



DUAL AXIS SOLAR TRACKING SYSTEM

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ABSTRACT- By constantly monitoring the sun's location, the Dual Axis Solar Tracking System with Arduino is a clever and effective way to optimize solar energy production. One of the most plentiful and sustainable energy sources accessible today is solar energy. Nevertheless, because traditional solar panels are set at a specific angle, their capacity to effectively absorb sunlight throughout the day is limited. Fixed solar panels receive less sunlight for a large part of the day because to the sun's seasonal variations in elevation and movement from east to west. In order to get over this restriction, a dual axis solar tracking system was created, which automatically modifies the solar panel's position in two directions to maximize exposure to sunlight.

The solar panel in this system travels along two axes: vertical (elevation) and horizontal (azimuth). The solar panel can follow the sun's path from sunrise to sunset and adapt to seasonal variations thanks to its dual movement. The system measures the amount of sunshine by using light sensors like Light Dependent Resistors (LDRs). To detect the difference in light, these sensors are positioned at various points around the solar panel. The system identifies the sun's direction and modifies the display when one sensor detects more light than the others.

Keywords: Dual Axis Solar Tracking System, Arduino Uno, Solar Panel, LDR Sensors, Servo Motor, Renewable Energy, Solar Tracking, Energy Efficiency, Automatic Solar Tracker, Microcontroller, Sustainable Energy

I. INTRODUCTION

The Arduino Uno, which serves as the project's brain, controls the whole system. After processing the inputs from the LDR sensors, the Arduino transmits control signals to the motors. The solar panel is rotated both horizontally and vertically using servo motors or DC motors. To effectively regulate the motor activity, a motor driver may also be utilized. To guarantee optimal solar energy absorption, the Arduino continually analyzes sensor data and automatically modifies the panel position.



Compared to fixed solar panels, the dual axis solar tracking system has several benefits. By keeping ideal alignment with the sun, it may boost solar energy efficiency by about 30% to 40%.

II. OBJECTIVES

How To Increase Solar Energy Production

- To Boost the Efficiency of Solar Panels
- To Automatically Track Sun Movement
- To Boost Power Production
- To Lower Losses of Energy
- To Deliver Reliable Energy Production
- To Boost Seasonal Efficiency

III. SYSTEM OVERVIEW

- By continually aligning a solar panel with the sun's position in both horizontal (east–west) and vertical (north–south) directions, a dual-axis solar tracking system utilizing Arduino is a sophisticated solar energy system intended to maximize power output. In contrast to single-axis tracking, this technique guarantees that the solar panel stays perpendicular to the sun's beams all day long and in all seasons, greatly increasing efficiency. The illustration you supplied displays
- a complete setup consisting of a solar panel, multiple LDR sensors, an Arduino (microcontroller), servo motors, and additional modules such as data storage, data logger, and output display. When a relay is activated, the connected appliance turns ON, and when the relay is deactivated, the appliance turns OFF.



Fig.1- System Design

At the top of the system is the solar panel, which is the main energy-generating component. It converts solar radiation into electrical energy using photovoltaic cells. The amount of energy generated depends on how directly sunlight strikes the panel, which is why continuous alignment with the sun is important. In this dual-axis system, the panel is mounted on a movable structure that can rotate in two directions with the help of motors.

The system uses four LDR (Light Dependent Resistor) sensors, typically arranged in a cross or quadrant configuration around the solar panel. These sensors detect the intensity of sunlight from different directions. Each LDR changes its resistance based on the light falling on it. When sunlight is unevenly distributed among the sensors, it indicates that the panel is not properly aligned with the sun. The difference in resistance values is converted into voltage signals and sent to the Arduino.

IV. HARDWARE COMPONENTS

- **Arduino Uno**

The Arduino Uno plays a central role in the Dual Axis Solar Tracking System by acting as the brain of the entire setup. It is responsible for processing signals received from sensors and controlling the movement of servo motors to track sunlight efficiently in both horizontal and vertical directions. In this system, four Light Dependent Resistors (LDRs) are connected to the analog input pins of the Arduino Uno. These sensors are positioned in four directions East, West, North, and South to detect sunlight intensity from multiple angles. The Arduino continuously reads analog voltage values from these LDRs and processes the data to determine which direction receives the maximum sunlight.

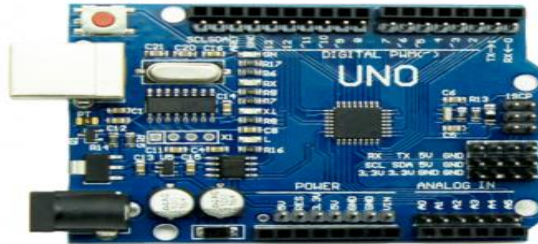


Fig.2- Arduino Uno

After collecting sensor data, the Arduino compares the voltage values from each LDR. If there is any variation in light intensity between the sensors, the Arduino identifies the direction where sunlight is strongest. It then calculates the difference between the LDR readings and checks whether the difference exceeds a predefined threshold value.

- **Solar Panel**

The Solar Panel is the main energy-generating component in the Dual Axis Solar Tracking System. Its primary function is to convert sunlight into electrical energy using the photovoltaic effect. In this project, the solar panel is mounted on a dual-axis structure controlled by servo motors, allowing it to follow the sun's movement throughout the day and maximize energy generation.

In the dual-axis solar tracking system, the solar panel continuously changes its orientation based on the position of the sun. The Arduino controller receives input from Light Dependent Resistors (LDRs) placed around the panel. When the sunlight intensity changes, the Arduino sends control signals to servo motors that rotate the solar panel along horizontal (East–West) and vertical (North–South) axes. As a result, the solar panel always remains perpendicular to the sun's rays, which increases the efficiency of power generation.



Fig.3- Solar Panel

- **LDR Sensors**

The LDR Sensor plays an important role in the Dual Axis Solar Tracking System by detecting sunlight intensity and providing input signals to the Arduino controller. LDR stands for Light Dependent Resistor, and its resistance changes according to the amount of light falling on its surface. When the light intensity increases, the resistance of the LDR decreases, and when the light intensity

decreases, the resistance increases. This property makes LDR sensors ideal for solar tracking applications.

In the dual-axis solar tracking system, four LDR sensors are used and placed at four different positions around the solar panel. These positions typically represent East, West, North, and South directions. The LDR sensors are connected to the analog input pins of the Arduino through voltage divider circuits. Each LDR works in combination with a resistor to generate varying voltage signals depending on the light intensity. These analog voltage values are continuously monitored by the Arduino microcontroller

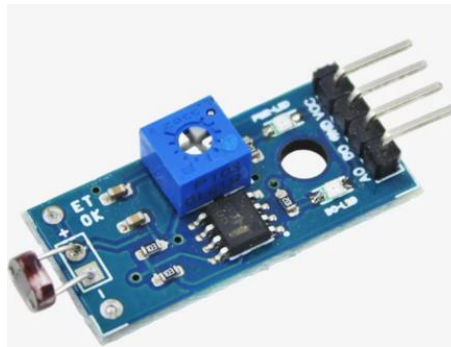


Fig.4- LDR Sensor

V. WORKING PRINCIPLE

The Dual Axis Solar Tracking System continually aligns the solar panel with the sun's position throughout the day in order to optimize solar energy output. An Arduino microcontroller, light-dependent resistors (LDRs), servo motors, a voltage regulator, a power supply unit, and additional electrical components installed on a printed circuit board (PCB) make up the majority of this system's circuit layout. Each part is crucial for detecting sunlight, processing information, and regulating the solar panel's movement in both horizontal and vertical directions. The Arduino microcontroller, which serves as the tracking system's brain, is in its center. Four LDR sensors positioned at various points around the solar panel continually send analog signals to the Arduino.

Circuit Diagram:

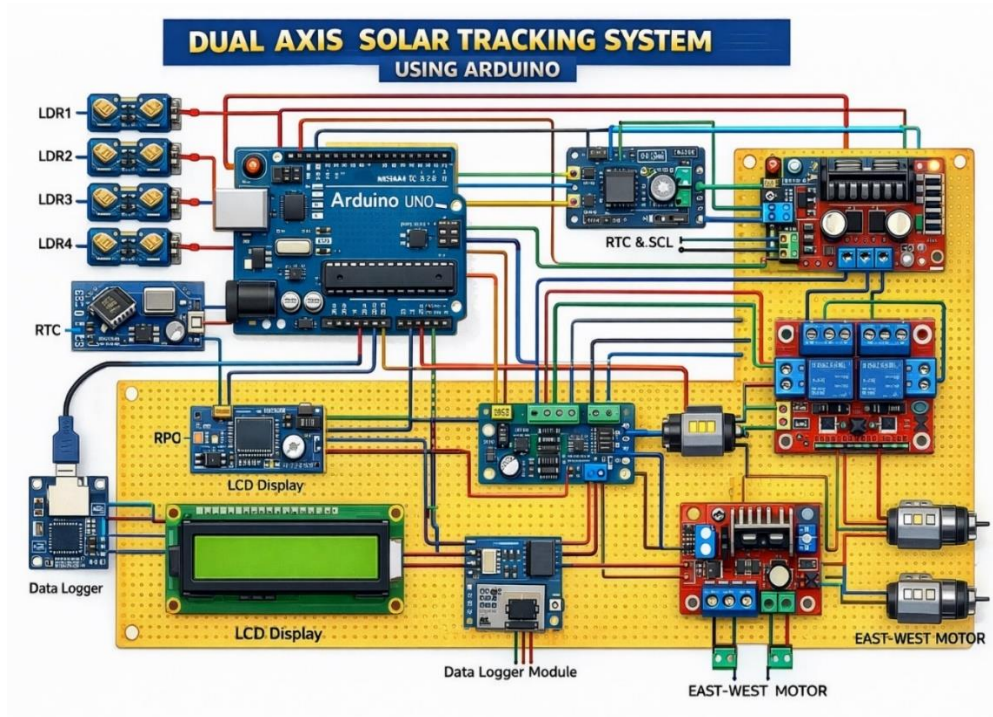


Fig.5- Circuit Diagram

These resistance variations are converted into voltage signals using voltage divider circuits connected to the PCB. The analog pins of Arduino read these voltage values and compare them to determine the brightest direction. The LDR sensors are mounted in a cross pattern on the PCB to detect sunlight from four directions: east, west, north, and south. When the sunlight intensity on one side becomes higher than the others, the Arduino processes the difference and sends control signals to the servo motors. This enables the system to move the solar panel toward the direction where maximum sunlight is available.

Two servo motors are used in this system to achieve dual-axis tracking. One servo motor controls horizontal movement (East-West direction), while the other controls vertical movement (North-South direction). These servo motors are connected to the PWM pins of the Arduino on the PCB. When Arduino sends PWM signals, the servo motors rotate to a specific angle, adjusting the position of the solar panel accordingly.

Flow Chart of the System:

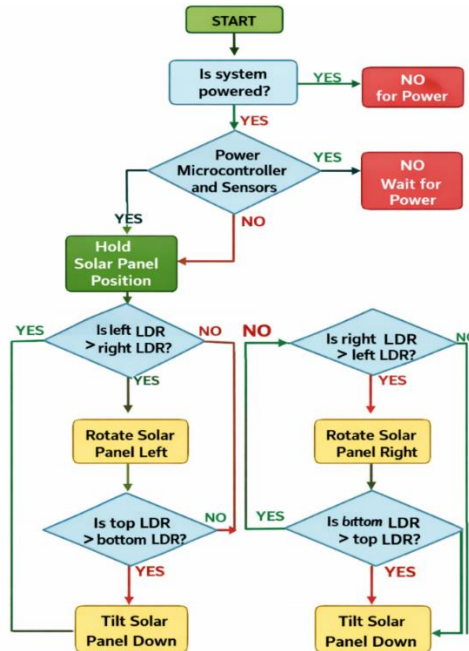


Fig.6- Flow Chart of the proposed system

The flow chart of the dual axis solar tracking system explains the step-by-step working of the system using a sequence of Yes/No decision-making processes. The operation begins with the START condition, where the system initializes all components including the Arduino Uno, sensors, and motors. The first decision in the flow chart checks whether the system is powered. If the answer is NO, the system remains in the waiting state until power is available. If the answer is YES, the system proceeds to the next stage where the microcontroller and sensors are powered and initialized. The next decision checks whether the microcontroller and sensors are working properly. If the answer is NO, the system waits for proper initialization and holds the solar panel position. This prevents unwanted movement of the panel and protects the system from malfunction. If the answer is YES, the system moves to the next stage where it holds the solar panel in its current position and begins analyzing sunlight conditions using the LDR Sensor sensors.

After initialization, the system checks the sunlight intensity using two horizontal LDR sensors placed on the left and right sides of the solar panel. The next decision in the flow chart checks whether the left LDR value is greater than the right LDR value. If the answer is YES, it means that more sunlight is falling on the left side of the panel. Therefore, the system commands the servo motor to rotate the solar panel towards the left direction. This movement ensures that the panel aligns with the maximum sunlight source. If the answer is NO, the system moves to the next decision. The next decision checks whether the right LDR value is greater than the left LDR value. If the answer is YES, it indicates that the sunlight intensity is higher on the right side.

Experimental Set up

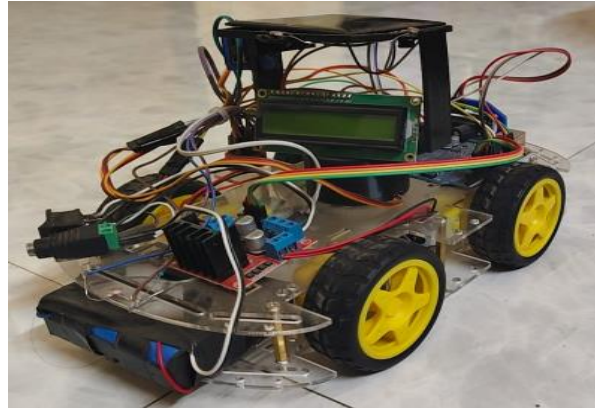


Fig.7- Experimental Set up

VI. RESULT AND DISCUSSION

When compared to a fixed solar panel, the Dual Axis Solar Tracking System's results demonstrate a notable improvement in power generation. The dual axis tracking technology generates increased power production throughout the day, particularly in the morning and evening when sunlight angles are constantly changing, according to the graphical depiction. The dual axis tracking system is shown by the green curve, which peaks at noon and performs better in low-angle sunlight. Because it cannot move with the sun, the fixed solar panel, represented by the orange curve, produces less electricity. The pie chart further

demonstrates performance improvement, where the dual axis system contributes about 60% of total power output, while the fixed panel provides only 40%. This indicates approximately 20–30% higher efficiency using solar tracking. Hence, the dual axis solar tracking system improves energy harvesting, increases efficiency, and maximizes solar panel utilization throughout the day.

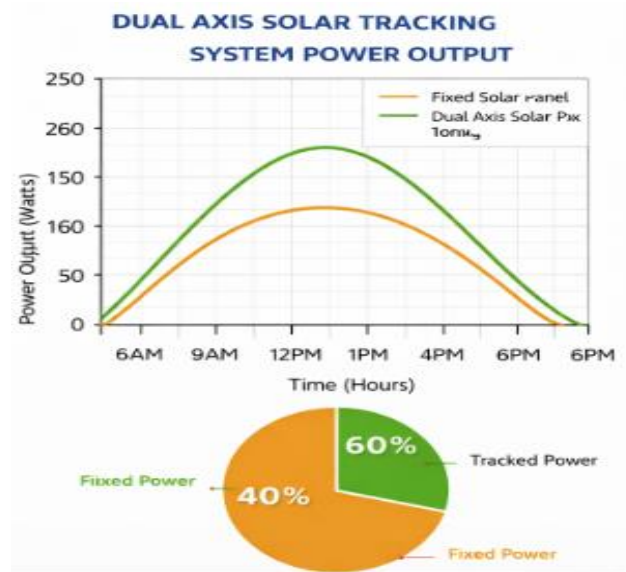


Fig.8- Result Analysis

The results show that solar power generation increases from morning to afternoon, reaching maximum output around midday. The battery voltage increases during charging and provides stable power to the ESP32 microcontroller and relay modules. The system maintained high efficiency (around 85–90%), ensuring reliable operation of home appliances controlled through the IoT platform.

VII. CONCLUSION

By continually monitoring the sun's position throughout the day, the Dual Axis Solar Tracking System is an effective and dependable way to maximize solar energy output. This method ensures maximum sunshine exposure at all times by adjusting the panel orientation in both horizontal and vertical directions, in contrast to traditional fixed solar panels. The system increases total energy efficiency by automatically detecting the greatest light intensity and moving the solar panel in accordance with it utilizing sensors, a microprocessor, and motor mechanisms.

In this work, the Arduino Uno interprets sensor data and manages the servo motors while Light Dependent Resistors (LDRs) detect the intensity of sunshine. The solar panel can be precisely aligned with the sun thanks to the motors' two-axis rotation. This automation lessens the need for physical labor and enhances energy production. The use of efficient power supply components, resistors, capacitors, and motor drivers ensures smooth and stable operation of the system.

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