Innovative Journal for Opportunities and Development in Science & Technology,
Volume 6, Issue 7, June 2026
Paper Id: – IJ2026V6I7 -1 A-E
ISSN 2582-6026

DESIGN AND FABRICATION OF SOLAR PANEL CLEANING MECHANISM

[1]Dr.H.S.Avchat, [2]Shubham Pawar, [3]Rutuja Pawar,[4]Anushka More, [5]Kartik Padir

[1]Assistant Prof., Department of Electrical Engineering, HSBPVT's GOI Kashti, Ahilyanagar
[2]UG Scholar, Department of Electrical Engineering, HSBPVT's GOI Kashti, Ahilyanagar
[3]UG Scholar, Department of Electrical Engineering, HSBPVT's GOI Kashti, Ahilyanagar
[4]UG Scholar, Department of Electrical Engineering, HSBPVT's GOI Kashti, Ahilyanagar
[5]UG Scholar, Department of Electrical Engineering, HSBPVT's GOI Kashti, Ahilyanagar

ABSTRACT- In this project, an ESP32 microcontroller-based solar panel cleaning mechanism is designed and implemented. Using a 1 HP water motor pump, a gear motor with a sprocket-chain mechanism, and a wiper assembly, the system is made to automatically clean solar panels in order to maximize solar energy output. The electrical characteristics of the solar panel are continually monitored by voltage and current sensors. The BTS7960 motor driver regulates the gear motor that moves the panel wipers. Real-time panel voltage, current, and system functioning status is shown on a 20x4 LCD display. A 12V 8A battery coupled to two 50W solar panels powers the system. The add-on water spraying panel's 1 HP water motor is managed by a relay module. Through IoT-based automated control, the suggested solution increases solar panel efficiency, lowers the cost of manual cleaning, and guarantees steady energy production.

Keyword : - ESP32, Solar Panel Cleaning, IoT, BTS7960 Motor Driver, Gear Motor, Relay, Current Sensor, Voltage Sensor, 20x4 LCD Display, 1HP Motor, Sprocket Chain, Automatic Cleaning, Solar Energy

I. INTRODUCTION

As a clean and sustainable energy source, solar panels are widely employed in industrial, agricultural, and residential settings. However, the amount of energy produced by solar panels is greatly decreased by the buildup of dust, bird droppings, and other debris on their surface. According to studies, filthy solar panels can reduce their energy generating efficiency by up to 25–30%. Manual cleaning is time-consuming, labor-intensive, and sometimes unfeasible, particularly for big installations or panels installed at heights. Conventional solar panel cleaning techniques are completely dependent on physical labor, which is either sporadic or necessitates constant human effort. Microcontroller-based automatic cleaning systems are now a viable and affordable option due to the quick development of embedded systems and the Internet of Things.

The ESP32 microcontroller's integrated dual-core CPU

For such an advanced automatic cleaning system, Wi-Fi and wide peripheral compatibility make it the perfect platform. In order to provide a fully automated and real-time panel cleaning solution, this project proposes an Internet of Things (IoT) Based Automatic Solar Panel Cleaning System that combines an ESP32 microcontroller with a current sensor, a voltage sensor, a relay module, a BTS7960 motor driver, a gear motor with a sprocket-chain mechanism, a 1HP water motor, a 20x4 LCD display, and two 50W solar panels with a 12V 8A battery. To guarantee maximum solar panel efficiency at all times, the system automatically turns on the cleaning mechanism at predetermined intervals or in response to sensor feedback..

II. OBJECTIVE

- The ESP32 microcontroller will be used in the design and implementation of an Internet of Things-based automated solar panel cleaning system.

Using a gear motor with a sprocket-chain system and a 1 HP water motor for water spraying, solar panel cleaning may be automated.

- To use current and voltage sensors to track the voltage and current output of two 50W solar panels in real time.

To show the voltage, current, and system status of solar panels in real time on a 20x4 LCD screen.

For smooth wiper operation over the panel surface, a BTS7960 motor driver is used to regulate the gear motor's direction and speed.

- To increase solar panel efficiency and save labor expenses for manual cleaning by using IoT-based automated scheduling and control.

III. LITERATURE REVIEW

In their work on photovoltaic module monitoring, M. Faifer et al. emphasize how soiling losses can drastically lower energy production in outdoor settings and explore the need of real-time performance monitoring of solar systems. The usage of microcontroller-based platforms with motor actuators for automated dust removal from photovoltaic surfaces in arid and semi-arid environments is demonstrated by P. Kumar and A. Rawat's work on automated solar panel cleaning system M. Faifer et al. highlight how soiling losses can significantly reduce energy output in outdoor settings and examine the necessity of real-time solar system performance monitoring in their work on photovoltaic module monitoring. P. Kumar and A. Rawat's work on an automated solar panel cleaning system demonstrates the use of microcontroller-based platforms with motor actuators for automatic dust removal from photovoltaic surfaces in arid and semi-arid regionsThe BTS7960 H-bridge driver is suitable for controlling medium to high-power DC motors in automated industrial systems with accurate direction and speed control, according to V. Nair and C. Krishnamurthy's work on BTS7960-based high-current motor driver applications. K. Suresh and M. Arjun claim that

their research on ESP32-based IoT applications for renewable energy systems shows how well the ESP32 works for motor control, remote monitoring, and real-time sensor data collecting, making it a perfect platform for solar energy management solutions.

The block diagram of the IoT Based Automatic Solar Panel Cleansing System consists of the following main blocks: Power Supply Unit (12V 8A Battery + 2x 50W Solar Panels), Sensor Unit (Current Sensor, Voltage Sensor), ESP32 Microcontroller, Relay Module (for 1HP Water Motor), BTS7960 Motor Driver (for Gear Motor), Gear Motor with Sprocket Chain Mechanism, 1HP Water Motor with Add-on Water Panel, and 20x4 LCD Display. The sensor unit continuously feeds panel output data to the ESP32, which processes the signals and controls both the gear motor cleaning mechanism and the water spraying relay as per the automated cleaning schedule.

IV. WORKING

The IoT Based Automatic Solar Panel Cleaning System functions by automatically cleaning solar panels on a planned and sensor-triggered basis. All connected sensors, the relay module, the BTS7960 motor driver, and the 20x4 LCD display are initialized by the ESP32 at power-up. Solar panel voltage, current output, and system operating status are all shown in real time on the LCD. The solar panels' output voltage is measured by the voltage sensor, and their output current is measured by the current sensor. The ESP32 processes these signals to calculate the power generation level in real time. When the cleaning cycle is initiated, the ESP32 triggers the relay to turn on the 1 HP water motor, which concurrently drives the BTS7960 motor driver to move the gear motor ahead and pumps water via the add-on water panel to moisten the solar panels' surface. The wiper assembly is driven over the surface of the solar panel by the gear motor, which is coupled via a sprocket-chain system to remove collected dust and debris. The ESP32 reverses the BTS7960 motor driver to return the wiper to its starting position when it reaches the end of the panel. The relay disconnects the water motor and stops the gear motor after the cleaning cycle is over. The 20x4 LCD display shows the cleaned panel data (better voltage and current), verifying the cleaning cycle's efficacy.

4.1 ESP32 Microcontroller

Espressif Systems created the ESP32, a powerful, inexpensive, dual-core microcontroller module. It has a dual-core Xtensa LX6 CPU operating at 240 MHz, numerous ADC channels, integrated Wi-Fi and Bluetooth connections, and an extensive array of digital I/O connectors. The ESP32 serves as the core processing unit in this system. To track solar panel output, it uses its ADC channels to read analog signals from the voltage and current sensors. During the automated cleaning cycle, it creates control signals for the BTS7960 motor driver to run the gear motor and triggers the relay to turn on and off the 1 HP water motor. Through the I2C interface, all sensor data and system status are shown on the 20x4 LCD display.

Innovative Journal for Opportunities and Development in Science & Technology,
Volume 6, Issue 7, June 2026
Paper Id: – IJ2026V6I7 -1 A-E
ISSN 2582-6026

4.2 Relay Module

The relay module is an electrically powered switch that enables a high-power motor circuit to be switched by the ESP32's low-power control signal. The 1 HP water motor in this project is connected to or disconnected from the power source using a single-channel relay module. The relay can manage the water motor's load on the switching side and runs on 5V DC from the control side. The 1 HP motor that pumps water via the add-on water spraying panel is turned on by the relay coil when the ESP32 starts a cleaning cycle. The relay is de-energized to turn off the motor after the cycle.

4.3 HP Water Motor

Fig.1 - HP Water Motor

The water supply source for the solar panel cleaning process in this system is a 1 HP (746 W) water motor pump. It requires a full-load current of about 6-7A and runs on a 230V AC, 50Hz supply. When a cleaning cycle begins, the motor, which is connected to the relay output, automatically turns on to pump water via the additional water spraying panel that is installed above the solar panels. In order to ensure effective water consumption, the relay turns the engine off when the cleaning cycle is over.

4.4 Current Sensor

In this project, the output current of the solar panels is measured using a linear current sensor based on the Hall effect. It can measure currents with excellent sensitivity and precision in the range needed for a 50W solar panel output. An analog voltage that is proportionate to the current coming from the solar panels is produced by the sensor. The ESP32's ADC input receives this analog output. This reading is processed by the ESP32 to determine the solar panels' real-time current output, which is then shown on the 20x4 LCD display to allow for the monitoring of panel performance and the efficiency

Innovative Journal for Opportunities and Development in Science & Technology,
Volume 6, Issue 7, June 2026
Paper Id: – IJ2026V6I7 -1 A-E
ISSN 2582-6026

Fig. 2 - Current Sensor

4.5 Voltage Sensor

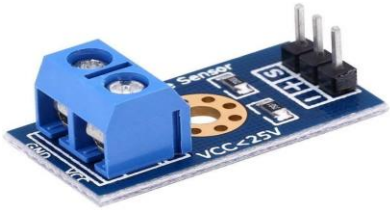

Fig.3 - Voltage Sensor

In this paper, the DC output voltage of the two 50W solar panels is measured using the voltage sensor module. It lowers the panel output voltage to an analog signal level that is safe for the ESP32's ADC to read. This reading is processed by the ESP32 to determine the voltage that the panels are producing in real time. This information is shown on the 20x4 LCD and is also utilized to assess how much the panel output has improved following each automatic cleaning cycle, demonstrating the system's efficacy.

Innovative Journal for Opportunities and Development in Science & Technology,
Volume 6, Issue 7, June 2026
Paper Id: – IJ2026V6I7 -1 A-E
ISSN 2582-6026

4.6 Gear Motor with Sprocket-Chain Mechanism

Fig.4 - Gear Motor with Sprocket-Chain Mechanism

A 50W DC gear motor drives the wiper cleaning mechanism across the surface of the solar panels. The gear motor provides sufficient torque to provide consistent and smooth wiper movement. A sprocket chain mechanism is fastened to the gear motor output shaft in order to convert the rotational motion into linear displacement of the cleaning wiper. The sprocket-chain arrangement guarantees dependable mechanical power transfer over the panel surface. Following each cleaning cycle, the ESP32 sends direction and speed control signals to the BTS7960 motor driver, which then turns on the gear motor to advance the wiper and restore it to its starting position.

4.7 BTS7960 Motor Driver

The 50W gear motor in this application is best controlled by the BTS7960, a high-current H-bridge motor driver that can drive DC motors with currents up to 43A. The ESP32 sends PWM direction control signals to the BTS7960 module, which then drives the gear motor forward and backward as needed throughout the cleaning cycle. It ensures safe and dependable motor running by offering protection against overcurrent and over temperature. Because of its large current capacity, the BTS7960 is a good choice for powering the gear motor under a variety of mechanical stresses while the panel is being wiped.

Fig.5 - BTS7960 Motor Driver

Innovative Journal for Opportunities and Development in Science & Technology,
Volume 6, Issue 7, June 2026
Paper Id: – IJ2026V6I7 -1 A-E
ISSN 2582-6026

4.8 12V 8A Battery and Solar Panels

Fig.6- 12V 8A Battery and Solar Panels

The main energy source for this project is two 50W solar panels. A 12V, 8A sealed lead-acid battery is used to store the DC electrical energy they produce from sunshine. The ESP32, relay module, BTS7960 motor driver, and 20x4 LCD display are all powered steadily by the battery. Additionally, the saved energy guarantees that the automatic cleaning system can function even when there is little sunshine. In order to offer enough energy reserve for several cleaning cycles without requiring constant direct solar input throughout the cleaning process, a 12V 8A battery capacity was used.

V. ADVANTAGES

- Provides fully automatic solar panel cleaning, eliminating the need for manual labor and reducing operational costs.
- Significantly improves solar panel energy output by maintaining clean panel surfaces free from dust and debris accumulation.
- The 20x4 LCD display provides real-time visibility of solar panel voltage, current output, and cleaning system status.
- The BTS7960 motor driver ensures smooth, reliable, and safe bidirectional control of the gear motor during cleaning cycles.
- Low cost and easy implementation using readily available components make the system suitable for residential and agricultural solar installations.
- The ESP32's built-in Wi-Fi capability allows future extension for remote monitoring, scheduling, and IoT cloud integration.
- The sprocket-chain mechanism provides reliable mechanical power transmission for consistent and uniform panel surface cleaning.
- Reduces solar panel degradation and extends operational life by preventing long-term soiling damage to the panel surface.

VI. RESULT

Parameter	Clean Panel (D1-5)	Dusty Panel (D6-10)
Avg Voltage	12.0 V	10.98 V
Avg Current	4.08 A	3.32 A
Avg Power	49.0 W	36.6 W
Avg Efficiency	97.7%	73.7%
Total Power Loss	---	12.4 W avg
Efficiency Loss	---	~24%

VII. CONCLUSION

The ESP32 microcontroller was used to create the IoT Based Automatic Solar Panel Cleaning System, which effectively illustrates how embedded IoT systems may enhance solar panel performance through automated maintenance. Using specialized sensors, the system efficiently tracks the voltage and current output of solar panels and initiates the cleaning mechanism automatically at predetermined intervals. The system is straightforward and easy to operate because to the incorporation of a 20x4 LCD display, which offers real-time feedback on panel output and cleaning progress. While the BTS7960 motor driver offers dependable bidirectional control of the gear motor for the wiper cleaning mechanism, the combination of current and voltage sensors guarantees precise and continuous monitoring of solar panel electrical output. For the 1 HP water motor, the relay offers a reliable switching mechanism. The panel surface is consistently cleaned mechanically thanks to the sprocket-chain drive. With the ESP32's built-in connection, the project may be expanded to incorporate Wi-Fi-based remote monitoring, IoT cloud dashboard integration, and scheduling via a mobile application, creating a complete automated solar panel maintenance solution.

REFERENCES

[1] M. Faifer, C. Laurano, R. Ottoboni, S. Toscani and M. Zanoni, “Photovoltaic Module Monitoring: Soiling and Performance Characterization,” IEEE Transactions on Instrumentation and Measurement, 2019.
[2] P. Kumar and A. Rawat, “Automated Solar Panel Cleaning System for Enhanced Energy Yield,” International Journal of Renewable Energy Research, 2020.
[3] R. Singh and S. Sharma, “IoT Based Solar Energy Monitoring and Management Using ESP32,” International Journal of Engineering Research and Technology, 2021.

[4] A. Mehta and B. Patel, "Gear Motor and Sprocket Chain Mechanism for Solar Panel Surface Cleaning," Journal of Mechanical and Energy Engineering, 2019.
[5] V. Nair and C. Krishnamurthy, "BTS7960 H-Bridge Motor Driver Applications for Industrial DC Motor Control," IEEE Industrial Electronics Conference, 2018.
[6] K. Suresh and M. Arjun, "ESP32-Based IoT Applications for Renewable Energy Systems," Journal of Embedded Systems and IoT, 2021.