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Arduino Based Solar Tracking System with Automatic Wiper Mechanism

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ABSTRACT —

Solar panels are widely used in renewable energy systems but often suffer from inefficiencies due to fixed positioning and accumulation of dust and debris, especially during rainy seasons. In this project, a smart system has been developed using Arduino Uno, two LDR sensors for dynamic solar tracking, a water sensor for rain detection, and two servo motors — one for tilting the solar panel and another for the wiper mechanism. The system automatically aligns the solar panel towards the highest light intensity and activates the cleaning wiper during rain, thus maintaining panel efficiency without manual intervention. This work aims to maximize solar energy capture while reducing maintenance efforts and ensuring the durability of the panel. Potential future enhancements include the addition of IoT monitoring and dual-axis tracking for even greater efficiency.

Keywords— ***Solar tracking, Solar panel cleaning, Arduino Uno, LDR sensors, Servo motor control, Water sensor, Renewable energy system, Automation.***

I. INTRODUCTION

The growing demand for renewable energy solutions has led to widespread adoption of solar panels. Despite their advantages, solar panels' efficiency can be heavily impacted by two main factors: suboptimal sun exposure throughout the day and the accumulation of debris, dust, or water on their surfaces.

Fixed solar panels are unable to track the sun's movement, leading to reduced power output during non-peak hours. Furthermore, rainwater residue and accumulated dust layers can block sunlight and reduce efficiency by up to 20-30% if not cleaned promptly.

Furthermore, rainwater residue, dust, and bird droppings can accumulate on solar panels, blocking sunlight and reducing efficiency by up to 20-30% if not cleaned promptly. Traditional cleaning methods are manual and labor-intensive, often leading to inconsistent cleaning schedules.

Automatic solar tracking and cleaning systems offer a significant solution by ensuring maximum sunlight exposure and maintaining panel cleanliness. Automation reduces dependency on manual intervention, improves energy capture rates, and extends the lifespan of the solar panels.

This project proposes an affordable and efficient design using Arduino Uno, LDRs for tracking, a water sensor for rain detection, and servo motors for mechanical control. The integration of automatic tracking and cleaning mechanisms ensures optimal performance of the solar panels throughout the day and under different weather conditions.

II. A REVIEW OF EXISTING SOLAR

TRACKING AND CLEANING SYSTEMS

Various methods have been proposed to address solar panel efficiency challenges. Traditional dual-axis tracking systems offer maximum efficiency but involve high installation and maintenance costs, making them unsuitable for small-scale or residential projects.

Manual cleaning processes are labor-intensive and irregular, leading to performance degradation. Automatic robotic cleaning systems have emerged but are highly costly and complex to install.

Several low-cost solar trackers have been built using Arduino microcontrollers and Light Dependent Resistors (LDRs) for basic sun tracking functionalities. While these systems provide an affordable alternative, most designs focus solely on tracking and fail to incorporate automatic cleaning, particularly during rain — a major factor affecting real-world solar panel performance.

Recent studies highlight that even minor dust accumulation can reduce solar panel efficiency by 20–30%, emphasizing the urgent need for an integrated, self-maintaining system. Despite technological advancements, a gap remains for a low-cost, lightweight, and self-sufficient mechanism that simultaneously addresses dynamic tracking and cleaning.

The innovation in our project lies in the integration of a rain-activated wiper mechanism alongside dynamic solar tracking using Arduino Uno. This dual-functionality approach presents a complete, cost-effective, and self-sustaining solution for enhanced solar energy systems, particularly suited for small to medium-scale deployments where cost and simplicity are critical.

Wearable posture correction belts are another alternative available. They feel when one is slouching and provide vibrational cues to transition to better posture. Tracking of posture is even included using smartphone technology on some models. But extended usage will be discomforting, and the relatively costly nature of high-quality models is still a point preventing mass application.

III. System Design

The solar tracking and automatic cleaning system is designed to optimize the performance and maintenance of solar panels through automation. This section provides an overview of the architecture, hardware components, and circuitry required to operate the system effectively.

A. Overall Architecture

The system consists of two key modules working in tandem: the **Solar Tracking Module** and the **Automatic Cleaning Module**. Both modules are managed by an **Arduino Uno** microcontroller, which processes inputs from sensors and controls actuators accordingly.

Solar Tracking Module: This module ensures that the solar panel is always facing the direction with the most sunlight. It uses two **LDR (Light Dependent Resistor)** sensors positioned on opposite sides of the panel. These sensors measure the light intensity from two directions, and based on the values, the **Arduino** adjusts the position of the solar panel using a **large servo motor** to maintain the optimal angle for sunlight capture.

Automatic Cleaning Module: This module helps maintain the efficiency of the solar panel by cleaning it when necessary. A **water sensor** continuously monitors for rain. When rain is detected, the **Arduino** activates a **SG90 servo motor** connected to a wiper, which sweeps across the solar panel to remove any accumulated rainwater and debris.

B. Hardware components

The system employs several essential hardware components that enable the tracking and cleaning functions to work efficiently.

The system's central processing unit is the Arduino Uno microcontroller board. The open-source platform was chosen because of the simplicity of coding, small size, and sufficient processing capability to perform sensor data acquisition, solar tracking and wiper algorithm.

Fig 1. Arduino Uno microcontroller board.

Two LDRs are used to detect the intensity of sunlight. These sensors help the system determine which side of the solar panel is receiving more sunlight.

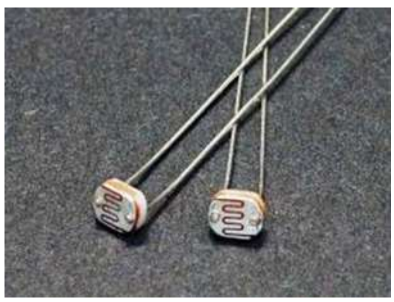


Fig 2. Light Dependent Resistor (LDR)

Water sensor detects the presence of rainwater on the panel and helps trigger the cleaning mechanism when it detects rain, ensuring the solar panel remains clear for optimal energy capture.

Fig. 3. Water Sensor

MG90S Micro Digital Servo Motor is used to adjust the angle of the solar panel based on the light intensity detected by the LDR sensors.

Fig. 4. MG90S Micro Digital Servo Motor

A SG90 Servo Motor is used to operate the wiper mechanism that sweeps across the panel when rain is detected

Fig. 5. SG90 Servo Motor

For gathering light and producing electricity, there is a solar panel, it is also the primary object of this project.

Fig. 6. Solar Panel

A. Circuitry and Connections

This section describes how the hardware components are connected together to form a functional circuit for the solar tracking and cleaning system.

1. **LDR Sensors**: The two LDR sensors are connected to the analog input pins A0 and A1 on the **Arduino Uno**. These sensors are wired with pull-down resistors to ensure correct voltage readings. The sensors measure the light intensity from opposite directions, and the **Arduino** compares their values to determine which direction the solar panel should face.

2. **Water Sensor**: The water sensor is connected to the **A2** analog input pin on the **Arduino**. This sensor detects the presence of rainwater on the solar panel and sends an input signal to the Arduino.

3. **Large Servo Motor**: The large servo motor is connected to the **D9 PWM pin** on the **Arduino Uno**. This motor is used to tilt the solar panel to the optimal angle based on the sunlight intensity detected by the LDR sensors.

4. **SG90 Servo Motor**: The SG90 servo motor is connected to the **D6 PWM pin** on the **Arduino Uno**. This motor is responsible for activating the wiper mechanism during rain, ensuring that the panel remains clean.
5. **Power Supply**: The **9V battery** is connected to the **Vin** and **GND** pins of the **Arduino Uno**. The system can also be powered via a USB adapter. Optionally, a **relay** can be included in the circuit to switch the power on/off for safety reasons when dealing with higher-powered servos.

After completing the sweep, the servo returns the wiper to its initial resting position.

After the cleaning cycle, the system resets itself and continues monitoring for any further rain events, ensuring the panel remains clean and efficient.

IV. Working

Upon system startup, the Arduino microcontroller initializes all connected sensors (Light Dependent Resistors and water sensor) and actuators (servo motors). It then continuously monitors environmental conditions to control the solar panel's orientation and maintain its cleanliness. The working mechanism can be divided into two main parts.

Two Light Dependent Resistors (LDRs) are positioned on either side of the solar panel to detect the intensity of sunlight from different directions. The Arduino continuously reads the analog voltage values from both LDRs, which are directly proportional to the intensity of incident light.

The microcontroller compares the light intensity values from the left and right LDRs:

If the left LDR detects higher light intensity than the right, it indicates that the sun is more towards the left side. Consequently, the Arduino commands the large servo motor to slightly tilt the solar panel towards the left to align it perpendicular to the sunlight.

Conversely, if the right LDR measures greater light intensity, the servo motor rotates the panel towards the right.

If both LDRs report approximately equal intensity values (within a predefined tolerance), the panel is considered optimally aligned and remains stationary. This real-time adjustment mechanism ensures that the solar panel continuously follows the sun's path across the sky, maximizing solar energy absorption throughout the day.

A water detection sensor mounted on or near the panel surface monitors for the presence of rain or water droplets. It outputs a signal to the Arduino when moisture is detected.

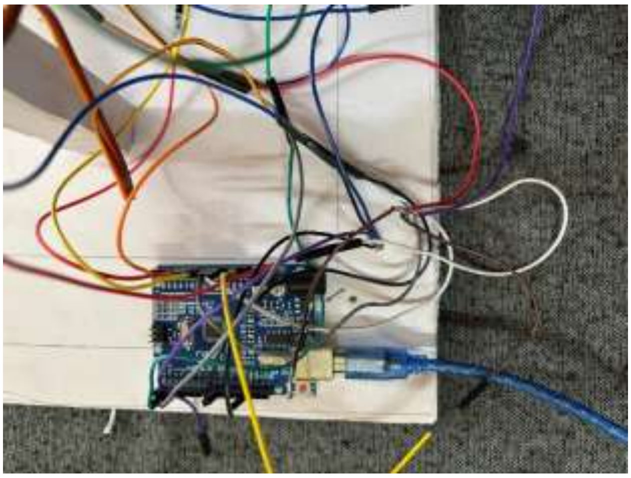
Upon detection of water:

The Arduino immediately triggers the SG90 servo motor connected to a wiper mechanism.

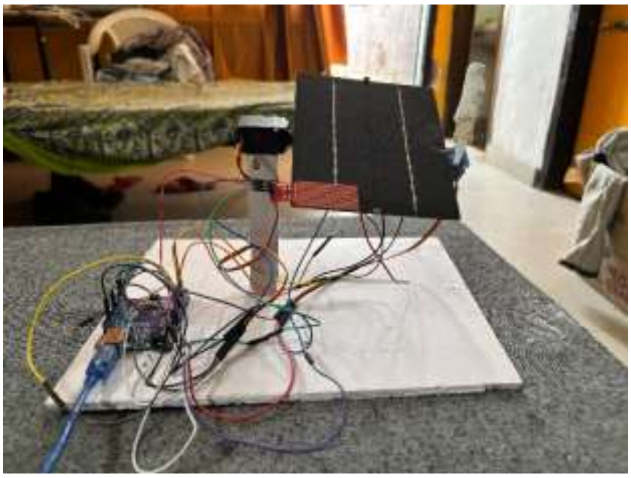
The servo motor moves the wiper blade across the surface of the solar panel in a sweeping motion to clear away rainwater, dust, or any debris.

V. Results

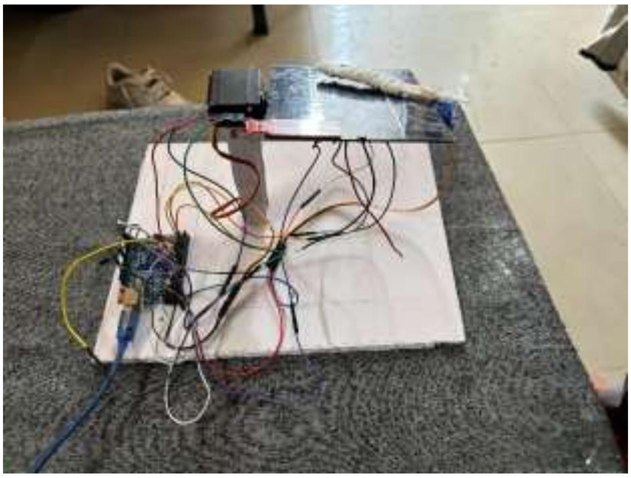
Thus, we successfully developed a prototype system that automatically tracks the sun's movement and maintains the cleanliness of the solar panel surface. The system used real-time light intensity differences to adjust the panel's orientation, ensuring optimal sun tracking throughout the day.



During rain simulations using water spray, the water sensor accurately detected moisture, triggering the wiper mechanism to automatically clear the panel surface. The system effectively maintained both the orientation and cleanliness of the panel, resulting in noticeably higher power output compared to a static and uncleaned panel. Over several consecutive days of testing, the system operated reliably without any manual resetting, demonstrating its robustness and practical effectiveness.



The combination of these features not only enhanced the overall performance of the solar panel but also reduced the need for manual maintenance. This makes the system a practical solution for increasing the longevity and energy output of solar installations, especially in environments with variable weather conditions.



VI. Conclusion

This project successfully developed a fully autonomous solar tracking and cleaning system using Arduino Uno, LDR sensors, a water sensor, and servo motors. The system improved solar panel efficiency by ensuring maximum sunlight exposure and maintaining a clean panel surface during rain.

By offering a low-cost, easy-to-implement solution, this project contributes to making renewable energy systems more practical and efficient for residential and small-scale users.

Future enhancements may include dual-axis tracking, integration of environmental monitoring sensors, IoT-based data logging, and solar-powered battery charging to make the system even more sustainable.

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