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Sunwise: Intelligent Solar Tracking for Increased Yield

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Abstract: Solar energy is incredibly important as it is a clean, renewable, and abundant source of power. Automatic solar trackers create a significant impact by increasing the energy production of solar panels, making renewable energy more efficient. They help maximize the use of solar power and contribute to a greener and sustainable future. By tracking the movement of the sun throughout the day, these trackers ensure that the panels are always facing the sun directly, capturing the maximum amount of sunlight. By optimizing energy production, these trackers contribute to the wider adoption of solar power, making it more cost-effective and sustainable. It's an exciting technology that helps harness the full potential of solar energy. In this paper, we have studied and implemented the dual-axis solar tracking system, which aligns the solar panel in the direction of maximum intensity of sunlight in both horizontal and vertical directions with the help of various sensors and motors. While a single-axis tracking system can only track one direction. Our focus in this paper is mainly on designing and forming a prototype for a dual-axis solar tracking system based on an Arduino microcontroller along with basic concepts of solar panels and their uses.
Keywords: Energy production, Sun tracking, Dual-axis, Solar panels, Renewable energy, Cost-Effectiveness, and Sustainability

I. INTRODUCTION

Energy is one of the most important factors in our daily lives. We use, transform, or produce enormous amounts of energy every day. The most common sources of energy are fossil fuels, wind energy, nuclear energy biomass energy, etc. However, there are some limitations that we have to face while using these resources such as fossil fuels are in a limited amount in nature, wind energy requires a lot of space and has noise impacts, nuclear energy faces issues related to radioactive waste disposal, safety concerns, and biomass energy is expensive to produce and may cause pollution due to the burning of organic materials. Hence, nowadays researchers are focusing more on renewable energy resources such as they have many benefits such as they are inexhaustible, environment-friendly, improve public health, are less expensive, and are present in nature in plenty of amounts. One of the well-known and common sources of renewable energy is solar energy. This energy is obtained with the use of solar panels. Solar panels generate electricity by converting sunlight into usable energy the amount they can produce varies depending on factors like the weather conditions, the panel size and wattage, the efficiency of solar cells, and the angle at which the sunlight hits the panels that's where the solar tracking device comes in. To improve the output yield of the solar plant the other factors depend on the materials used, and the weather conditions, but we can implement a methodology known as a solar tracking system to align the solar panels in the direction of maximum intensity of sunlight which noticeably increases the energy output.

Solar tracking devices have sensors and motors that move the panels throughout the day by following the sun's path and by doing this they make sure that the panels are always positioned at the best angle to capture the most sunlight.

There are different types of solar tracking systems including single-axis, dual-axis, and dual-axis trackers that can move panels in both horizontal and vertical directions. With a dual-axis tracker we can achieve a yearly gain of around 30% to 45% depending on location and a single-axis device can increase the energy by 15% to 25%.

These devices not only make financial sense but also have a positive environmental impact by reducing reliance on fossil fuels and decreasing CO2 emissions.

II. LITERATURE REVIEW

Solar tracking systems have undergone significant development since their inception by C. Finster in 1962, when the first mechanical system was created. Over time, research efforts have led to the evolution of modern dual-axis solar trackers, which are notably more efficient. Several notable studies have contributed to this advancement.

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For instance, "A Project Report on Automatic Sun Tracking Solar Panel Based on Open Loop Concept" by Pritam Pokhra, Rajeshwari, and Raj Kumar Yadav focused on designing and analyzing an Automatic Sun Tracking Solar Panel based on the open loop concept. Similarly, Jerin Kukiakose Tharamuttam and Andrew Keong Ng, in their work titled "Design and Development of an Automatic Solar Tracker," proposed a microcontroller-based solar tracker with a hybrid algorithm for locating the sun's position, aiming to maximize solar panel efficiency. Additionally, Deekshith K, Dhruva Aravind, Nagaraju H, and Bhaskar Reddy, in their paper "Solar Tracking System," provided an overview of solar tracking systems based on microcontrollers, highlighting their simple and attractive features, along with their comparatively low operation and maintenance costs. Rajan K, in "Solar Tracking System - A Review," presented a review of major types of sun-tracking systems developed over the past 20 years, categorizing them based on their mode of rotation and actuator type. Lastly, A Mohamad, H Mhamdi, NAM Amin, M Izham, NA Aziz, and SY Chionh, in "A review of automatic solar tracking systems," reviewed previous work on simulation and experimental analysis of solar tracking systems, emphasizing the reduced number of solar panels needed to generate the same amount of electrical energy when utilizing a solar tracker. This review encompassed both single-axis and dual-axis solar tracking systems, showcasing the continual advancement in this field.

III. OBJECTIVES

1) To develop an efficient solar plant that could give a sufficient amount of energy to replace the other energy resources that are hazardous to nature and are expensive.
2) To increase the efficiency of the solar power plant.
3) To decrease the usage of non-environment-friendly, non-renewable energy resources.
4) To reduce the cost of solar energy production by increasing the yield.
5) Aligning the solar panels in the direction of the sun throughout the day, and according to the weather conditions.
6) Obtaining the optimal angle according to the sun's rays to increase efficiency.

IV. METHODOLOGY

This block diagram explains the methodology used for the dual-axis solar tracking system.

V. COMPONENTS/ MATERIALS/CONCEPTS

A dual-axis solar tracker utilizing Arduino typically includes the following components:

1) Solar panels: Solar panels are photovoltaic panels that transform sunlight into electrical energy. We have used

Figure 1: Solar Panel

2) Arduino Board: A microcontroller that interprets data and directs the movement of the solar tracker. In this prototype, we have used ATmega328P microcontroller

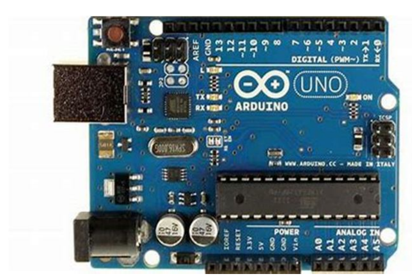

Figure 2: Arduino Uno

3) Light sensors: Light sensors are used to measure the intensity and direction of sunlight to track it accurately.

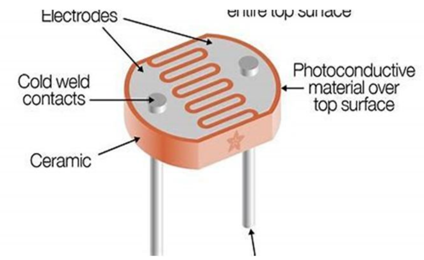

Figure 3: LDR Sensors

4) Motor Controllers: Devices that control motor movement in response to sensor data, thereby altering the position of solar panels.

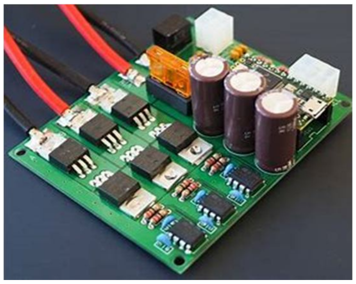

Figure 4: Motor controllers

5) Servo motor: Stepper motors, also known as servo motors, are actuators that physically move solar panels in response to Arduino control signals. The servo motor used in this project is an SG90 micro servo

Figure 5: Servo Motor SG 90

6) Power Supply: Powers the Arduino, sensors, and motor controllers.

Figure 6: Batteries

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7) The support structure: It is the frame or structure that holds the solar panels, and servo motors and allows them to move following the dual-axis tracking system.

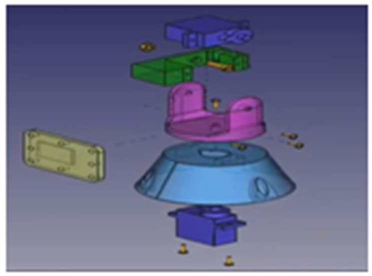


Figure 7: 3D Printing materials

8) Wiring and Connectors: Electrical connections between components for effective communication and power delivery.

Figure 8: Jumper Wires

9) Programming Interface: Software code built for the Arduino to control the tracking system using sensor inputs.
10) Single-axis Tracking system: It only has one degree of freedom in which it can rotate its direction. It is further divided into various types based on the direction of movement and the methodology used to change the direction.

- Horizontal Single-Axis Trackers (HSAT): This tracker can only move on a horizontal axis, i.e. in the east-west direction.
- Vertical Single-Axis Trackers (VSAT): This tracker can only move on a vertical axis, i.e. in the north-south direction.
- Tilted Single-Axis Trackers (TSAT): This tracker combines both horizontal and vertical movement, and is more efficient than the others.

Now this system is also divided into

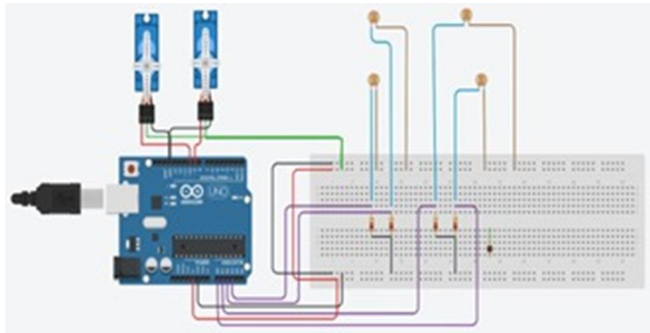
- ➢ Manual Single-Axis Solar Trackers: The direction of the solar panel is changed manually which is very inconvenient.
- ➢ Passive Single-Axis Solar Trackers: Uses a liquid that evaporates when exposed to sunlight, this results in changing the direction of the solar panel.
- ➢ Active Single-Axis Solar Trackers: Use various motors and sensors to detect the direction of sunlight and align itself automatically.

Dual-Axis Tracking System: A mechanism for adjusting the orientation of solar panels horizontally and vertically to maximize sunshine exposure. This system has two degrees of freedom and is more efficient than the single-axis tracking system.

The methodology used in a dual-axis solar tracker involves an advanced system designed to maximize solar energy harvesting by precisely orienting solar panels along the horizontal and vertical axes. To achieve this, sensors, continuously monitor the sunlight intensity. The controller interprets these signals and calculates the optimal position for the solar panels. Actuators, such as motors, then adjust the orientation of the panels accordingly. This dual-axis tracking ensures that the solar panels constantly face the sun, optimizing exposure throughout the day and across seasons. Overall, the dual-axis solar tracker methodology integrates sensing, control, and actuation mechanisms to dynamically align solar panels for optimal energy capture.

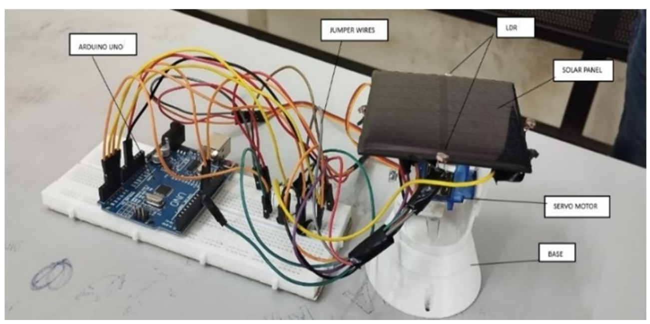
VI. DESIGN AND IMPLEMENTATION

CIRCUIT DIAGRAM



There are total of 4 LDRS which are placed on the solar panels. The light sensors detect the sunlight intensity in two directions that are X and Y. After that the Arduino receives the input from all the LDRs and then calculates the proper intensity so that the solar panels can be fixed in such a way that it could absorb the maximum amount of energy. Through the Arduino the signals are forwarded to the motor drivers so that it could adjust the solar panels. There are two motors, X direction motor and Y direction motor these motors are used to move the solar panels in both the direction to align them with the sun. Here the voltage regulator is used because the input voltage from the solar panels is not consistent and it ensures that component receives a reliable voltage. The system always tracks the sun’s position and take the data and adjust itself.

VII. RELATED WORK



One study 1 came across compared single-axis and dual-axis trackers. They found that dual-axis trackers., which can move in two directions, were more efficient as there is maximum energy generation compared to single-axis solar trackers. Another study looked at the economic side of things, researchers analyzed the cost-effectiveness of using solar tracking devices in different initializations. They found that although there might be higher upfront costs. The increased energy production over time could make it financially worthwhile.

VIII. RESULTS AND DISCUSSIONS

We have studied that dual-axis solar tracking systems can significantly increase the energy generation of solar panels compared to fixed systems. On average, dual-axis tracking devices can increase energy production by 20% to 40%, depending on various factors such as location, weather conditions, and panel efficiency. One research study conducted in a sunny region found that a dual-axis solar tracking system increased energy output by approximately 35% compared to fixed panels. Another study in a location with limited sunlight showed an energy gain of around 25% with dual-axis tracking. Additionally, research has demonstrated that dual-axis solar tracking devices can effectively mitigate the effects of shading. By continuously adjusting the panel's position to face the sun, these systems can minimize the impact of shading from nearby objects, resulting in improved energy generation. Furthermore, studies have also highlighted the impact of dual-axis tracking on temperature management. By optimizing the orientation of solar panels, these systems can help dissipate heat more efficiently, reducing the risk of overheating and improving overall panel performance. Overall, the research indicates that dual-axis solar tracking devices offer significant benefits in terms of increased energy generation, shading mitigation, and temperature management. While they may involve additional costs and maintenance requirements, the improved efficiency and performance make them a promising option for maximizing the potential of solar panels.

IX. CONCLUSION

In recent years, there has been a surge in the development of innovative sun tracking systems. These advancements have revolutionized solar energy collection by enabling panels to dynamically adjust their position throughout the day, constantly facing the sun for maximum sunlight exposure. This innovation has unlocked the potential for a diverse variety of solar thermal and photovoltaic systems, far surpassing the capabilities of traditional fixed-position panels. Compared to their static counterparts, sun tracking systems have demonstrably increased energy production, making solar power a more viable and attractive option for a wider range of applications

Further delving into the world of sun tracking systems reveals a fascinating distinction between two primary categories: single-axis and dual-axis trackers. Each classification boasts a unique rotational method, specifically designed to optimize solar energy capture. Single-axis trackers, as the name suggests, rotate along a single axis, typically following the sun's east-west movement. Dual-axis trackers, on the other hand, exhibit a more sophisticated approach, incorporating both east-west and north-south adjustments, enabling them to mimic the sun's complete arc throughout the day. Understanding these distinct functionalities is crucial for selecting the most suitable tracking system for a specific application.

This research delves into the exciting realm of novel dual-axis solar tracking systems, specifically focusing on the creation of a system designed to maximize solar radiation capture. The proposed design prioritizes simplicity and efficiency, utilizing a minimalistic approach with a reduced number of components. This not only streamlines the construction process but also holds the potential for increased affordability and ease of maintenance. However, the true merit of this design lies in its ability to significantly enhance solar radiation yield, paving the way for a more efficient and impactful utilization of solar energy.

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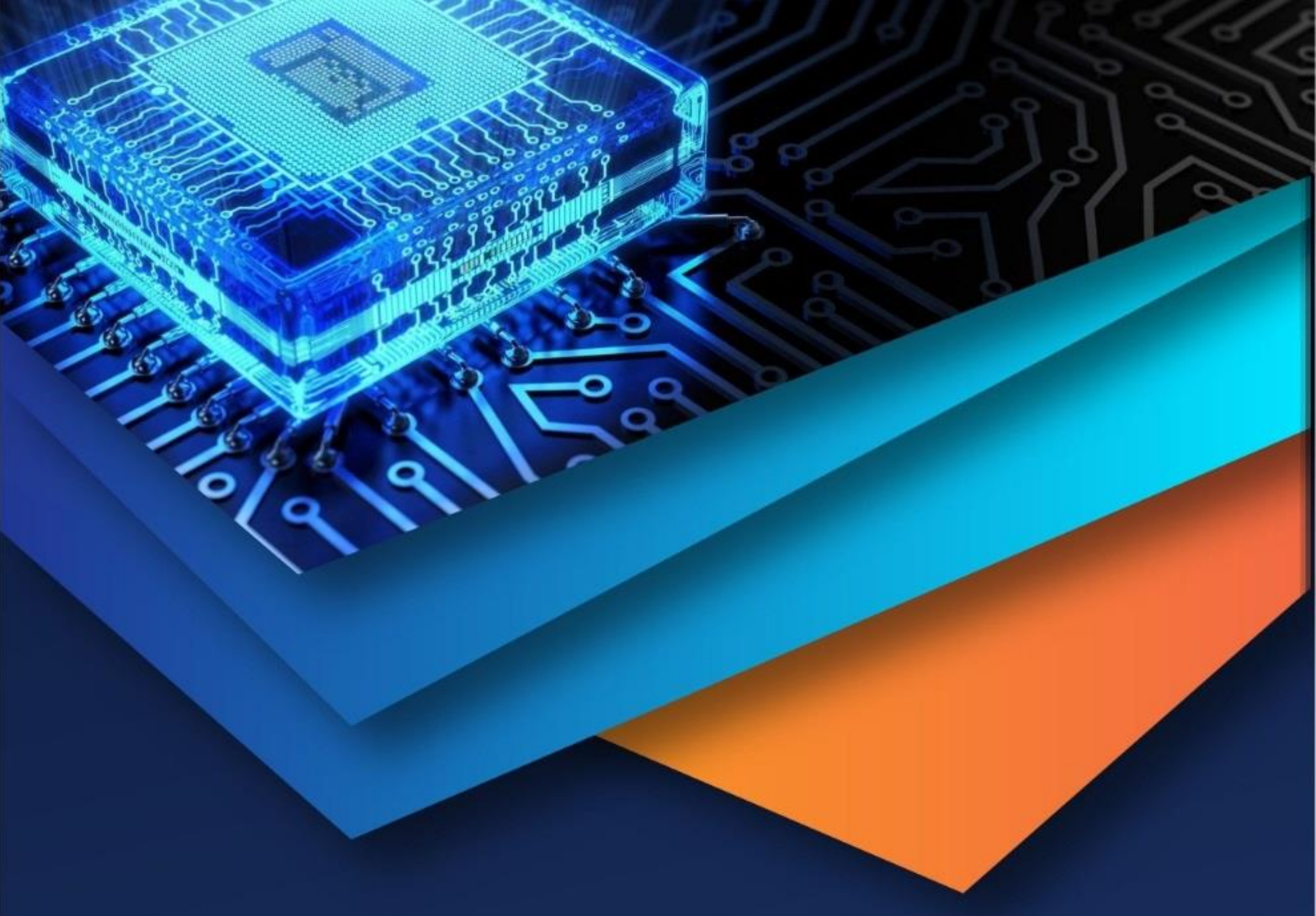

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