ES116 Final Project
Dual Axis Solar Tracker

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***Abstract*—This paper describes a project that aims to build a dual-axis solar tracking system designed to improve the efficiency of solar panels by maintaining optimal alignment with the sun. Using Light Dependent Resistors (LDRs), an Arduino, and servo motors, the system detects light intensity and adjusts the panel's position accordingly. The setup utilizes Pulse Width Modulation (PWM) for motor control and implements a closed-loop feedback mechanism to ensure real-time accuracy. Results show improved energy capture over fixed panels, highlighting the system's potential for scalable solar applications.**

***Index Terms*—Solar Tracker, Dual Axis, Arduino, PWM, LDR, Renewable Energy, Control Systems**

I. Introduction

A. Motivation

Since the dawn of civilization, energy has been at the heart of human progress — from fire and steam to electricity and digital technology. In today's world, our lives revolve around energy more than ever. Amidst the growing demand for cleaner and more sustainable sources, solar energy has emerged as a transformative innovation. It offers a cleaner, decentralized, and renewable alternative, reshaping our relationship with the environment. We aim to maximize this source's efficiency through intelligent engineering.

B. Aim

By applying electrical engineering concepts like Sensors & Signal Conditioning, ADC, Microcontroller Logic, Control Systems, and PWM, we aim to build a technically sound and impactful dual-axis solar tracker to enhance solar panel efficiency.

C. Apparatus

- Solar panels [2]
- LDRs [4]
- 10k resistors [4]
- Arduino Uno
- SG90 servo motors [2]
- USB cable
- Breadboard
- Jumper wires

II. Theory Applied

A. Photoresistive Behavior of LDRs

LDRs show decreasing resistance as light intensity increases. This helps the system detect the sun's direction and reorient the solar panel.

B. Voltage Divider Rule

Using the voltage divider formula:

$$V_{out} = V_{in} \times \frac{R_{LDR}}{R_{LDR} + R_{fixed}}$$

This outputs a variable voltage into Arduino analog pins for processing.

C. Analog-to-Digital Conversion (ADC)

The Arduino's ADC converts the analog voltage (0–5V) into a digital value (0–1023), enabling accurate light intensity comparisons.

D. Pulse Width Modulation (PWM)

PWM controls the servo motor position via duty cycle modulation, allowing precise adjustments to the solar panel orientation.

E. Control Systems

A closed-loop control system with LDRs as input and servos as actuators:

- Input: Light data from LDRs
- Processing: Arduino compares values
- Output: PWM to servo motors
- Feedback: Continuous LDR monitoring

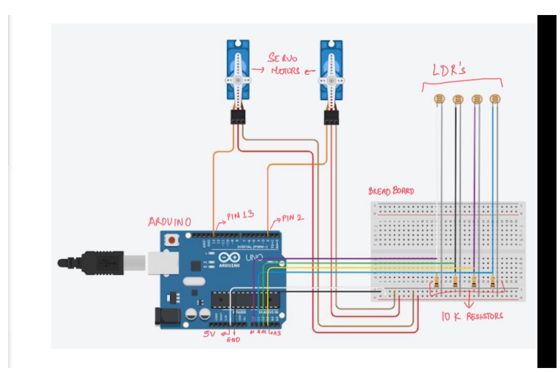

Fig. 1: Circuit Diagram of Dual Axis Solar Tracker

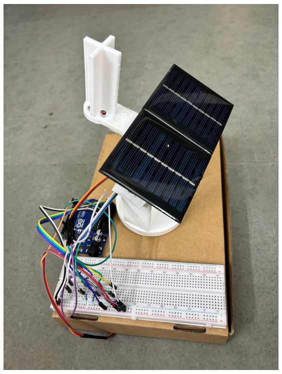

Fig. 2: Model of Dual Axis Solar Tracker

III. Results

Two control strategies were tested:

A. Method 1: Real-Time Differential Tracking

This approach continuously measures the light intensity values from multiple Light Dependent Resistors (LDRs) placed in a quadrant-like configuration. The system calculates the difference between paired sensor readings (e.g., left-right and top-bottom) to determine the direction of maximum light intensity, and adjusts the servo motors accordingly to realign the solar panel toward the sun. While this method enables a smooth and instantaneous response to changing light conditions, it is highly sensitive to slight variations in sensor readings. This often results in jittery or unstable servo movements, particularly under diffused lighting or when the sun is near its peak and when light intensity is nearly uniform across sensors.

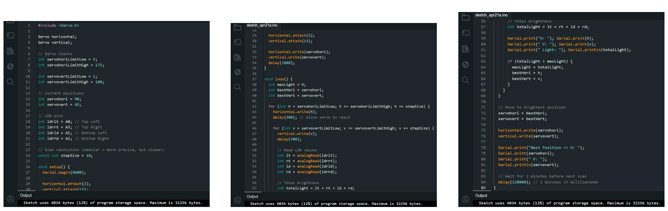

Fig. 3: Method 1 Code

B. Method 2: Full-Axis Scanning

This method involves scanning step-wise through the axes to find the optimal solar panel position for maximum light intensity. The system moves the servos across predefined horizontal and vertical angles, measuring light from all four Light Dependent Resistors (LDRs) at each position. The servo angles corresponding to the highest light intensity are then selected and the panel is adjusted accordingly. After each scan, the system waits for 2 minutes to conserve power and avoid unnecessary movement. While this method gives accurate and stable positioning, it is slower and less responsive to instantaneous changes in light.

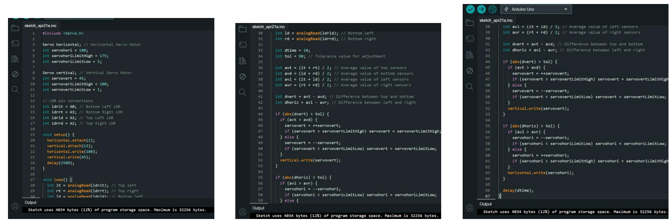

Fig. 4: Method 2 Code

C. Use Case Comparison

TABLE I: Comparison of Tracking Methods

Use Case	Recommended Method
Fast, continuous tracking	Method 1
Maximum light accuracy	Method 2
Stable, jitter-free output	Method 2
Short-term efficiency	Method 1
Battery-saving systems	Method 2

IV. Problems Faced

We initially employed MG90S servos, which resulted in persistent buzzing. Upon investigation, we identified that the Arduino's 5V output was likely unable to provide sufficient current for these motors. Replacing them with SG90 servos resolved the issue, leading to stable operation and consistent tracking behavior.

V. Conclusion

This project deepened our understanding of control systems and sensor integration. We gained practical experience in ADC, PWM, and servo motor control. Both tracking methods had unique benefits. Real-time tracking suited dynamic conditions, while scanning excelled in stable environments. The project demonstrated how hardware and software can cooperate for efficient, renewable energy solutions.

Acknowledgment

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References

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