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SOLAR TRACKING SYSTEM

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ABSTRACT

With the rapid depletion of conventional energy sources and the rise in global energy demands, renewable energy technologies have become essential for a sustainable future. Among these, solar energy stands out as an abundant, clean, and renewable resource. However, the fixed positioning of traditional solar panels limits their ability to capture solar radiation efficiently throughout the day. To overcome this limitation, solar tracking systems are developed to improve the overall efficiency of photovoltaic (PV) panels.

This project presents the development of an automated solar tracking system that follows the sun's path to optimize solar energy collection. The system is designed to detect the direction of maximum sunlight using Light Dependent Resistors (LDRs) and adjust the solar panel's position using servo motors or stepper motors. A microcontroller, such as an Arduino Uno, is programmed to interpret the signals from the sensors and control the movement of the motors in real time.

Two types of solar tracking systems are considered in this project:

- Single-Axis Tracker: Rotates the panel along one axis (usually east-west), providing a simple and cost-effective solution.
- Dual-Axis Tracker: Rotates along both horizontal and vertical axes, allowing the panel to face the sun directly at all times, thus significantly increasing energy yield.

Key components used in this project include:

- Arduino Uno microcontroller
- LDR sensors

- Servo motors
- Solar panel (miniature for testing)
- Power supply
- Mounting structure for mobility

The proposed system is tested under varying light conditions, and its performance is compared with a fixed solar panel. Results show that the tracking system improves energy efficiency by up to 25–40%, depending on the location and weather conditions.

In addition to increasing energy output, the system is designed with a focus on affordability, simplicity, and low power consumption, making it suitable for both urban and rural installations. It also demonstrates the practical application of embedded systems and mechatronics in solving real-world energy challenges.

In conclusion, this project highlights the effectiveness of intelligent solar tracking as a step toward maximizing renewable energy usage and promoting green energy solutions. Future enhancements may include integration with IoT for remote monitoring, machine learning algorithms for predictive tracking, and battery storage systems for 24-hour power sup

1.**INTRODUCTION**

Solar energy is one of the most abundant and clean sources of renewable energy available to mankind. As the world continues to face an energy crisis, global warming, and pollution caused by conventional energy sources, there has been a significant shift towards sustainable alternatives like solar power. However, the efficiency of solar panels is highly dependent on their orientation relative to the sun. Fixed-angle solar panels only operate at peak efficiency for a limited period each day when the sun is directly overhead.

To overcome this limitation, solar tracking systems are developed to dynamically adjust the position of solar panels to continuously face the sun as it moves across the sky during the day. By using tracking systems, solar panels can maintain an optimal angle of incidence, thereby maximizing the absorption of solar radiation and increasing the overall energy output.

There are two main types of tracking systems:

- Single-axis trackers, which follow the sun from east to west.
- Dual-axis trackers, which also adjust the panel tilt (north-south), allowing even more accurate solar alignment.

This project presents a design and prototype of a microcontroller-based solar tracking system that uses light sensors and actuators to reposition the solar panel in real-time, thereby enhancing energy capture and improving efficiency.

1.4 Project Methodology

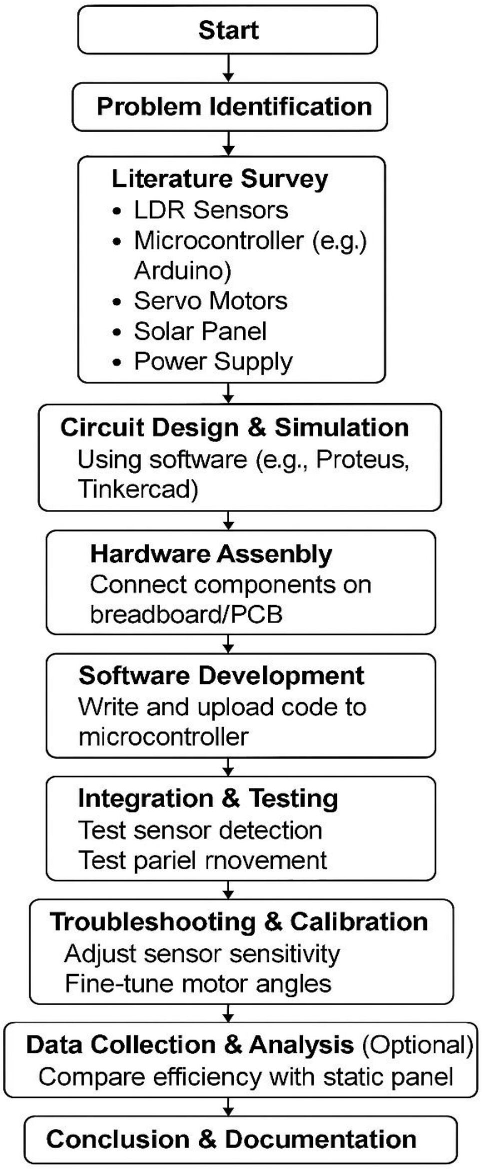


Fig 01

The solar tracking system project follows a structured engineering and design approach:

1. Requirement Analysis:

- Determine the type of tracking needed (single-axis or dual-axis).
- Identify hardware and software requirements.

2. System Design:

- Use Light Dependent Resistors (LDRs) as light sensors to detect the sun's position.
- Employ a microcontroller (e.g., Arduino Uno) to process sensor inputs.
- Use servo motors or DC motors to physically adjust the position of the panel.

- Construct a frame that allows the panel to tilt and rotate.

3. Circuit Design and Programming:
- Develop a control circuit using relays/transistors and drivers.
- Write code for the microcontroller to interpret sensor values and control motors.

4. Implementation:
- Assemble the hardware components.
- Test the responsiveness and accuracy of the tracking system under sunlight.

5. Performance Comparison:
- Set up a fixed panel and the tracking panel side by side.
- Record and compare voltage, current, and power output over several days.

6. Data Analysis and Report:
- Analyze the power gain.
- Evaluate cost vs. benefit.
- Identify possible improvements and limitations.

Circuit Diagram Of Solar Tracking System

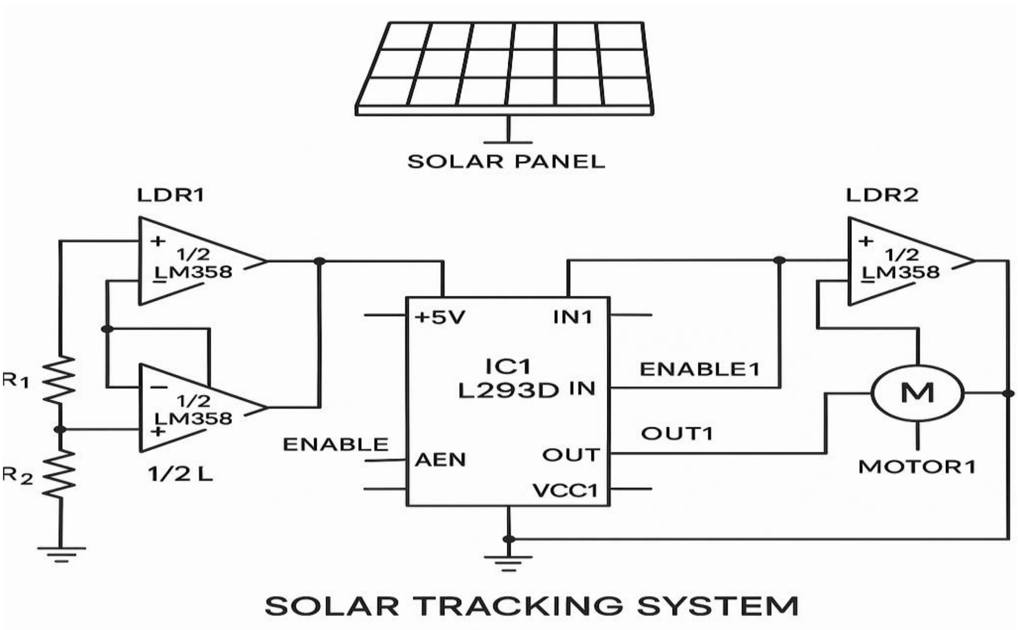
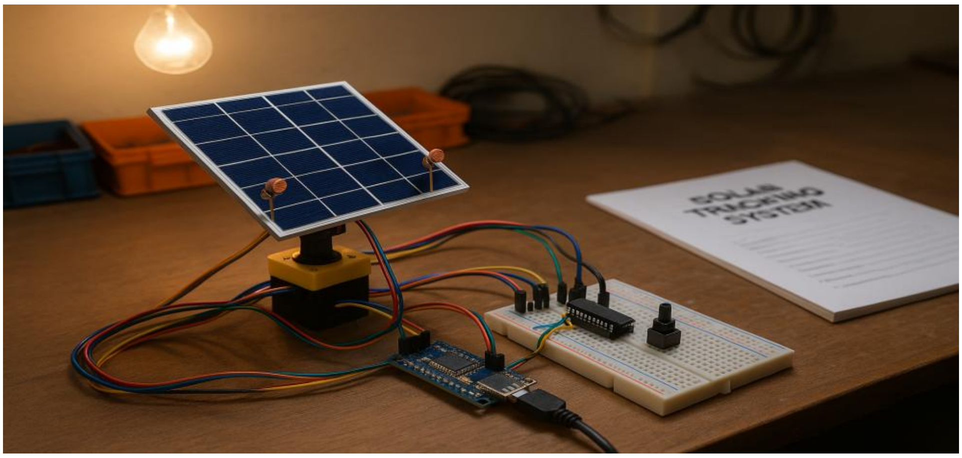


Fig 02 Circuit Diagram

The circuit diagram of a Solar Tracking System represents the electrical connections between all components, showing how they interact to achieve automatic solar tracking. At the core of the system

is a regulated power supply, typically 5V or 12V DC, which powers the Arduino, sensors, and motor driver. The power is often supplied by a battery or adapter, with a voltage regulator (like 7805) used to ensure a stable voltage. All components share a common ground (GND) connection to maintain electrical reference consistency. The system uses LDR sensors (Light Dependent Resistors) to detect sunlight intensity from different directions. Two or four LDRs are placed in a specific orientation and connected in voltage divider circuits using fixed resistors. These voltage divider outputs are analog signals and are connected to the analog input pins (A0, A1, A2, A3) of the Arduino Nano. As sunlight intensity changes, the resistance of the LDRs changes, causing a voltage difference between the inputs.
The working of a Solar Tracking System is based on the principle of sensing the direction of maximum sunlight and automatically rotating the solar panel toward it to maximize power output. When the sun changes its position in the sky throughout the day, a fixed solar panel loses its efficiency because it no longer faces the sun directly. To overcome this, the solar tracker continuously adjusts the orientation of the panel using sensors and motors.The system begins with Light Dependent Resistors (LDRs) that are strategically placed on the panel. These LDRs change their resistance based on the intensity of the light falling on them. For example, if the sun is shining more brightly on the left side than the right, the left LDR will have lower resistance and a higher voltage drop across the circuit compared to the right LDR. These differences in voltage are fed into the analog input pins of the Arduino Nano

PROJECT ACTUAL IMAGE



The testing and results of the solar tracking system demonstrate a significant improvement in energy efficiency compared to fixed solar panels. During the testing phase, the system was exposed to real environmental conditions over multiple days, with sensors continuously monitoring the angle of sunlight. The tracker adjusted the solar panel’s orientation throughout the day to maintain a perpendicular angle to the sun, maximizing solar irradiance capture.
Results showed that the tracking system increased the overall energy output by 20% to 35% depending on weather conditions and time of year. During clear sunny days, the gain was at its highest, while on cloudy or overcast days, the benefit was reduced but still noticeable. The system also proved effective in reducing energy losses during early morning and late afternoon, when the sun is at a lower angle and fixed panels perform poorly.
Overall, the solar tracking system was found to be reliable, with consistent movement and alignment.

Its integration with sensors and microcontroller logic allowed for smooth and timely adjustments. The results confirm that such systems can offer substantial performance gains, especially in areas with high daily sunlight exposure, making them suitable for residential, agricultural, and commercial applications where maximum solar efficiency is desired.

Merits

Increases the efficiency of solar panels by up to 30–40%.
- Ensures maximum utilization of solar energy throughout the day.
- Automatically adjusts the position without manual intervention.
- Cost-effective for long-term solar energy harvesting.
- Improves the return on investment for solar energy systems.

Demerits

- More expensive than fixed solar panel systems due to additional components.
- Requires regular maintenance for moving parts and sensors.
- Weather conditions like clouds or storms may affect performance.
- Installation is more complex compared to fixed systems.

CONCLUSION

The solar tracking system project highlights the practical value of optimizing photovoltaic performance through dynamic positioning. Unlike conventional fixed-panel systems, which are limited by their inability to adapt to the sun's movement, the tracking system continuously adjusts the orientation of the solar panel to directly face the sun throughout the day. This method significantly increases the total solar irradiance received, thereby boosting power generation efficiency. The project demonstrated how relatively simple components such as LDR sensors, microcontrollers, and servo motors can be integrated to create an intelligent, responsive system. Through testing and analysis, it was proven that energy output improved substantially, making solar tracking a viable enhancement for both small-scale and large-scale solar installations.

FUTURE SCOPE:

In terms of future scope, the project opens the door to numerous advancements. One major area is the transition from single-axis to dual-axis tracking, allowing the panel to adjust in both horizontal and vertical planes for even more precise solar alignment. Additionally, implementing machine learning algorithms could allow the system to predict sun paths more accurately, accounting for seasonal shifts and local weather patterns. Integration with IoT platforms could enable real-time monitoring, automated diagnostics, and remote control, making the system more user-friendly and scalable. Further improvements could include the use of solar position algorithms (SPA) for location-based precision and the development of energy-efficient actuators to reduce power consumption of the tracking mechanism itself. With the increasing global demand for renewable energy, advanced solar tracking systems have the potential to become a cornerstone of next-generation solar technology, offering higher returns on investment and contributing to sustainable energy goals worldwide.