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Solar tracker using Arduino microcontroller and light dependent resistor

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ABSTRACT

This paper presents a dual-axis solar tracker using Arduino and LDRs. The aim of the proposed paper is to enhance the competence of solar energy harvesting by developing an intelligent solar tracking system. This system employs light-dependent resistors (LDRs) as sensors to detect ambient light levels, enabling precise adjustments of solar panels along both azimuth and elevation axes. The Arduino microcontroller serves as the intellect of the system, orchestrating the synchronized movement of dual-axis servo motors to align solar panels optimally with the sun's point during the day. The core functionality of the solar tracker involves real-time monitoring of LDR readings to calculate the solar azimuth and elevation angles. These angles are then used to situation the solar panels dynamically, ensuring they are constantly oriented near the sun for maximum energy absorption. The implementation of the dual-axis solar tracker using Arduino and LDRs offers several advantages, including increased energy output, better system efficiency, and a reduction in dependency on fixed solar installations. The low-cost and adaptable nature of the proposed system makes it suitable for various applications, such as residential solar installations, off-grid power systems.

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1. INTRODUCTION

To sustain life on Earth, we need dynamism for our bodies through food and for machines through external sources. Since non-renewable energy sources are depleting, there is a shift toward renewable energy, with the sun being a key source. Solar cells currently harness only a small fraction of solar dynamism due to their fixed positioning. To enhance energy capture, solar trackers are employed to follow the sun's movement. Authors focuses on a dual-axis solar tracker using real-time tracking technology, which can boost solar energy production by up to 45% [1]-[5]. This paper analyzes the performance of three DC/DC converter topologies predictable, quadratic, and double flowed boost converters used in a solar PV system with a perturb-and-observe maximum power point tracking (MPPT) controller. While a conventional boost converter increases solar PV output voltage, it struggles with high step-up ratios, necessitating cascaded boost converters for higher voltage conversion and efficiency. The P&O technique is employed for its simplicity and cost-effectiveness to maximize power extraction under varying solar radiation and temperature. MATLAB/Simulink simulations are conducted to compare the performance of these converter topologies [6]-[10]. This study introduces a numerical method to evaluate and enhance the maintainability of a dual-axis planetary tracking system for residential use, aiming to boost energy production. The research has three main objectives: Development of an independent dual-axis solar tracker using a low-power electronic schematic with a single motor driver to control azimuth and promotion angles. Key components include an Arduino Mega2560, TB6560 stepper driver, stepper motors, sensors, and other automation hardware [11]-[15]. Replacement of the Arduino board with a custom low-cost application-specific PCB based on the AVR controller. Potential risks like stuck-at-0 and stuck-at-1 defects, along with challenges like hardware modularity and accessibility, are analyzed for improved serviceability. Introduction of a novel maintainability index that integrates identified factors to optimize and evaluate the system's maintainability. Experimental results show enhanced system repair ability and uptime due to the proposed metrics. This study proposes a dual-axis solar tracker system designed to optimize energy capture by uninterruptedly adjusting solar panels to remain perpendicular to sunlight. The system uses light sensors to track the sun's elevation and azimuth angles, with a microcontroller determining the optimal panel alignment. Motor controllers and actuators adjust the panels based on the sensor data, while an IoT-enabled monitoring system provides real-time tracking and parameter updates via a webpage [16]-[20]. The results demonstrate that the dual-axis tracker significantly outdoes fixed solar panel systems in energy efficiency, particularly in regions with high solar angles and variable sunlight.

2. SYSTEM ARCHITECTURE

Figure 1 shows the lump drawing of a dual-axis solar tracker represents the flow of data and control signals between its main components. Each block performs a specific function, contributing to the system's ability to adjust the solar panel's position to maximize energy capture. Below is a detailed explanation of each block in the system. The light dependent resistors (LDRs) are the primary input sensors in the system. Four LDRs are positioned in a cross-like arrangement around the solar panel. Each LDR measures the sunlight intensity in its specific direction. The analog signals from the LDRs indicate the brightness of sunlight in their area. These signals are fed into the microcontroller's analog pins, where they are converted into digital data for further processing. This detection system forms the foundation of the tracker, allowing it to detect the sun's position accurately. At the core of the system is the microcontroller, such as an Arduino, which acts as the brain of the tracker. It processes the data from the LDR sensors by comparing the intensity values between opposite LDR pairs (e.g., left vs right for horizontal tracking and top vs bottom for vertical tracking). If there is a difference in intensity, the microcontroller calculates how much the solar panel needs to move to align with the sun. Using this calculation, it generates precise pulse width modulation (PWM) signals to control the motors [21]-[25]. The microcontroller also ensures that the panel stays within predefined limits to avoid over-rotation. The motor driver, such as the L298N or L293D H-bridge module, is an interface between the microcontroller and the motors. It receives the PWM signals from the microcontroller and translates them into appropriate control signals for the motors. The motor driver ensures that the motors operate safely by providing sufficient current and controlling their direction (clockwise or counterclockwise). This block plays a dangerous role in converting the control logic into physical movement.

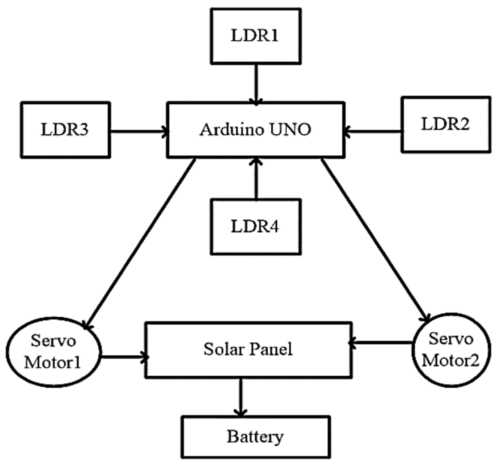

Figure 1. Dual-axis solar tracker block diagram

3. RESULTS AND DISCUSSION

3.1. Simulation studies

Figure 2 shows the dual-axis solar tracker TinkerCAD diagram. Tinkercad is an excellent platform to design and simulate a dual-axis solar tracker before building the physical prototype. It allows you to virtually experiment with circuits, components, and Arduino code to ensure proper functionality. Here's a description of how to create and simulate a dual-axis solar tracker in Tinkercad. The Tinkercad imitation for a dual-axis solar tracker involves replicating a system where the solar panel adjusts its position to maximize sunlight exposure. The system uses light sensors, servo motors, and an Arduino microcontroller to automate the tracking mechanism.

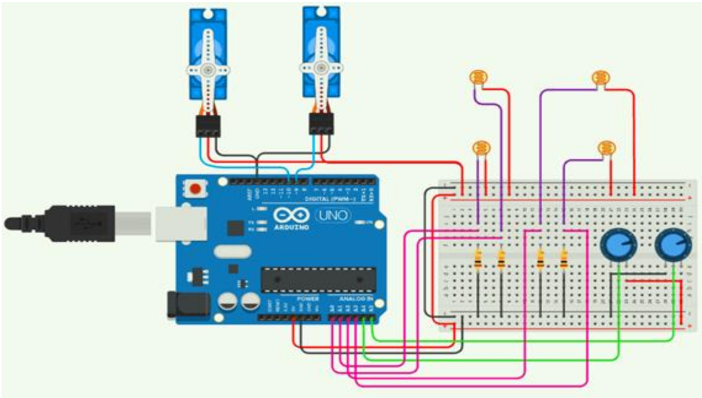

Figure 2. Dual-axis solar tracker tinkercad diagram

3.2. Practical implication applications in residential and off-grid systems

Figure 3 shows the single-axis solar tracker. A single-axis solar tracker is an innovative and efficient system planned to maximize the energy output of solar panels. Unlike stationary solar panels, which can only capture sunlight at fixed angles, single-axis trackers actively follow the sun's effort across the sky from east to west during the day. This system improves the efficiency of solar energy group by ensuring the solar panels are always aligned with the sun's rays, thereby increasing the overall power generation. Single-axis trackers are widely used in residential, commercial, and industrial solar power installations due to their cost-effectiveness and simplicity.

Figure 4 shows the single-axis solar tracker control scheme. A single-axis solar tracker consists of several key components, solar panel: The primary energy-harvesting unit. Light sensors, microcontroller, DC motor, motor drive, frame, and mounting system. Typically LDRs, used to measure sunlight intensity. The microcontroller is brain of the system that processes sensor data and controls the motor. A motor that rotates the solar panel along a single axis. An electronic circuit or module L298N that regulates motor movement based on microcontroller signals. A mechanical structure is supports the panel and allows it to rotate.

Figure 5 shows the DC Motor linked with solar tracker. These solar trackers are used in a variety of applications, ranging from small housing systems to large utility-scale solar farmhouses. They are especially valuable in regions with high solar irradiance, where maximizing energy output is crucial. These systems are also used in agriculture, where solar panels power irrigation systems, and in off-grid installations to provide reliable energy in remote areas. Their versatility and efficiency make them an integral component of modern solar energy solutions.

Figure 6 shows the dual-axis solar tracker. This is a progressive system designed to maximize solar panel efficiency by adjusting its position to follow the sun in both the horizontal (azimuth) and vertical (altitude) directions. Using Arduino as the central controller, this system combines sensors, motors, and mechanical components to ensure optimal solar energy capture throughout the day and year. The system uses four LDR sensors placed in a cross pattern around the panel. These sensors measure the intensity of sunlight and provide analog inputs to the Arduino. The Arduino processes the LDR readings and calculates the difference in sunlight intensity between opposite sensors. If the light intensity differs along the horizontal axis, the Arduino signals the horizontal motor to adjust the panel's azimuth angle. If the intensity differs along the vertical axis, the Arduino signs the vertical motor to adjust the panel's tilt. The process continuously adjusts the panel's position to maintain maximum exposure to sunlight. At night or in the absence of sunlight, the system parks the panel in a default position to avoid unnecessary movement. Table 1 shows the solar panel parameters.

Figure 3. Single-axis solar tracker

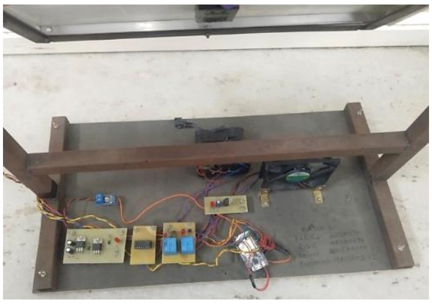

Figure 4. Single-axis solar tracker control scheme

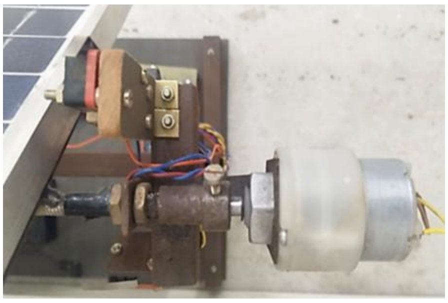

Figure 5. DC motor linked with single-axis solar tracker

Figure 6. Dual-axis solar tracker prototype diagram

Table 1. Solar panel features

S.No	Features	Rating
1	Output voltage	5 V
2	Max power	1 W
3	Open circuit voltage	6 V
4	Short circuit current	220 mA

4. CONCLUSION

In this research paper, both single-axis and dual-axis solar trailer systems are investigated for their potential to enhance solar energy production by continuously orienting the panels toward the sun. The single axis tracker, while simpler and more cost-effective, demonstrated a notable improvement in energy capture compared to fixed panel systems by adjusting the panel's orientation along one axis. However, the dual-axis solar tracker, which adjusts the panels along both the azimuth and elevation axes, proved to be far more efficient, maximizing energy capture throughout the day and across seasons by maintaining the optimal panel angle relative to the sun. In conclusion, while the dual-axis solar tracker offers larger energy efficiency, the choice amid single-axis and dual-axis systems depends on factors such as installation cost, complexity, and the specific energy requirements of the site. Both systems, however, represent promising solutions for enhancing the overall show of solar power systems and contribute to the ongoing transition toward renewable energy sources.

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