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Sun Tracking Solar Panel Using Arduino

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Abstract: *A Sun Tracking Solar Panel system is designed to improve the efficiency of solar energy generation by continuously aligning the solar panel with the direction of maximum sunlight. Traditional fixed solar panels receive sunlight at varying angles throughout the day, resulting in reduced energy output. This project utilizes an Arduino-based control system to automatically track the sun's movement from east to west.*

The system employs light-dependent resistors (LDRs) to detect the intensity of sunlight and determine the optimal orientation of the panel. Based on the sensor inputs, the Arduino microcontroller processes the data and drives servo or DC motors to adjust the panel's position accordingly. This real-time tracking mech-anism ensures that the panel remains perpendicular to sunlight, thereby maximizing energy absorption.

The proposed system is cost-effective, energy-efficient, and suitable for both small-scale and large-scale solar applications. Experimental results demonstrate a significant increase in power output compared to stationary panels. This project highlights the potential of embedded systems in enhancing renewable energy technologies and contributes to sustainable power generation.

Keywords*:* Solar Energy, Sun Tracking System, Arduino, Renewable Energy, Light Dependent Resistor (LDR), Servo Motor, Embedded Systems, Automatic Solar Tracker, Photovoltaic System, Energy Efficiency Microcontroller, Sustainable Energy, Real-Time Tracking, Dual Axis / Single Axis Tracking

I. INTRODUCTION

The increasing demand for energy and the depletion of non-renewable resources have led to a growing interest in renewable energy sources, particularly solar energy. Solar power is abundant, clean, and environmentally friendly, making it one of the most promising alternatives to conventional energy sources. However, the efficiency of solar panels largely depends on their orientation with respect to the sun. Fixed solar panels are limited in their ability to capture maximum sunlight throughout the day, as the sun's position continuously changes from east to west.

To overcome this limitation, a Sun Tracking Solar Panel system is developed to automatically adjust the position of the solar panel in accordance with the movement of the sun. This project utilizes an Arduino microcontroller to control the tracking mechanism. Light Dependent Resistors (LDRs) are used as sensors to detect sunlight intensity from different directions. Based on the input from these sensors, the Arduino processes the data and drives motors to orient the panel toward the direction of maximum light intensity.

The implementation of a sun tracking system significantly enhances the efficiency of solar energy collection compared to stationary systems. By ensuring that the panel remains aligned with the sun, more energy can be harvested throughout the day. This project demonstrates the application of embedded systems in renewable energy solutions and provides a cost-effective method to improve solar panel performance.

II. LITERATURE SURVEY

Solar energy is one of the most promising renewable energy sources, but its efficiency largely depends on the orientation of photovoltaic (PV) panels. Traditional fixed solar panels fail to capture maximum sunlight throughout the

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day due to the continuous movement of the sun. To overcome this limitation, researchers have developed sun tracking systems using Arduino, which automatically adjust panel orientation for maximum energy absorption.

Several studies have focused on the design and implementation of dual-axis solar tracking systems. A study by Abd Wahid et al. (2023) proposed a system using four Light Dependent Resistors (LDRs) and two servo motors controlled by an Arduino microcontroller. The system adjusts both horizontal and vertical angles, ensuring maximum sunlight capture and improved efficiency compared to static systems .

Similarly, Naif (2020) developed an Arduino-based dual-axis tracker using five LDR sensors and linear actuators. The research highlighted that dual-axis tracking systems provide higher efficiency than both fixed and single-axis systems due to their ability to track the sun in multiple directions .

Another study by Paestum and Santikos (2023) emphasized that solar panels produce maximum energy when positioned perpendicular to sunlight. Their work proposed a prototype sun tracker to address inefficiencies in fixed installations, demonstrating the importance of dynamic orientation systems .

Research by Arjo et al. (2025) introduced an advanced Arduino-based system integrating sensors such as an RTC module and INA219 for real-time tracking and monitoring. Their experimental results showed an improvement of 6–12% in energy output compared to static panels, validating the effectiveness of automated tracking systems .

Halim and Tiron (2022) developed a solar tracker using LDR sensors and servo motors, where the Arduino controller rotates the panel toward the highest light intensity. Their findings indicated that such systems significantly increase power generation and reduce the need for manual adjustment

Recent work by Saini et al. (2025) demonstrated a voltage-based dual-axis tracking system, achieving up to 38.5% higher energy efficiency than fixed panels. The study highlighted the advantages of low-cost Arduino-based solutions for small-scale and off-grid applications .

Additionally, comparative studies have explored intelligent techniques such as machine learning for predicting solar position and improving tracking accuracy, indicating future advancements in smart solar

III. SCOPE OF THE PROJECT

The Sun Tracking Solar Panel Using Arduino project focuses on developing an automated system that aligns a solar panel with the sun to maximize energy output. It uses LDR sensors to detect sunlight intensity and an Arduino to control panel movement. The system adjusts the panel position in real time using motors. This increases efficiency compared to fixed solar panels. It is suitable for small-scale and educational applications. The design is cost-effective and easy to implement. It can be expanded for larger systems with advanced features. Overall, the project promotes better utilization of renewable energy.

I. Functional Scope

• Detects sunlight intensity using LDR sensors.
• Automatically tracks the sun's position.
• Controls motors to adjust panel orientation (single/dual axis).
• Processes real-time data using Arduino.
• Maximizes solar energy output.
• Includes safety limits to prevent over-rotation.

II. Non-Functional Scope

• Performance: Quick response to sunlight changes.
• Reliability: Stable operation in varying conditions.
• Accuracy: Precise sun tracking for better efficiency.
• Durability: Suitable for outdoor environments.
• Cost Efficiency: Uses low-cost components.

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• Maintainability: Easy to repair and manage.

IV. METHODOLOGY / APPROACH

1. System Design

• Design a solar panel setup with a movable mount for rotation.
• Decide between single-axis (East-West) or dual-axis (East-West + North-South) tracking.
• Select components: Arduino, LDR sensors, motors (servo/DC), and motor driver.

2. Sensor Placement

• Place LDR sensors on the panel to detect sunlight intensity from different directions.
• Ensure sensors are calibrated for accurate light detection.

3. Arduino Programming

• Write a program to read LDR values.
• Compare sensor values to determine the direction of maximum sunlight.
• Control the motors to rotate the panel toward the highest light intensity.
• Implement safety limits to prevent over-rotation.

4. Motor Control

• Use servo motors for precise angular movement or DC motors with gear mechanisms.
• Connect motors to Arduino via a motor driver circuit.
• Adjust rotation speed and angle based on sensor input.

5. Testing & Calibration

• Test the system under different sunlight conditions.
• Fine-tune LDR thresholds and motor angles for accurate tracking.
• Measure energy output to verify efficiency improvements over fixed panels.

6. Optimization & Monitoring

• Optionally, add data logging or IoT modules for remote monitoring.
• Analyze performance and make adjustments to maximize solar energy capture.

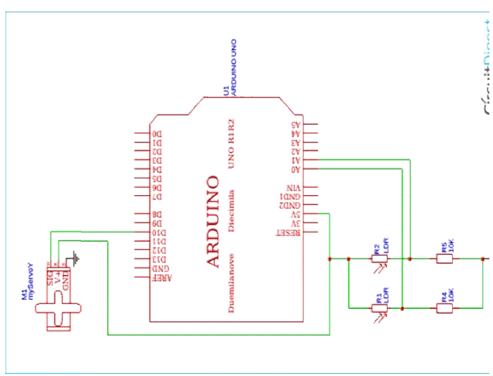

Fig. Circuit Diagram

1. Problem Analysis & Requirement Identification

Problem Analysis

• Fixed solar panels do not always face the sun directly
• This leads to low energy efficiency and power loss
• Manual adjustment is not practical for continuous operation

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Requirements
• A microcontroller like Arduino Uno
• Light sensors (LDRs) to detect sunlight direction
• Actuator (servo motor like SG90 Micro Servo Motor)
• Power supply and solar panel
• Simple control algorithm for automatic a

2. System Architecture & Design
Architecture
• Input: LDR sensors (light detection)
• Processing: Arduino microcontroller
• Output: Servo motor movemen

Design Flow
1. LDRs sense light intensity
2. Arduino compares sensor values
3. Decision is made for movement direction
4. Servo rotates panel toward maximum light

Design Type
• Single-axis or dual-axis tracking system

3. Hardware Integration & System Development
Integration Steps
• Connect LDRs to analog pins of Arduino Uno
• Use voltage divider circuit for LDRs
• Connect servo motor to PWM pin
• Power the system properly

Development
• Write Arduino code for sensor reading
• Implement comparison logic
• Control servo movement accordingly

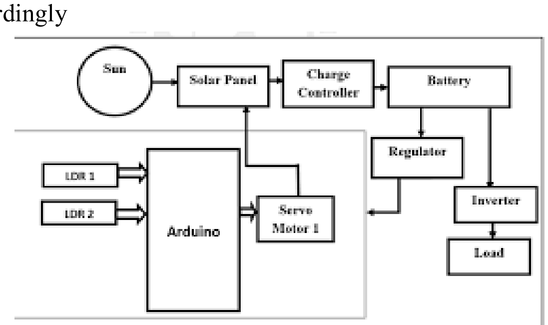

Fig. Block Diagram

4. Testing & System Validation
Testing Methods
• Check LDR response under different light conditions

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• Verify servo movement accuracy
• Simulate sunlight direction using a torch

Validation
• Compare output power with fixed panel
• Ensure smooth and stable tracking
• Check response time and accuracy

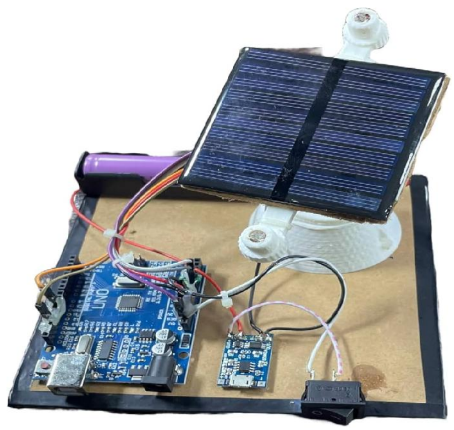

Fig. Working Model

5. Implementation & Monitoring Implementation
• Install system in open sunlight area
• Mount solar panel securely with servo Monitoring
• Observe panel movement throughout the day
• Measure voltage/current output
• Identify performance improvements

V. ADVANTAGES

1. Higher Efficiency:
Tracks the sun → captures more sunlight → generates more power than fixed panels.

2. More Energy Output
Can produce 20–40% more energy compared to stationary systems.

3. Better Use of Daylight
Works efficiently from morning to evening as it follows the sun.

4. Cost Effective in Long Run
More energy = better return on investment over time.

5. Automation with Arduino
Arduino makes the system smart, automatic, and programmable.

6. Useful for Small Projects & Learning
Great for students to learn about electronics, coding, And renewable energy.

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VI. APPLICATIONS.

1. Solar Power Plants
Used in large solar farms to increase electricity production by tracking the sun.

2. Street Lighting Systems
Solar street lights can use tracking to store more energy during the day.

3. Water Pumping Systems
Used in agriculture to power solar water pumps more efficiently.

4. Solar Battery Charging
Helps charge batteries faster for homes, inverters ,and small devices.

5. Satellite & Space Technology
Solar panels on satellites track the sun for maximum energy.

VII. CONCLUSION

The Sun Tracking Solar Panel Using Arduino project demonstrates an effective method to enhance solar energy efficiency through automation. By integrating LDR sensors and an Arduino microcontroller, the system can detect the sun's position and adjust the solar panel accordingly. This real-time tracking ensures that the panel always faces the direction of maximum sunlight, significantly improving energy output compared to fixed panels.

The project successfully combines hardware and software components, including motors, sensor circuitry, and control programming, to create a functional prototype. Testing under different sunlight conditions shows that energy generation is consistently higher, validating the effectiveness of the tracking mechanism.

The design is cost-effective, using readily available components, and is easy to implement, making it suitable for educational purposes and small-scale solar applications. Its modular nature allows future expansion to dual-axis tracking systems, integration with IoT for remote monitoring, or large-scale solar farms.

This project also highlights the importance of renewable energy technologies in sustainable development and demonstrates a practical solution to maximize solar energy utilization. By reducing dependence on fixed panels, the system contributes to better energy efficiency and resource management.

In conclusion, the Sun Tracking Solar Panel system is a practical, efficient, and scalable solution that merges automation with green technology, offering a tangible approach for optimizing solar power generation. It serves as a strong foundation for further research, innovation, and real-world applications in sustainable energy systems.

VIII. ACKNOWLEDGMENT

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[2]. Based on the difference in light intensity, the Arduino controls a servo motor (e.g., SG90 Micro Servo Motor) to rotate the solar panel toward the direction of maximum sunlight. This ensures optimal exposure throughout the day, improving efficiency compared to fixed solar panels.
[3]. The system can be implemented as a single-axis tracker (east–west movement) or a dual-axis tracker (horizontal and vertical movement), with dual-axis systems providing higher accuracy and energy output.
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