DESIGN, FABRICATION AND OPERATION OF A BLUETOOTH RC CONTROLLED SOLAR PANEL CLEANING ROBOT

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***Abstract*—Solar energy is known as one of the most dependable and sustainable renewable energy sources accessible today. Dust, dirt, and environmental debris can significantly lower the energy production of solar panels when they settle on the surface of a panel. This additional layer of material blocks sunlight from reaching the solar cells and limits the ability of the panel to convert solar energy into usable electricity. Maintaining solar panels requires performing regular maintenance cleaning; however, manual cleaning processes take considerable effort and time, plus they are unrealistic for the majority of the larger solar panel installations.**

The proposed solution is to develop a Solar Panel Cleaning Robot that automates the cleaning process. The robot is equipped with a removable chassis to provide movement and consists of both DC motors to provide power to the chassis, soft nylon cleaning brushes to physically remove the debris from the surfaces of solar panels, and an electric water pump to spray a cleaning solution onto the surface of the panels to aid in the removal of any debris. The robot can be controlled from an Android device using a Bluetooth (HC-05) module and uses a rechargeable lithium battery for powering the operation of the robot.

A solar monitoring system consists of a monitoring system that will collect several parameters of a solar panel such as: the voltage of a solar panel; temperature of the surrounding area; humidity; and intensity of light. The parameters are measured with 3 different types of sensors: a voltage sensor; a DHT11; and a LDR. The data collected from the sensors will be displayed on a 16×2 LCD and transmitted to the internet via a Wi- Fi module (ESP8266). Users can then access the information remotely and see how the system is performing.

An Arduino Uno microcontroller controls the entire system and is programmed in Embedded C language. This project provides a sustainable and efficient solution to cleaning solar panels, increasing energy production from solar panels; reducing the labour and cost of maintaining solar panels.

***Index Terms*—Solar Panel Cleaning, Automated Cleaning, Arduino Based**

I. Introduction

Solar energy is a fast-growing division of renewable energy, so much that today solar panels are accepted as a viable solar energy solution to meet the renewable energy target. Due to the fact that solar panels are generally located outdoors (i.e., roof tops, open land and light industrial sites), they are regularly exposed to various forms of debris and pollutants including dust, dirt, bird droppings, etc. These

contaminants can significantly decrease the amount of sunlight that reaches the surface of the solar panel, which can subsequently reduce the efficiency of the panel to produce energy by anywhere from 15% to 30%. In order to maintain optimal performance, it is critical to clean solar panels on a regular basis. Unfortunately, traditional manual cleaning methods are time-consuming and labour-intensive, and may also be hazardous, especially for larger solar panel installations or installations located at high elevations.

This project proposes the design and implementation of an automated solar panel cleaning robot to improve the efficiency of solar panel cleaning and minimize the amount of manual labour required to perform the cleaning task.

The system that will be built to support this proposed project will consist of a mobile robotic base with rotating brushes, a water spray nozzle and a squeegee that will be used to mechanically remove contaminants from the surfaces of the solar panels. The robot will be controlled via an Android application through the use of a Bluetooth (HC-05) module and will be powered by a rechargeable lithium battery.

The system also includes sensors to measure temperature and humidity (DHT11), light intensity (LDR), and voltage monitoring for the operation of solar panels. Data from these various sensors will reside on a 16×2 LCD display that will be transmitted using an ESP8266 Wi-Fi module, enabling IoT capability through real-time data monitoring.

By improving efficiency, reducing the need for expensive maintenance, lessening the amount of manual labour required, and increasing safety, this proposed solution will be an effective and usable solution to provide automated solutions for maintaining solar panels within current energy systems.

II. OBJECTIVES

The main goal of this project is to design and build a Solar Panel Cleaning Robot that can clean solar panels automatically. This will help improve their efficiency and overall performance.

The specific goals of this project are:

- To develop a cleaning system that uses a movable robot equipped with a brush, a water spraying system, and a wiper for effective cleaning.
- To control the robot wirelessly with an Android phone via Bluetooth (HC-05 module).
- To use DC motors with an L298N motor driver to manage the robot's movement and cleaning tasks.
- To include a water tank and a submersible pump for spraying water on the solar panel surface during cleaning.
- To measure important environmental and performance factors, such as temperature and humidity with a DHT11 sensor, light intensity with an LDR sensor, and output voltage with a voltage sensor.
- To display the collected sensor data on a 16x2 LCD screen with an I2C interface.
- To send real-time data to the cloud using an ESP8266 Wi-Fi module for remote monitoring.
- To power the robot with a rechargeable lithium battery so it can operate in remote or off-grid areas.

- To develop and integrate the system using Embedded C programming in the Arduino IDE.

III. METHODOLOGY

The Solar Panel Cleaning Robot was developed step by step using a clear approach that involved design, hardware setup, programming, and IoT integration. The main steps followed in this project are listed below:

1. Problem Study and Requirement Collection

First, we studied how dust and dirt affect the performance of solar panels. We found that manual cleaning takes a lot of time and effort, so an automatic solution was necessary. From this, we identified key requirements, such as remote control operation, battery power, and real-time monitoring with sensors.

2. System Design and Selection of Components

We created a basic design for the robot using 16-gauge mild steel to make the structure strong and durable. We chose suitable electronic components for various functions, including:

- Arduino Uno as the main controller
- L298N motor driver to control all motors
- DC motors for robot movement and brush rotation
- HC-05 Bluetooth module for wireless control
- ESP8266 module for internet connectivity
- Sensors like DHT11, LDR, and a voltage sensor to monitor environmental conditions and panel performance

3. Mechanical Assembly

We assembled the robot body by attaching the chassis, motors, support wheels, and battery. We also mounted the cleaning components, such as the rotating brush, water pump, pipes, wiper, and water tank, securely on the frame. We made sure to align all parts correctly so the robot could move smoothly and clean effectively.

4. Circuit Design and Wiring

All necessary connections have been made to each element. The Arduino board is connected with sensors for receiving data. The motor driver is connected to the DC motors for controlling their motion and cleaning activity. The HC-05 module is connected with the Arduino by means of a TX and RX connection pin for wireless controlling. The ESP8266 module is connected for establishing connection

with the Internet using Wi-Fi. Additionally, a 16x2 LCD with an I2C module is connected for showing information on the display screen. Jumper wires are used for making all connections.

5. Integration and Testing

All devices were assembled and powered with a rechargeable lithium-ion battery. All elements were tested individually for correct working. The following tests were carried out:

- Robot movement using Bluetooth control application
- Correct brush and water spraying system rotation
- Exact sensor readings on LCD
- Correct data uploading to the cloud platform

IV. COMPONENTS

1. Ardiuno uno
2. L298 n drivers
3. Hc05
4. Chassis
5. Battery holder
6. switch
7. batter
8. Wheel
9. dummy wheels
10. Motor
11. water tank
12. pipe
13. acrylic sheet
14. wiper
15. Brush
16. Water motor
17. pipe
18. jumper Wire
19. dht11sensor
20. ldr sensor
21. esp8266

22. lcd with i2c
23. voltage sensor
24. solar panel

V. Working

The Solar Panel Cleaning Robot is designed to clean solar panels automatically and check their performance in real time. The system has two main parts: the cleaning mechanism and the sensor monitoring system with IoT support.

1. Cleaning Mechanism

- The robot has a strong metal frame and moves with two DC motors connected to the rear wheels. Two additional wheels in the front provide support and balance.
- An Android mobile controls the robot's movement (forward, backward, left, and right) through Bluetooth communication with the HC-05 module.
- A soft nylon brush is attached to a separate motor that rotates continuously to remove dust and dirt from the solar panel while the robot moves.
- A small water pump sprays water from a storage tank through a pipe, which helps loosen dirt and makes cleaning more effective.
- A wiper at the back of the robot removes excess water, preventing marks or streaks on the panel.
- All motors, including the wheel motors, brush motor, and pump, are controlled by the L298N motor driver, which receives signals from the Arduino Uno.

2. Sensor Monitoring and IoT System

- The robot has sensors to monitor the condition of the solar panel:
- A DHT11 sensor measures temperature and humidity.
- An LDR sensor detects sunlight intensity.
- A voltage sensor measures the electrical output of the solar panel.
- The system displays the collected data on a 16x2 LCD display with an I2C interface, making it easy to read in real time.
- This data is also sent to the cloud using the ESP8266 Wi-Fi module, allowing users to monitor the system remotely through platforms like Thing Speak.

3. Programming and Control

- The system is programmed using Embedded C and uploaded through the Arduino IDE.
- All control logic, including motor control, sensor reading, and data transmission, is handled

by the Arduino Uno microcontroller.

Fig.5 Solar Panel Cleaning Robot

VI. Design Calculations

1. Torque Requirement per Wheel

Total weight = 5 kg

Friction coefficient (mu) =

0.3 Wheel radius (r) = 0.05

m

T = (W * g * mu * r) / 2 = (5 * 9.81 * 0.3 * 0.05)/2 0.368 Nm Recommended torque per motor 0.6

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0.8 Nm.

2. Battery Sizing Calculation

Total current = 1.5 A (motors + electronics)

Required run time = 1 hour

Battery capacity needed = 1.5 Ah

Selected battery = 2200 mAh (7.4V), sufficient for ~1.5 hours of operation.

3. Robot Speed Calculation

Motor RPM (with gear) =

150 Wheel radius = 0.05 m

Linear speed v = (2pi * 150 / 60) * 0.05 =0.785 m/s

4. Brush Motor Power

Brush Motor: 12V, 0.3 A

Power = V * I = 12 * 0.3 = 3.6 W

5. Water Pump Pressure

Flow rate = 1 L/min, Head = 1.5 m

Pressure P = rho * g * h = 1000 * 9.81 * 1.5 = 14715 Pa = 0.147 bar

6. Energy Consumption Per Cycle

Drive motors (2): 6 W, Brush: 3.6 W, Pump: 6 W (half time),

Design Calculations: Solar Panel Cleaning Robot

Sensors + controller: 1 W

Total energy 2.44 Wh per 10-minute cleaning cycle

7.LCD and Sensor Power

Total draw 25 mA - negligible impact on power budget.

8.Communication Modules Power

HC-05: ~30 mA

ESP8266: 70-200 mA during bursts Moderate overall impact on battery.

VII. RESULTS AND DISCUSSION

The fabricated prototype was tested under different dust conditions. The robot successfully cleaned the panel surface and demonstrated reliable Bluetooth communication. The cleaning mechanism effectively removed dust particles, resulting in improved panel cleanliness and operational efficiency.

VIII. CONCLUSION

The Solar Panel Cleaning Robot successfully addresses the challenges of maintaining solar panel efficiency by automating the cleaning process., the system not only cleans panels effectively but also provides real-time data on environmental conditions and panel performance. This combination enhances the overall productivity and reliability of solar power systems.

The robot's remote control via Bluetooth, along with cloud-based data monitoring, makes it user- friendly and suitable for various applications, from small residential setups to large solar farms. The use of readily available, cost-effective components ensures that the design is practical and scalable.

Overall, this project contributes to maximizing solar energy harvest, reducing manual labor, and promoting sustainable energy management through smart technology integration.

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