PROJECT REPORT

on

Solar Tracker

Submitted To :
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Subject: Control System Lab
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CERTIFICATE

This is to certify that Sanshray Choudhary, Enrollment No. 00816412823, has completed the project "Solar Tracker" as part of the academic requirements for University School Of Information, Communication, and Technology, Guru Gobind Singh Indraprastha University, under the guidance of Dr. Shiv Ram Meena.

Date:

Signature:

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Dr. Shiv Ram Meena

DECLARATION

I, Sanshray Choudhary, Enrollment No. 00616412823, hereby declare that the project "Solar Tracker" is my original work and has not been submitted elsewhere for any other degree or diploma.

Date:

Signature:

- Sanshray Choudhary   00816412823
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Lastly, I am deeply grateful to my family for their unwavering support and encouragement. Their belief in me has always been a driving force behind my success.

ABSTRACT

This project presents the design and implementation of an automatic planting system using an Arduino Uno, a soil moisture sensor, a water pump, and a relay module. Unlike traditional manual irrigation methods, this system automates the watering process based on real-time soil moisture levels, ensuring optimal water usage and plant health. The soil moisture sensor continuously monitors the moisture content in the soil and sends data to the Arduino. When the moisture level falls below a predefined threshold, the Arduino activates the water pump through a relay to irrigate the soil. Once adequate moisture is restored, the pump is automatically turned off. Built with affordable and readily available components, this system offers a practical and efficient solution for small-scale agriculture, home gardening, and educational purposes.

CONTENT

INTRODUCTION

1.1 Background

With the global push towards sustainable and renewable energy sources, solar power has emerged as one of the most promising solutions to reduce dependence on fossil fuels. However, the efficiency of solar panels is significantly influenced by their orientation toward the sun. Fixed-position solar panels are unable to maintain an optimal angle to the sun throughout the day, resulting in sub-optimal energy generation. To address this, solar tracking systems have been developed to follow the sun's path, increasing exposure time and improving energy output. This project focuses on building a dual-axis solar tracker using affordable and readily available components like the Arduino Nano, servo motors, and light-dependent resistors (LDRs), allowing the solar panel to adjust both horizontally and vertically to track sunlight in real-time.

1.2 Objectives

- To design and implement a dual-axis solar tracker that continuously aligns a solar panel with the direction of maximum sunlight.
- To increase the efficiency of solar power collection compared to static panels.
- To develop a low-cost, scalable, and DIY-friendly tracking system using Arduino Nano and basic electronic components.
- To test and evaluate the effectiveness of the tracking system in improving sunlight exposure.
- To create a functional prototype that can be further enhanced for larger-scale or weatherproof applications.

Literature Survey

2.1 Previous Work

Solar tracking systems have been widely studied and implemented in both academic research and commercial applications. The most common types are single-axis and dual-axis trackers.

- Single-axis trackers allow movement along one direction (usually East-West), which helps to follow the sun's daily path.
- Dual-axis trackers, on the other hand, allow for vertical and horizontal adjustment, providing more precise tracking throughout the year and maximizing energy output.

Early systems were primarily mechanical or used predefined angular movement based on time, which lacked real-time adaptability. Later, systems evolved to include sensor-based methods using LDRs (Light Dependent Resistors) to detect sunlight intensity and microcontrollers like the Arduino to automate movement using servo or stepper motors.

Many studies have demonstrated that dual-axis trackers can improve energy efficiency by 20–40% compared to fixed panels. Researchers have also explored alternatives like using image processing, GPS-based tracking, and machine learning for smarter systems, but those approaches tend to be costlier and complex.

2.2 Key Findings

From the survey of existing designs and papers, several key findings were noted:

- Sensor-based systems using LDRs are cost-effective and work well in clear-sky conditions.
- Arduino-based platforms offer an ideal balance between simplicity and functionality, especially for educational and small-scale projects.
- While high-end trackers may use stepper motors for precision, servo motors provide a simple and sufficient solution for most lightweight solar panels.
- The use of four LDRs in a cross configuration yields accurate sun positioning by comparing light intensity differences along both axes.
- A major limitation in many models is the lack of weatherproofing and load-bearing capacity, making them unsuitable for full-scale deployment without further engineering.

This project builds upon these findings by using an Arduino Nano-based, dual-axis tracking mechanism controlled by four LDRs, aiming for low cost, ease of prototyping, and real-time adaptability.

METHODOLOGY

- The Solar Tracker system is made using a Arduino Nano, servo mounts, 2 Servos, and 4 LDR's

3.1 Design and Development

This project was developed using a structured engineering design process, involving conceptual planning, prototyping, hardware-software integration, and testing. The approach ensured systematic development and reliable performance of the solar tracking system.

3.1.1 Conceptual Design

The basic idea was to use four LDRs arranged in a cross formation to detect the sun's position. These sensors act as inputs to an Arduino Nano, which processes the light intensity differences to determine the direction of maximum sunlight. Two servo motors are used to align the solar panel in horizontal (X-axis) and vertical (Y-axis) directions.

The system was designed to be simple, energy-efficient, and cost-effective while retaining essential functionality for real-time solar tracking.

3.1.2 Prototyping

The prototype involved:

- Mounting the LDRs on a divider plate to reduce shadow interference.
- Placing the solar panel (or a placeholder for testing) on a dual-axis platform controlled by two servo motors.
- Using a breadboard setup for connecting resistors, LDRs, and power lines to the Arduino Nano.

Initial testing was done using artificial light sources to simulate sunlight and evaluate responsiveness.

3.1.3 Integration of Technologies

- LDRs were connected in voltage divider circuits with 10kΩ resistors and fed into four analog pins of the Arduino Nano.
- Servo Motors were connected to PWM-compatible digital pins to control movement.
- The Arduino Nano was programmed to continuously read sensor values and adjust the servo angles accordingly.
- A simple logic algorithm compared the light intensities and moved the panel until all LDR readings were balanced, indicating alignment with the light source.

3.1.4 Testing and Evaluation

Several tests were conducted under different lighting conditions:

- Daylight simulation indoors with torch/LED light
- Outdoor sunlight tracking
- Response time and alignment accuracy

The system successfully followed the light source, with both horizontal and vertical servos adjusting in real time. Results showed improved alignment compared to a fixed panel mockup, validating the concept.

3.2 Arduino Code Implementation

The Arduino code was developed using the Arduino IDE and included:

- Initialization of analog and PWM pins
- Reading and averaging LDR values
- Decision logic for servo adjustment based on differential light intensities
- Angle limits to prevent over-rotation of servos
- Delays and smoothing to prevent jitter

The code allows for continuous adjustment with a short delay, ensuring a balance between responsiveness and stability.

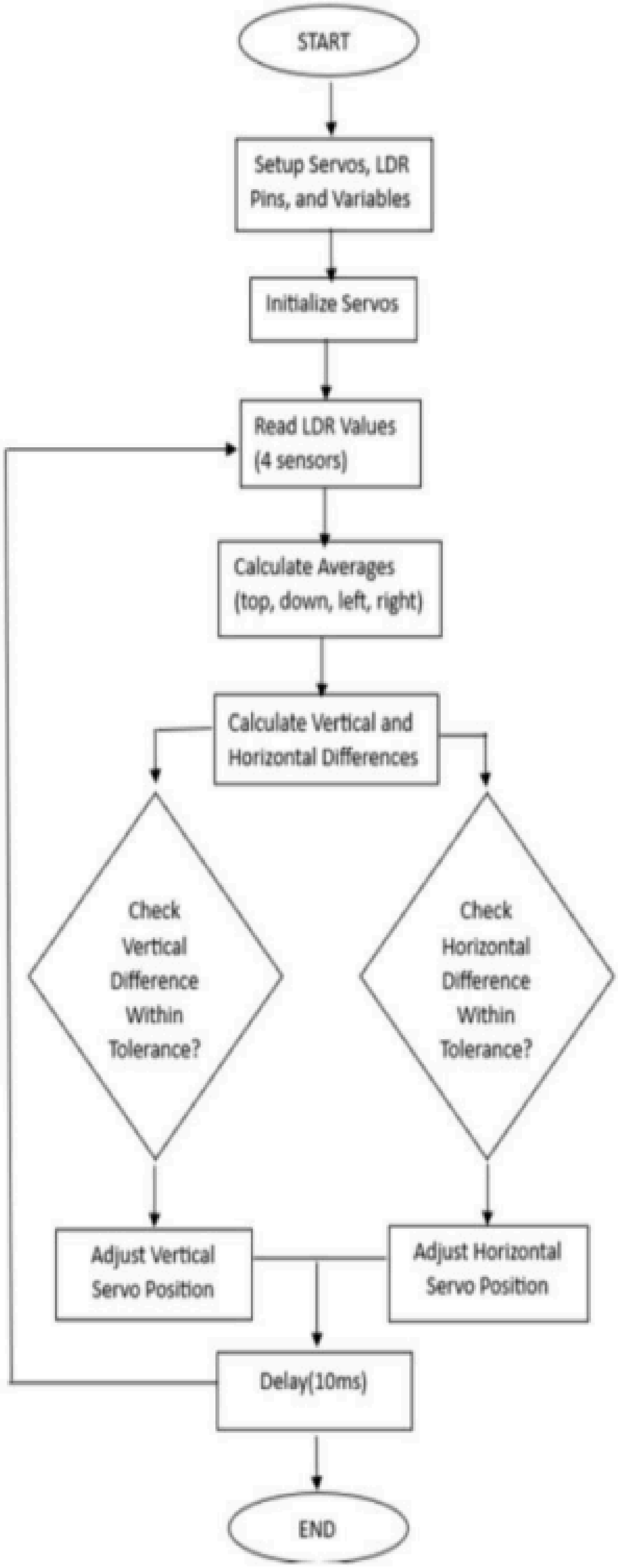
3.2 Arduino Code

```
#include <Servo.h>

Servo servoX; // Horizontal movement
Servo servoY; // Vertical movement

int ldrTopLeft = A0;
int ldrTopRight = A1;
int ldrBottomLeft = A2;
int ldrBottomRight = A3;

int servoXPos = 90;
int servoYPos = 90;

int tolerance = 50; // Sensitivity to light difference

void setup() {
  servoX.attach(9);
  servoY.attach(10);

  servoX.write(servoXPos);
  servoY.write(servoYPos);

  Serial.begin(9600);
}

void loop() {
  int tl = analogRead(ldrTopLeft);
  int tr = analogRead(ldrTopRight);
  int bl = analogRead(ldrBottomLeft);
  int br = analogRead(ldrBottomRight);

  int topAvg = (tl + tr) / 2;
  int bottomAvg = (bl + br) / 2;
  int leftAvg = (tl + bl) / 2;
  int rightAvg = (tr + br) / 2;

  int verticalDiff = topAvg - bottomAvg;
  int horizontalDiff = leftAvg - rightAvg;
```

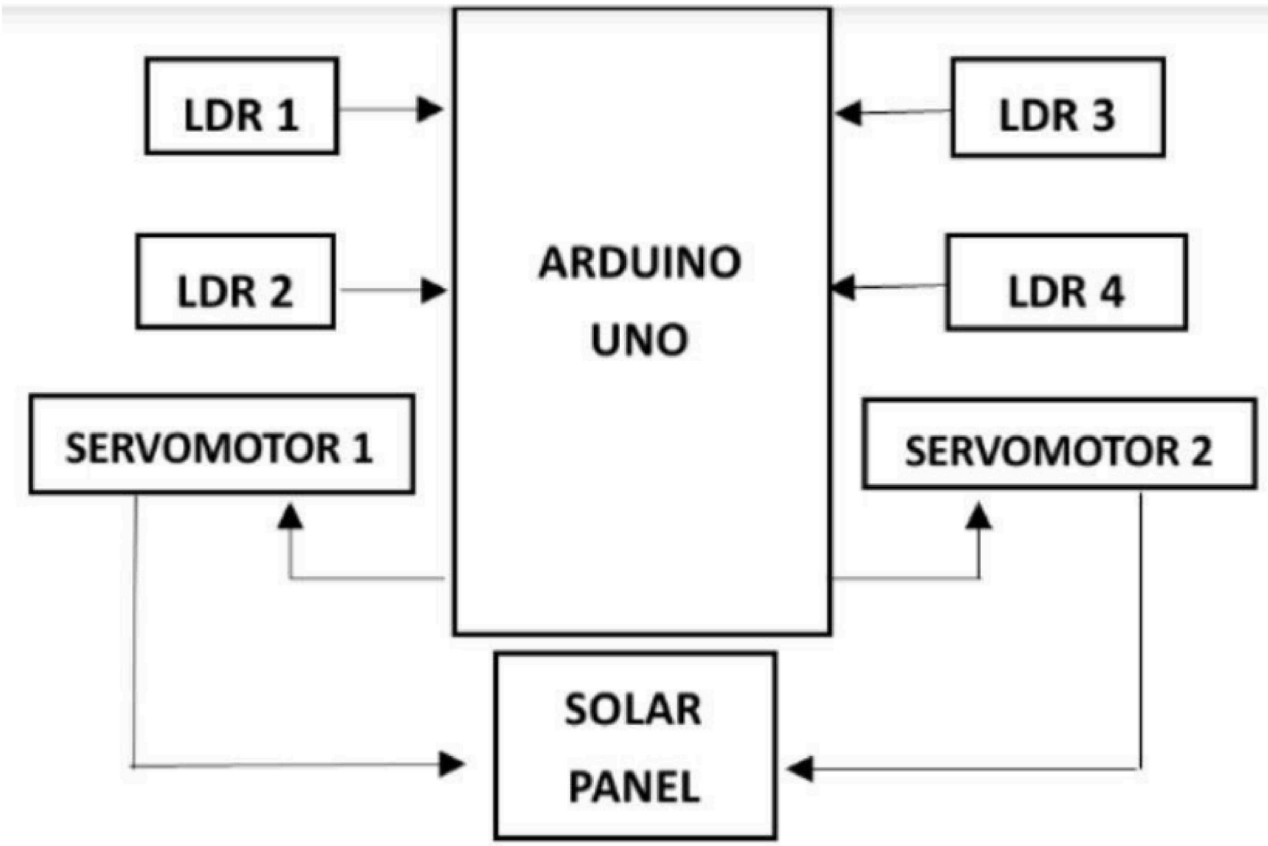
3.2 Arduino Code

```
// Vertical axis
 if (abs(verticalDiff) > tolerance) {
 if (verticalDiff > 0 && servoYPos < 180) {
 servoYPos++;
 } else if (verticalDiff < 0 && servoYPos > 0) {
 servoYPos--;
 }
 servoY.write(servoYPos);
 }

 // Horizontal axis
 if (abs(horizontalDiff) > tolerance) {
 if (horizontalDiff > 0 && servoXPos < 180) {
 servoXPos++;
 } else if (horizontalDiff < 0 && servoXPos > 0) {
 servoXPos--;
 }
 servoX.write(servoXPos);
 }

 delay(100); // Slow down movement and reduce jitter
}
```

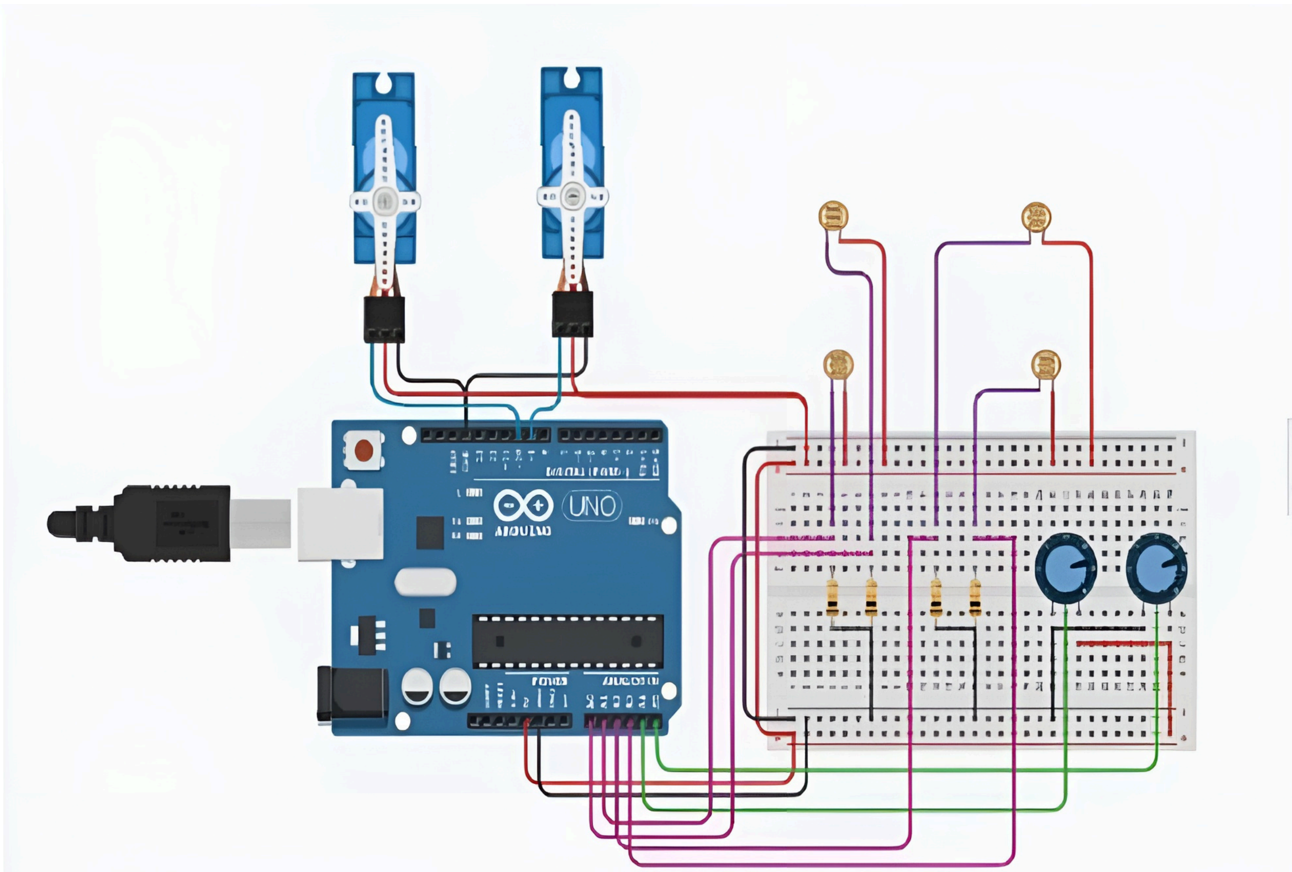
3.3 Flow Chart



3.4 Block Diagram



3.5 Circuit Diagram



FEATURES AND SPECIFICATIONS

- The dual-axis solar tracker has been designed with key functional features to maximize its ability to follow the sun accurately and autonomously. The system combines hardware and software to achieve precise alignment using real-time sensor feedback and motion control.

4.1 Dual-Axis Solar Tracking Mechanism

The system enables two degrees of movement:

- Horizontal (Azimuth) Tracking – Adjusts the panel side-to-side (East to West).
- Vertical (Altitude) Tracking – Adjusts the tilt of the panel (Up and Down).

This dual-axis movement allows the tracker to maintain optimal orientation with respect to the sun's changing position throughout the day and across seasons, significantly enhancing solar energy absorption.

4.2 Light Detection using LDR Sensors

Four Light Dependent Resistors (LDRs) are placed at the corners of a cross-shaped divider. Each LDR senses the intensity of sunlight falling in its direction. By comparing the values from the four sensors, the Arduino Nano calculates the direction of maximum sunlight and adjusts the panel accordingly.

- Sensor Arrangement: North, South, East, West positions
- Resolution: Sensitive to subtle changes in light intensity
- Noise Handling: Basic averaging and threshold logic used in code

4.3 Real-Time Servo Control

Two servo motors drive the tracking mechanism:

- Servo 1 (Horizontal axis)
- Servo 2 (Vertical axis)

These are controlled using PWM signals from the Arduino Nano. The servos adjust incrementally based on differential readings between LDR pairs, enabling smooth and accurate movement.

4.4 Efficiency and Accuracy Considerations

- Response Time: The system responds within 1–2 seconds to noticeable light direction changes.
- Power Efficiency: The system consumes minimal power and can operate from a small power bank or solar-charged battery.
- Scalability: Can be adapted for larger panels or different types of sensors.
- Portability: Lightweight and compact, ideal for educational or prototype demonstrations.

COMPONENTS USED

- The solar tracker is built using a set of affordable, commonly available electronic and mechanical components. Each component plays a specific role in enabling sensor input, control logic, and mechanical movement.

- **5.1 Arduino Nano**
  - Type: Microcontroller board based on the ATmega328P
  - Role: Central control unit that reads LDR inputs, processes logic, and sends PWM signals to the servo motors
  - Advantages: Compact size, low power consumption, USB programmable, ideal for embedded systems
- **5.2 LDR Sensors (4 Units)**
  - Type: Light Dependent Resistors
  - Role: Detect the intensity of sunlight in four directions (N, S, E, W)
  - Working: Resistance decreases with increasing light intensity, forming voltage dividers with resistors
  - Configuration: Arranged in a cross formation for differential detection
- **5.3 10kΩ Resistors (4 Units)**
  - Type: Fixed resistors
  - Role: Paired with each LDR to form voltage divider circuits
  - Purpose: Converts light intensity into a measurable voltage level for analog input pins on the Arduino
- **5.4 Servo Motors (2 Units)**
  - Type: Standard hobby servo motors (SG90 or MG90S)
  - Role: Provide motion along horizontal and vertical axes
  - Control: Angle control via PWM signals from Arduino
  - Torque: Sufficient for small panels or lightweight platforms
- **5.5 Servo Mount and Frame**
  - Type: Acrylic or wooden mount structure
  - Role: Mechanically supports the servos and the solar panel (or light sensor plate)
  - Features: Dual-axis pivot design for full range motion
- **5.6 Miscellaneous Components**
  - Breadboard: For prototyping the circuit without soldering
  - Jumper Wires: For making flexible connections between components
  - Power Source: USB or 5V regulated supply, optionally from a solar-charged battery or power bank

CONCLUSION

- The Solar Tracker system effectively demonstrates real-time solar position detection and dual-axis panel alignment using LDR sensors and servo motors. By continuously monitoring light intensity from four directions and adjusting its orientation accordingly, the system showcases automation in renewable energy optimization

Key Achievements

- Implemented an autonomous dual-axis tracking mechanism using two servo motors.
- Integrated four LDR sensors arranged for precise sunlight direction detection.
- Designed a responsive system that continuously adjusts orientation for maximum light exposure.
- Developed an efficient and low-cost prototype using Arduino Nano and basic electronic components.
- Achieved improved alignment compared to static panels, indicating potential for enhanced solar power generation.

Limitations and Future Scope

- The current model is suited for small-scale panels; further mechanical support is needed for larger panels.
- LDRs can be affected by weather conditions; integration of more advanced light or sun position sensors can improve accuracy.
- Power optimization and energy self-sufficiency (running the system entirely on solar) can be explored.
- Incorporation of real-time data logging, wireless connectivity (e.g., Wi-Fi or Bluetooth), and IoT integration can expand its use in smart solar systems.

Final Thoughts

- The Solar Tracker system serves as a working prototype demonstrating intelligent sun tracking using simple and affordable components. With enhancements in sensor precision, scalability, and connectivity, this concept can be developed into an effective solution for sustainable and smart solar energy harvesting in both residential and industrial settings.

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