Dual-Axis Tracking System With Load Integration for Enhanced Power Generation.

DENDI SAISREE
Electrical and Electronics Engineering.
Stanley College of Engineering and Technology for Women,Osmania University.
Hyderabad,India
reddydendi25@gmail.com

PADALA SWATHI
Electrical and Electronics Engineering.
Stanley College of Engineering and Technology for Women,Osmania University.
Hyderabad,India
swathipadala16@gmail.com

BUNGA LIKITHA
Electrical and Electronics Engineering.
Stanley College of Engineering and Technology for Women,Osmania University.
Hyderabad,India
bungalikitha04@gmail.com

***Abstract*—The Main Objective of this paper is to develop a laboratory prototype of a solar tracking system, aiming to optimize the performance of photovoltaic modules within a solar energy system. The system operates on the principle of maintaining constant alignment of the photovoltaic modules with sunbeams,thereby maximizing the exposure of the solar panels to the Sun's radiation. The Solar Tracking system, powered by an Arduino UNO R3 with PCB, four Light Dependent Resistors(LDR's), DC Motor and a Motor Driver IC dynamically optimizes solar panel positioning for enhanced energy capture. Strategically placed LDRs detect changes in light intensity, prompting real-time adjustments via the Arduino, ensuring continuous alignment with the maximum incident light and maximizing energy harvesting efficiency. The system hardware, including a printed circuit board for stable connections and precise control facilitated by the DC Motor and Motor Driver IC, contributes to its cost-effectiveness and sustainability. The Arduino with code processes LDR data to calculate optimal Tilt angles,Directing the Motor for seamless adjustments. This adaptable system showcases the practical application of Arduino UNO R3 with PCB technology in renewable energy, offering a versatile and efficient solution for increased solar energy utilization throughout the day.**

Keywords—Dual-Axis Tracking System, Arduino UNO R3,DC motor, LDR sensors, Renewable energy.

I. INTRODUCTION

Electric power is now considered as a basic need all around the world. As previously stated, the worldwide use of electricity is increasing as the population increases and develops. Fossil resources are not a viable alternative for the future because they are non-renewable resources that contribute to environmental damage. As a result, it is crucial to limit the consumption of nonrenewable resources,with renewable energy playing an important role in the future[1]. There are two sorts of solar energy: heat and light. The environment alters and absorbs sunlight and heat in a variety of ways. The main purpose of this study is to present strategies for gathering more solar energy[2]. The potential of renewable energy systems(RESs) to produce long-term ,environmentally benign solutions makes research into RESs a global priority. The most significant direct or indirect source of renewable energy is the sun, and the current solar radiation can be transformed into thermal or electrical energy thanks to technology. Solar energy can be employed to produce electricity in two ways: Photovoltaic(PV) systems and concentrated solar power(CSP)[3].The surge in demand for environmentally friendly and sustainable energy solutions has spurred a significant focus on solar energy harvesting within engineering circles.among various avenues of renewable energy exploration, solar power has developed as a prominent and widely researches fields[4]. Conventional solar setups often rely on fixed-tilt systems, which only capture sunlight optimally for short periods during the day. This limitation leads to the lower yields of the usable energy compared to what could be achieved ideally. In contrast, dual-axis solar trackers offer a dynamic solution by adjusting both the azimuthal and polar angles of the solar panel. This technology can boost solar energy capture by 30-45 percent compared to fixed ones[5].Dual-Axis solar charger trackers are essential components of PV power systems. These trackers contribute to maximizing energy output by altering the direction of the panels during the day to match with the sun's trajectory. Solar trackers, notably dual-axis ones, are essential for reducing the angular disparity between the solar panel and the incident light, so maximizing power generation. Proper alignment is required to harness solar energy properly. Dual-Axis trackers may move in both upward and downward directions, ensuring a continuous orientation towards sunlight. This ability allows them to trace the sun's movement along both axes, which enhances solar energy acquisition. Two major types of solar tracking systems have emerged:

1. Microprocessor Controlled: These systems utilize mathematical formulations forecast-west and north-south movements,leveraging astronomical coordinates of the sun for precise tracking.
2. Electro-Optical Type: These systems rely on sensors to detect solar intensities. Strategically positioned sensors detect radiation at points, and

collectors orientation is adjusted to minimize intensity differentials sensed[6][7].

This paper presents an Arduino-Driven dual-axis solar tracker developed for cost-effectiveness. This cost reduction is achieved through the utilization of motors and Arduino UNO R3 microcontroller. The hybrid nature of the tracker, combining both open and closed loop control tracking mechanisms, ensures efficient and accurate solar panel orientation throughout the day, maximizing energy harvesting potential.

II. Previous Studies

A. Single-Axis Tracking System.

The Automatic Solar Tracking System (ASTS)operates autonomously, ensuring the solar panel faces the sun at all times it is visible. Unlike conventional systems, ASTS doesn't rely on earth as its reference point; rather, it tracks the sun itself. Using active sensors, it continuously monitors sunlight intensity and adjusts the pane;s orientation to maximize exposure,managed by a microcontroller-based control panel. In Instances like cloudy weather when the sun isn't visible . ASTS pauses until the clouds disperse. Once sunlight is detected again, it realigns the panel to position the sun vertically, ensuring optimal efficiency throughout the day. Additionally, ASTS is equipped to handle errors.

The tracking mechanism is often driven by motors or actuators controlled by a tracking system, which can be based on various technologies such as GPS, light sensors, or timers[8].

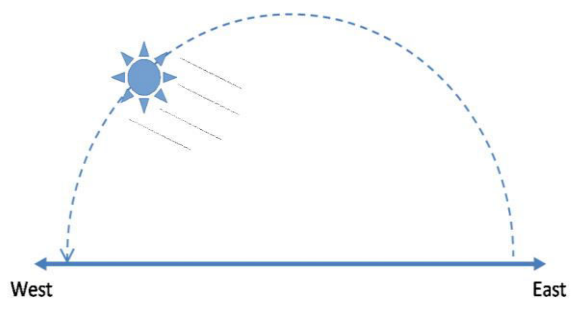

Fig.1. The Sun's Track

B. Dual-Axis Tracking System.

Dual-Axis trackers offer both horizontal and vertical movement capabilities, allowing them to effectively track the sun's apparent motion worldwide. The outcomes of a dual-axis solar tracker, Which consists of the three main components: input, controller and output. The input is provided by LDR, Which detects changes in sunlight intensity. The Arduino UNO R3 with PCB microcontroller operates as the central controller, Processing input data and generating corresponding output commands. The output is controlled by motors accountable for altering the alignment of the solar panels based on the input received from the LDRs.

The performance analysis of the dual-axis solar tracker involved assessing its ability to accurately track the sun's position throughout the day. The input from the LDRs was monitored and analyzed to determine the accuracy of solar tracking achieved by the controller. The output, represented by the position of the motor adjusting solar panel orientation, was observed and compared against the expected solar trajectory.

This system achieves several objectives:

1. Enhanced Energy Generation: By continuously adjusting panel orientation along both horizontal and vertical axes, the system ensures optimal exposure to sunlight leading to increased energy production.
2. Energy Harvest Optimization: Dual-Axis tracking allows panels to capture sunlight at near perpendicular angles, minimizing the angle of incidence and maximizing energy harvesting potential.
3. Adaptation to Daily and Seasonal Changes: The system accommodates variations in the sun's position all over the day and across seasons,ensuring panels capture the appropriate amount of sunlight for optimal performance[9][10].

In the analysis of the dual axis solar tracker demonstrated its effectiveness in optimizing solar panel orientation to maximize sunlight exposure. The integration of input from LDRs, controlled by Arduino UNO R3 with PCB microcontroller, and output through motors resulted in a robust tracking system capable of capturing maximum amount of the solar energy.

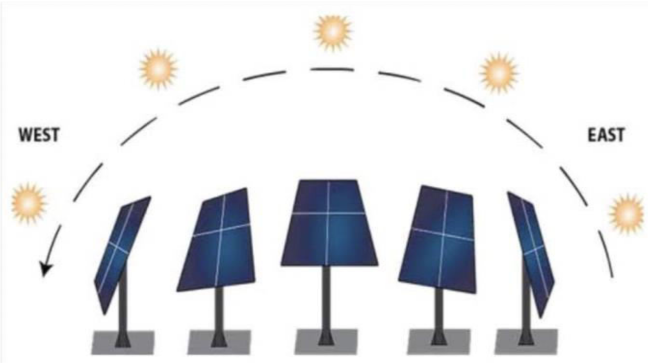

Fig.2. Sun's position for Dual-Axis tracking

The Dual-Axis solar tracker has proven to be highly practical for maximizing sunlight collection in many applications[11]; one such star harvesting application suggests integrating a sun tracking system into smart irrigation setups to enhance efficiency, particularly in areas where energy is costly or unreliable. It details the creation and implementation of such a system in a greenhouse environment, testing different watering strategies and solar panel orientations to optimize efficiency. The results indicate the potential of solar tracking devices to enhance smart irrigation systems. The proposed system is designed to be easily replicated and scalable across diverse agricultural settings, offering an eco-friendly and economical solution for irrigation management[12].

III. METHODOLOGY

The system is classified into two parts which are hardware and software:

A. *Hardware:*

Light Dependent Resistor(LDR):
An LDR, also known as a photoresistor, exhibits photoconductivity, with its resistance inversely proportional to incident light intensity. In this system, The LDR serves as an input device, transmitting light intensity data to the main controller.

Motor:
The type of DC motor operates within a 12V range. It comprises essential components including motor, position sensor, and motor driver. With a limited rotation of 180 degrees, motors are controlled using signals, enabling precise positioning. Motor is employed in the system for horizontal and vertical axis adjustments.

Solar Panel:
The solar panel converts light energy into electricity.The monocrystalline solar panel was chosen for its superior efficiency compared to other types, ensuring optimal energy conversion in the system.

Arduino UNO R3 with PCB:
Arduino, serves as the main controller of this system. This is selected for its compatibility and features, Includes a microcontroller based on Arduino,digital input/output pins, USB connectivity and power jack input. It has an ability to interface with sensors and execute programmed instructions makes it ideal for controlling the solar tracking system.

B. *Software:*

The software component of the system involves programming tasks implemented using embedded C language targeted for Arduino UNO R3. The software flowchart, depicted in Fig.4, outlines the procedural steps:

High-to-Weak signal conversion:
Four LDRs are connected to Arduino analog pins from A0 to A3, providing analog input data to the system. The built-in high voltage signal is given where it steps down the voltage and output is a weak signal.

Motor Control:
These signals determine the direction and position of the motor, facilitating precise adjustments of the solar panel orientation. The system selects the LDR input with the maximum light intensity, and the motor adjusts the solar panel to align with that position, optimizing sunlight capture.

Optimal Positioning:
This strategic positioning ensures efficient solar tracking and maximizes energy harvesting capabilities and is utilized in conjunction with four predefined LDR positions(right, left, up, down).

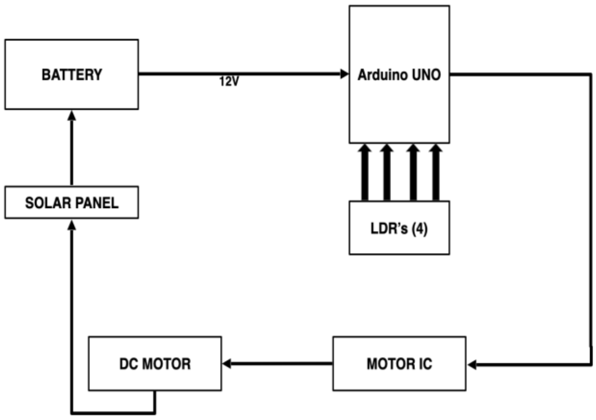

Fig.3. Block Diagram for Dual-Axis Tracker.

C. *Abbreviations*

LDR - Light Dependent Resistor.
DC - Direct Current.
IC - Integrated Circuit.
ASTS - Automatic Solar Tracking System.
GPS - Global Positioning System.
PV - photovoltaic.
PCB - Printed Circuit Board.
RES - Renewable Energy System.
CSP - Concentrated Solar Power.
USB - Universal Serial Bus.

Single-axis and dual-axis solar trackers are both designed to optimize the alignment of solar panels with the sun's position throughout the day, but they differ in their degree of movement and complexity. Single-axis systems adjust solar panels along one axis, typically the horizontal axis, to track the sun's east-west movement. This movement ensures that the panels remain perpendicular to the sun's rays, maximizing energy capture. Single-axis systems are relatively simpler and less expensive to install and maintain compared to dual-axis systems, making these possible for many solar applications where cost-effectiveness is a priority.

In contrast, dual-axis solar trackers have the capability to align solar panels along both horizontal and vertical axes. However, the increased complexity and moving parts of dual-axis systems make them more expensive to install and maintain, which may limit their use to applications where maximizing energy output is critical.

Overall, while both single-axis and dual-axis solar trackers offer benefits over fixed solar panels by improving energy capture, dual-axis systems provide higher precision and energy yield. Single-axis systems are simpler and more cost-effective, while dual-axis systems are ideal for applications where maximizing energy production justifies the additional cost and complexity.

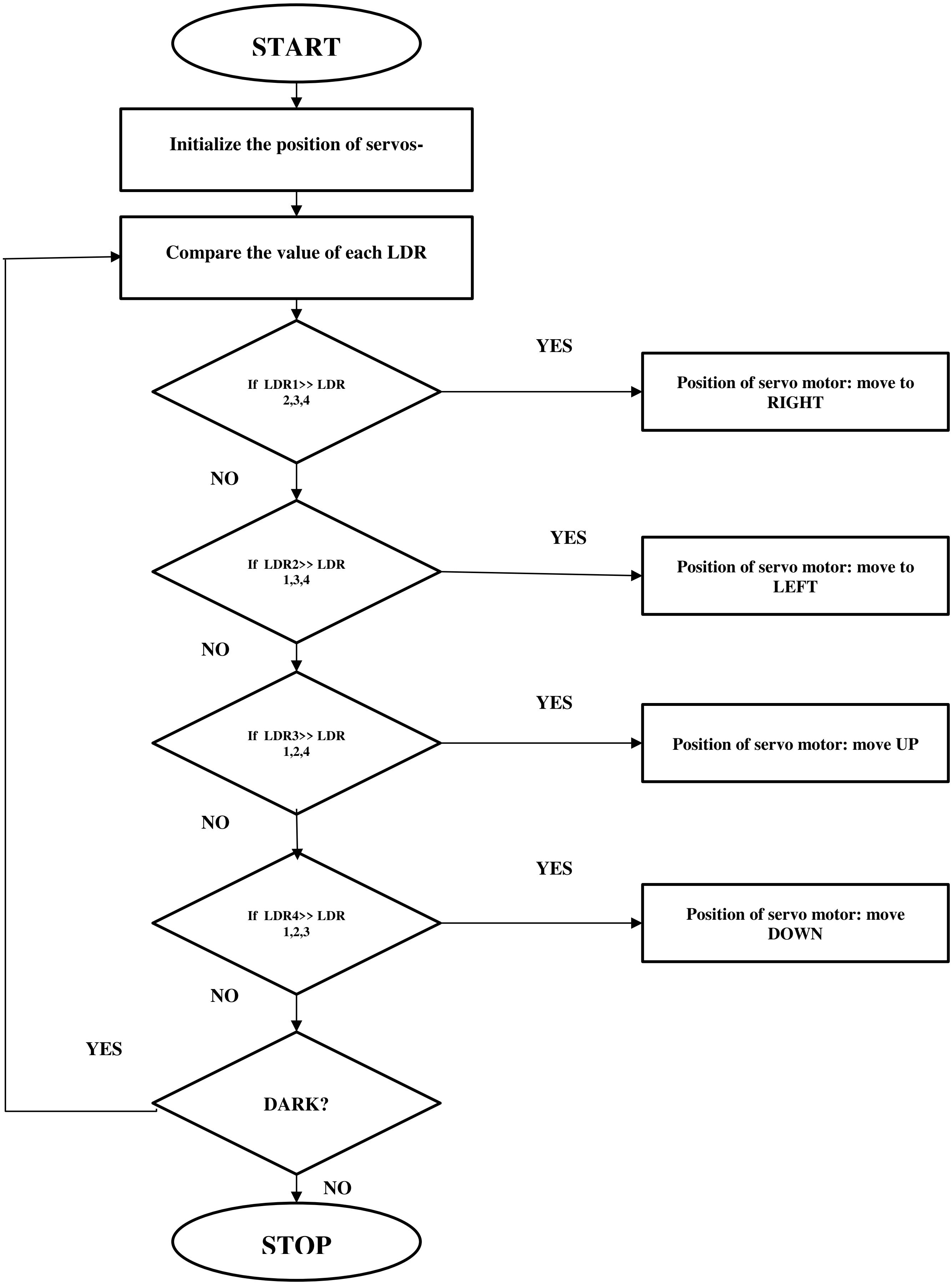

Fig.4.Flowchart of the software program.

IV. RESULT

The results showed that Dual-Axis Tracker produces 10.53watts more power than a single-axis system.This laboratory prototype demonstrated promising performance in optimizing the efficiency of PV modules within a solar energy system. Through continuous alignment with sunbeams, The system effectively maximized the exposure of solar panels to solar radiation, resulting in enhanced energy capture efficiency. Powered by Arduino, the system integrated four LDRs, a DC Motor, and a Motor Driver IC. These components work synergistically to potentially adjust the positioning of solar panels in response to differ in light intensity detected by the LDRs.

Real-time adjustments facilitated by the Arduino code ensured that the solar panels remained aligned with the maximum incident light throughout the day. The system's precise control mechanisms, Supported by stable connections provided by the PCB, contributed to its reliability and effectiveness.

Overall, the results demonstrate the viability of the laboratory prototype in optimizing solar energy utilization. The adaptable nature of the system, coupled with its cost-effectiveness and sustainability, underscores its potential for practical implementation in renewable energy application. Further testing and optimization efforts will be beneficial for refining the systems performance and maximizing its efficiency in real-world scenarios.

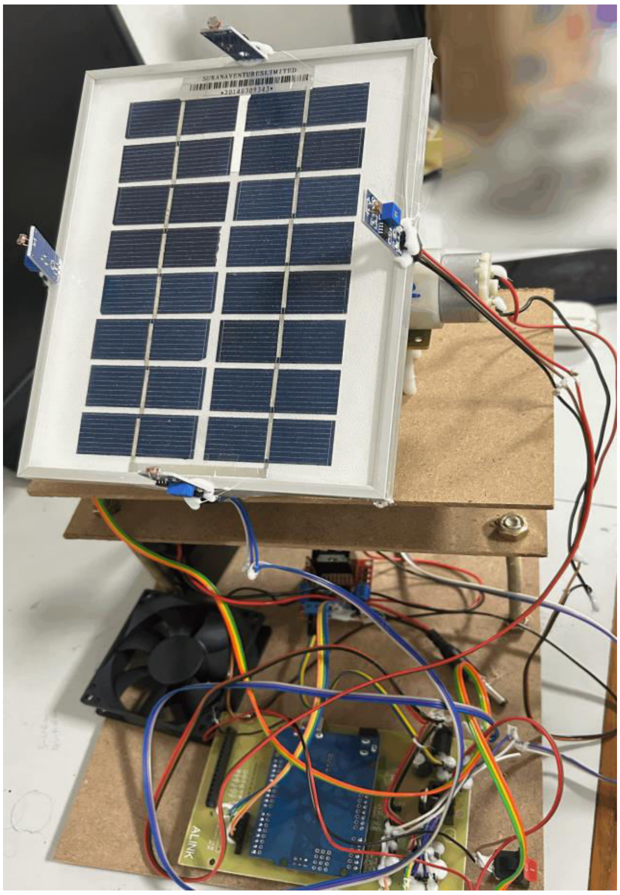

Fig.5. Laboratory Prototype for Dual-Axis Tracking System.

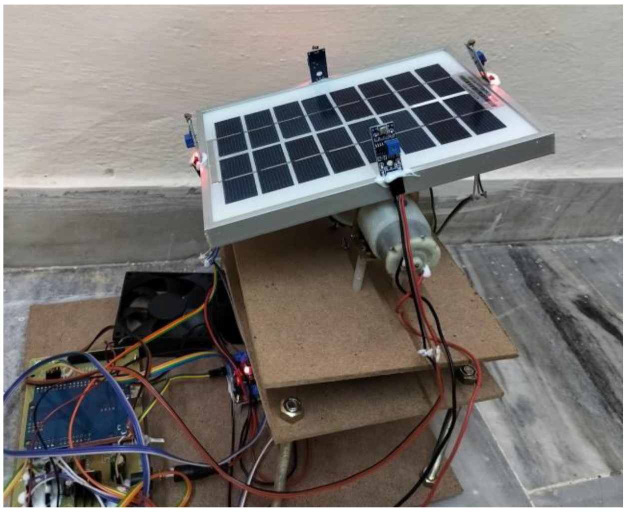

Fig.6(a)

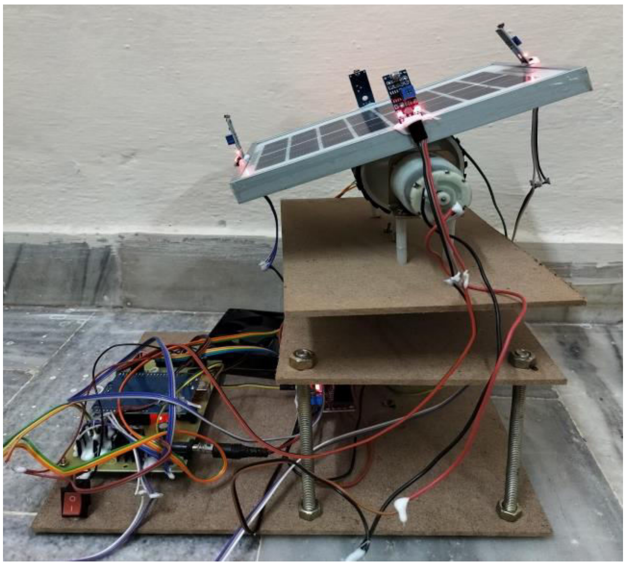

Fig.6(b)

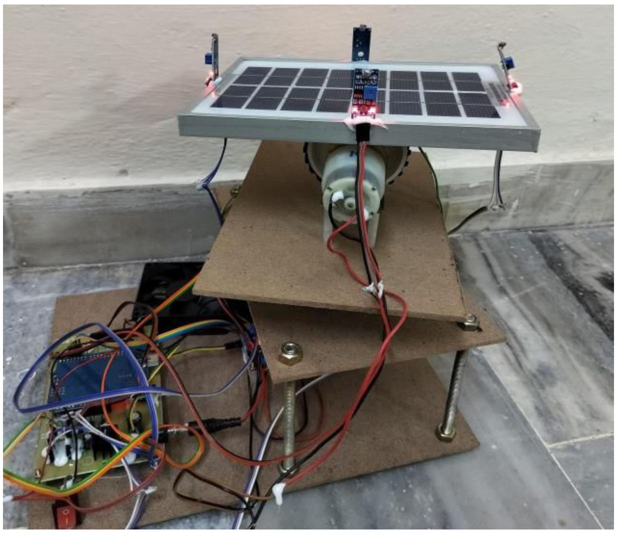

Fig.6(c)

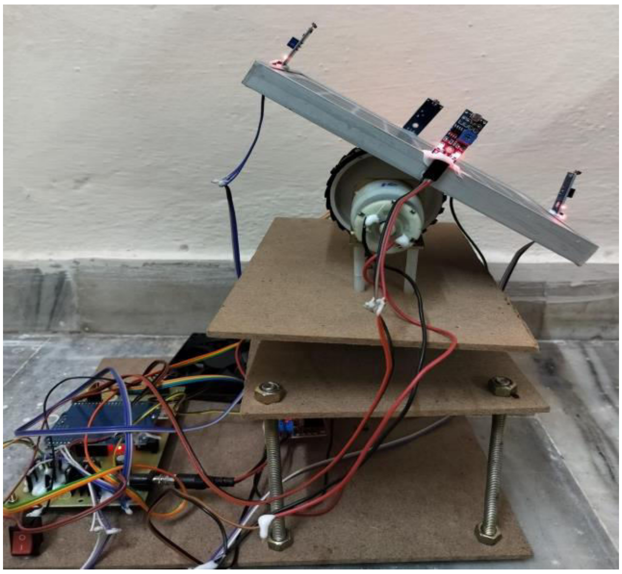

Fig.6(d)

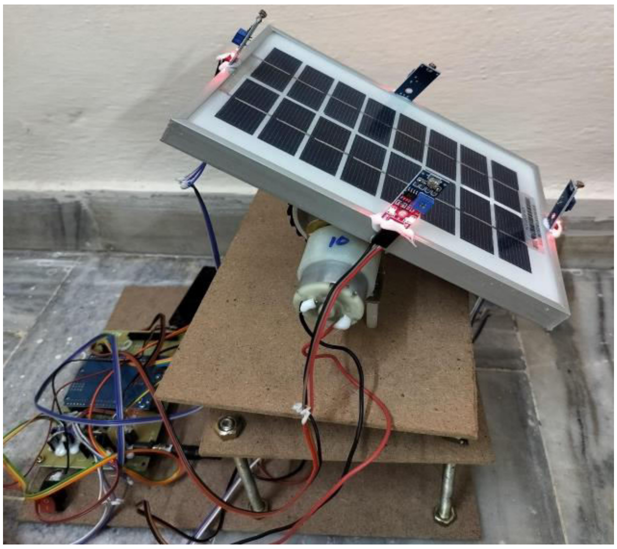

Fig.6(e)

The Figures, labeled as Fig.6(a),(b),(c),(d),(e), depict various positions of a laboratory prototype for Dual-Axis Tracking System.

V. Strategic Benefits of the Proposed Method

1. High Precision Sun Tracking Algorithm.
2. Calculated Angles.
3. High Quality,Industrial Hardened Component.
4. Off-the-Shelf Components.
5. Supply Chain Solutions.
6. Secure REmote Access/Monitoring.
7. Fast,Efficient Data Communications.
8. Faster Development/Troubleshooting.
9. Product Life Cycle.

VI. Conclusion

In conclusion, our analysis of the dual-axis solar tracking system has yielded promising results, comparing the system's performance with that of a static solar panel, we observed higher quality of output voltage, current and power. This underscores the effectiveness of the dual-axis tracking system in optimizing sunlight capture for solar harvesting applications. It also aligns with environmentally friendly practices , addressing the growing demand for electricity.

Looking ahead, there are the opportunity for more research. One recommendation is to explore the system’s performance with higher intensity solar panels, which could potentially yield increased output voltage and current, consequently enhancing overall power output.

Acknowledgment

This study was completed under the direction of Dr. Nagasekhara Reddy Naguru, Associate professor, Head of the Department, Electrical and Electronics Engineering at Stanley College of Engineering and Technology for Women. It gives us great pleasure to express our heartfelt appreciation and respect to our head for his continual guidance, encouragement, useful suggestions and unending patience as we progressed through this project. The Completion of this paper has been possible with his ongoing advice, persistence, and major assistance in completing the work.