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AUTOMATIC SOLAR PANEL CLEANING ROBOT

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ABSTRACT :

This project focuses on the design and development of an automated solar panel cleaning system. The priary objective of this prototype is to clean solar panels using an electrical mechanism, ensuring that the efficiency and performance of the panels are not compromised. In regions like the Gulf, particularly Saudi Arabia, frequent dust storms necessitate regular cleaning of solar panels. Manual cleaning of these solar panels is both costly and time-consuming. The proposed system incorporates water sprinklers to ensure effective cleaning while preserving the panels quality.

Keywords: Solar Panel Maintenance, Cleaning System, Automatic, Dust and Debris Removal, IoT Integration, Microcontroller-Based Automation, Robotic System Design.

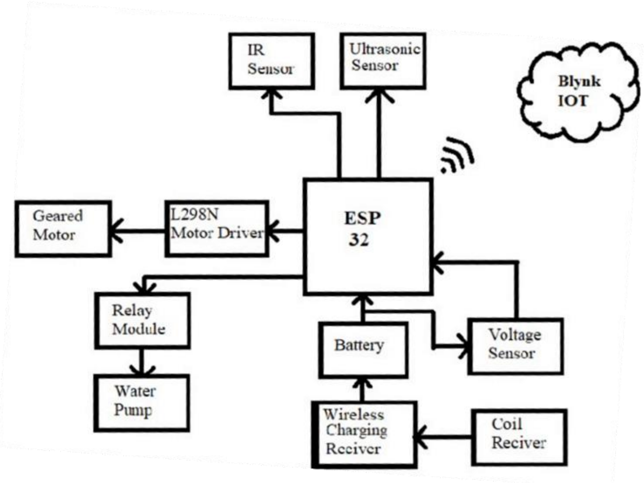
Introduction :

Sun radiates energy at a tremendous rate therefore, there is vast availability of solar energy in nature. Solar energy can be converted to different forms of energy using solar panels. Of many alternatives photovoltaic method of extracting power from solar energy have been considered as promising to meeting the continuously increasing demand for energy. However, the efficiency of solar panels is constrained by environmental factors, and thus accounting for parameters such as dust accumulation, humidity, and temperature variations is crucial to optimize performance. The main objective of this project is to design an automated dust removal system in order to enhance the efficiency and maintenance of solar panels. Traditionally, cleaning the solar panels has been manual, which has many downsides, such as the risk of injuries to staff, possible harm to the panels, and poor maintenance.

To address these problems, an automated dust cleaning system has been developed. This system overcomes the limitations of manual cleaning, offering an efficient, non-abrasive cleaning method that ensures consistent performance and mitigates productivity losses caused by dust accumulation. The studies conducted assessed the efficiency of solar panels with dust accumulation over periods of weeks, months,. Efficiency was also recalculated when these panels were cleaned on these same intervals. When these two efficiencies before and after cleaning were compared, the results reflect an improvement in the efficiency of the solar panel when it is cleaned. The model improves significantly the performance of solar panels.

Structure :

Fig 1: Cleaning Robot



The above block diagram represents the architecture of the 'Cleaning Robot' integrated with IoT capabilities using ESP32 as the central controller. Here's a detailed explanation of the components and their interactions:

- **ESP32:** ESP32 microcontroller as the central control unit. Various components are connected to the ESP32 to perform specific tasks, enabling automation and control.
- **IR Sensor:** Detects obstacles or objects in the cleaning path.
- **Ultrasonic Sensor:** Measures distances and help in navigation.
- **L298N Motor Drive:** Controls the Geared Motors used for movement. Receives commands from the ESP32 to adjust the robot's speed and direction..
- **Geared Motors:** Responsible for moving the robot.
- **Relay Module:** Used to switch on/off the Water Pump as directed by the ESP32. Ensures that cleaning liquid is dispensed when necessary.
- **Water Pump:** Pumps cleaning liquid to the robot's cleaning mechanism. Essential for wet cleaning operations.
- **Voltage Sensor:** Monitors the battery's voltage level. Provides real-time battery status to ESP32 for efficient power management.
- **Battery:** Powers all components of the robot, including ESP32, motors, sensors, and the pump.
- **Wireless Charging RX (Receiver):** Enables wireless charging of the robot's battery. Works with a Coil to receive power from a charging station.
- **Coil** : Acts as the transmitter for wireless charging.
- **Blynk IoT:** IoT platform for remote monitoring and control via a smartphone or PC. Allows the user to check robot status, battery levels, and start/stop cleaning remotely

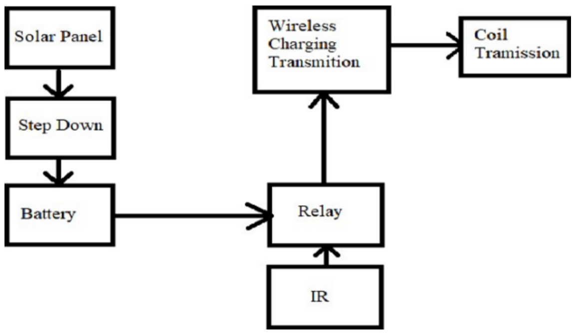
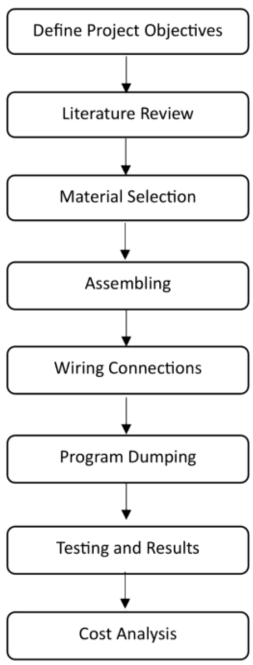


Fig 2: Charging Station

This block diagram represents the working of a solar-powered wireless charging station with the following components:

- **Solar Panel:** Captures solar energy and converts it into electrical energy.
- **Step-Down:** Regulates the voltage from the solar panel to a suitable level for the battery, preventing overcharging or damage.
- **Battery:** Stores the electrical energy from the solar panel for later use.
- **Relay**: It is a switch that controls the flow of power. It works on the input from the IR (infrared) sensor.
- **IR (Infrared Sensor):** It detects objects or conditions (for example, the presence of a device to be charged) and sends a signal to activate the relay.
- **Wireless Charging Transmission:** It facilitates the transfer of energy wirelessly from the battery to the load using electromagnetic induction.
- **Coil Transmission:** This term refers to the coils utilized for inductive coupling. It basically forms the core mechanism by which energy can be transferred wirelessly from the transmitter to the receiver.

Methodology:



The above flowchart represents the steps required in completing the project. At the first, define project objectives to have clear goals and scope. Then, a literature review is conducted, which delivers relevant information and insights from the previously conducted studies or references. Next, material selection occurs to meet project requirements. Assembling the components according to design is part of this stage. After assembly, wiring connections are made to ensure proper electrical or functional integration. Subsequently, program dumping refers to loading the required software or code into the system. The project then undergoes testing to evaluate functionality and performance, and results are analyzed. Finally, a cost analysis is performed to assess the overall expenses and financial feasibility of the project.

3.1 Working:

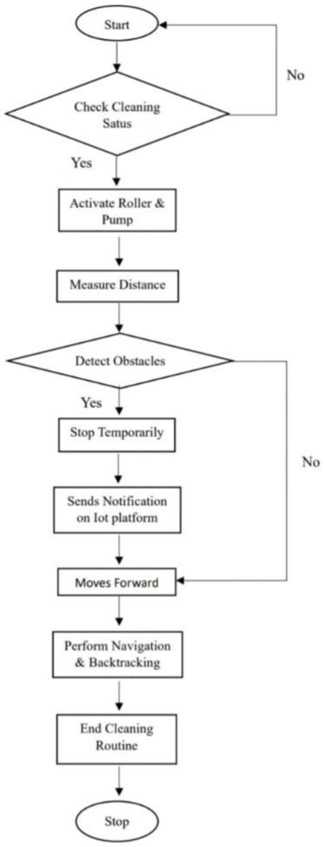


Fig 4: Flow Chart of the System

The flowchart represents the operational logic of a cleaning system. The system first checks the cleaning status, and if it is required, it activates components such as roller and pump. If the cleaning is not required it loops back to start. Next the system measures the distance to identify its surrounding and detect any obstacles in its path. If an obstacle is detected, the system stops its activity temporarily and sends an alert to an IoT platform, and resumes the movement for cleaning. In case if no obstacle is found, it moves forward to continue cleaning. The system performs navigation adjustments and backtracking as needed to ensure comprehensive coverage of the area. Once the cleaning task is completed, the cleaning routine ends, and the system terminates its operation.

Components used:

Chassi

Fig 5: Chassi

The Chassis in electric vehicles functions as the base structure onto which essential components such as the battery pack, electric motor, and suspension system are installed. It not only offers structural strength and stability but also allows for the specific configuration needed for electric drivetrains.

L298N Motor Driver

Fig 6: L298N Motor Driver

The L298N Motor Driver serves as an integrated solution for managing the speed and direction of DC motors and stepper motors. By integrating power amplification and switching circuits, this semiconductor device can effectively respond to input signals from a microcontroller or other control device to facilitate motor control.

ESP32 (30 Pins)

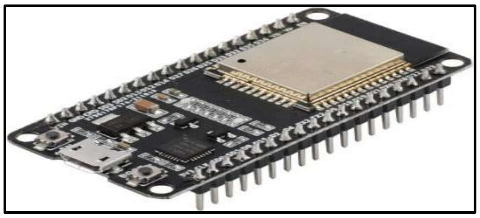


Fig 7: ESP32

Based on a dual-core processor mechanism, the ESP32 is a low-powered, low-cost microcontroller (MCU) board with built-in Bluetooth and Wi-Fi. The first is an ultra-low coprocessor (ULP) with only 8 KiB of memory that is intended to operate when the ESP32 is in deep sleep mode. It is similar to an Xtensa LX6 (~240 MHz) processor with 512 KiB of memory.

Battery

Fig 8:12V battery pack

The Fluke 12V 2.6Ah Sealed Lead Acid Battery is a reliable and durable battery that is definitely a good choice for a variety of applications. With a 12 volt output and a 2.6 amp hour capacity, this battery is definitely a good choice for powering a variety of devices.

XL4015

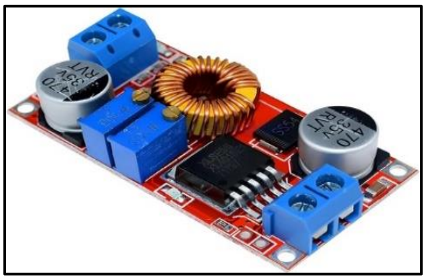


Fig 9. XL4015

The XL4015 is a popular DC-DC buck converter module commonly used in electronic circuits to step down voltage from a higher voltage source to a lower voltage output. It's efficient and versatile, making it suitable for various applications such as powering LED lighting, motors, and small electronic devices

4.1 Existing system:

Existing solar panel cleaning robots are those that remove dirt, dust, and debris that keep accumulating on photovoltaic systems to ensure the highest efficiency of such systems. They can be broadly divided into two categories: automation and semi-automation. Automated systems function independently, relying on sensors and programmed routines to navigate and clean the solar panel. They often run themselves on solar energy. Semi-automated systems need human intervention; for example, the control of the robot is to be done at a remote location. Various cleaning robots are provided with soft brushes, water sprayers, or air jets to provide thorough cleaning that is not abrasive. Some advanced systems also include artificial intelligence for optimized cleaning paths and real-time performance monitoring. Still, challenges include high costs, a low ability to adjust with respect to panel configurations, and water dependence in arid areas. These systems attempt to lower maintenance costs as well as increase energy efficiency for solar power installations.

Results:

- The "Automatic Solar Panel Cleaning Robot" appropriately addresses the challenge of keeping up ideal solar panels effectiveness through an independent and dependable cleaning arrangement.
- The robot can significantly improve the efficiency of the solar panels by restoring their optimal energy output, which can increase by upto 10% after cleaning.
- Compared to manual cleaning, the robot operates faster, reduces labor costs, and minimize safety risks associated with human involvement in maintenance.
- Moreover, the robot's operation is environmentally friendly, as it uses minimal water and energy while maintaining the panels functionality.

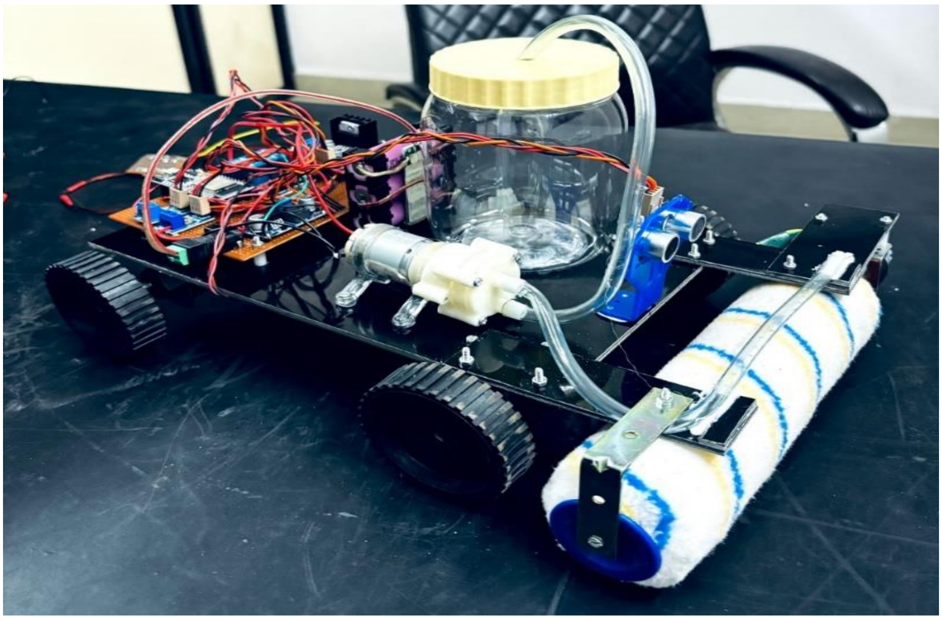


Fig 10: Project Model

Conclusion:

The Sun based Board Cleaning Framework extend was designed to provide a successful arrangement for maintaining the productivity of solar boards. The basic objective was to design and implement a machine equipped with an appropriate control framework to automate the cleaning process. This model acts asa base for addressing orders in a growing and rapidly developing market. During the development phase,
the project team faced several challenges and hurdles.

The plan of the control framework included picking up capability in ESP32 setups, and its integration with electrical components. The execution of the outlined circuit required hands-on involvement with fastening sheets, equipment wiring, transfers, and mechanical components, all of which were unused learning openings. In spite of these challenges, the venture effectively accomplished the aiming plan and usefulness of the control framework. The DC engines were managed through the use of both transfers and engine drivers to facilitate speed and direction control. In addition, control codes for both the DC engines and the water pump were designed and integrated into the system.

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