicating a significant reduction in performance. After cleaning, the panel voltage increased to 13.81 V, which is considered as the reference (100% performance condition). The percentage efficiency loss was calculated using:

$$\text{Efficiency Loss (\%)} = \frac{V_{\text{clean}} - V_{\text{dust}}}{V_{\text{clean}}} \times 100$$



- At 30% dust:  
Loss =  $((13.81 - 11.06) / 13.81) \times 100 \approx 19.9\%$
- At 60% dust:  
Loss =  $((13.81 - 10.0) / 13.81) \times 100 \approx 27.6\%$
- At 90% dust:  
Loss =  $((13.81 - 9.81) / 13.81) \times 100 \approx 29.0\%$

These results clearly demonstrate that increased dust accumulation leads to significant efficiency loss, while the cleaning mechanism effectively restores system performance.

#### IV. COST ESTIMATION OF THE PROPOSED SYSTEM

TABLE VI COST ESTIMATION OF THE PROPOSED SYSTEM

Components	Price
Solar Panel	2500
Charge Controller	350
Battery	370
Inverter	580
Buck converter	150
Node MCU	300
PCB	300
Relay Module	120
Voltage Sensor	80
Battery Monitor	250
DC Geared Motor	650
DC Motor	250
Motor Driver	180
Total	5740

#### V. COMPARISON BETWEEN THE PROPOSED AND EXISTING SOLAR PANEL CLEANER.

TABLE VI COST ESTIMATION OF THE PROPOSED SYSTEM

Proposed solar panel cleaner	Existing methods
1. Can be controlled automatically and manually via IoT (Blynk + ESP8266)	1. Time-based/manual operation
2. Designed mainly for prototype/small panels	2. Modular structure, adaptable for rooftop installations
3. Limited discussion on energy consumption	3. Optimized motor control using PWM and relay-based switching
4. Cleaning OR monitoring separately	4. Cleaning + Monitoring + Grass Cutting + Load Control in single framework



## VI. CONCLUSION

In this paper it is revealed that although previous works addressed either cleaning or monitoring of solar panels, there remains a need for an integrated and multifunctional system. The proposed project overcomes these limitations by combining automated water sprinkling and cleaning mechanisms with IoT-based real-time monitoring and a high-RPM grass cutting feature. This integrated approach enhances solar panel efficiency, reduces manual intervention, and improves system reliability. Thus, the proposed system contributes toward smarter and more sustainable solar energy management solutions.

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