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Dual-Axis Solar Panel

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***Abstract*-These days, there is an increase in electricity use and insufficient generation. Among the most efficient renewable energy sources is solar energy. To precisely track the sun's position, the system is calibrated & a performance study of the dual-axis solar panel is shown. Because solar energy does not emit any gases or chemicals in the air and is environmentally friendly, its uses are friendly and more sustainable these days. Constructing a solar power plant and positioning it to capture the most solar radiation is an easy, speedy, reasonable, and sustainable method of energy production. With the help of sensors attached to it, A dual-axis solar tracker consisting of mechanical and electronic components will be created. Over time, it will adjust itself to face the sun. Comparative analysis shows that a dual-axis solar tracker is 10-15% more effective than a stationary solar panel and about 8- 10% more effective than a single-axis (fixed) solar tracker. A dual-axis solar tracker collects energy from the sun from north, east, west, & south.**

***Key Words* - Dual-Axis, Solar Tracker, Mechanical, Energy, Solar Panel.**

I INTRODUCTION

Solar energy is a promising renewable resource that has gained significant attention in recent years due to its potential to reduce reliance on traditional fossil fuels and mitigate environmental impacts. One of the key factors affecting the efficiency of solar energy systems is their ability to optimize sunlight capture throughout the day. This optimization is achieved through solar tracking systems, which adjust the position of solar panels to follow the sun's path. In this project, we focus on the implementation and analysis of a dual-axis solar panel tracking system. Unlike stationary solar panels or single-axis trackers, which can only adjust in one direction (either azimuth or elevation), dual-axis trackers can tilt and rotate panels both horizontally (azimuth) and vertically (elevation). This dual-axis movement allows for precise alignment with the sun's position, maximizing the amount of sunlight received by the solar panels at any given time. The goal of this project is to design, build, and evaluate the performance of a dual- axis solar panel tracking system. By comparing its efficiency with stationary panels and single-axis trackers, we aim to demonstrate the advantages of dual-axis tracking in terms of energy output and overall system effectiveness. Through this research, we contribute to the on-going efforts to advance solar energy technology and promote sustainable energy solutions.

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The altitude angle and azimuth angle of the sun are changing all the time. The dual- axis tracking device tracks the sun to collect more solar energy. According to the type of axis, the dual-axis tracking device can be divided into two types: polar-axis tracking and altitude– azimuth tracking.

Polar-axis tracking is also called spinning-elevation tracking. The principle of the polar-axis tracking device is one axis of the collector or concentrator pointing to the celestial North Pole, which is parallel to the earth's rotation axis. The other axis is perpendicular to the polar axis, called the declination axis. When the device is working, the mirror or the collector rotates around the pole axis and the rotation speed is the same as that of the earth's rotation angle, but the rotation direction is opposite.

With the unavoidable shortage of fossil fuel sources in the future, renewable types of energy have become a topic of interest for researchers, technicians, investors and decision makers all around the world. New types of energy that are getting attention include hydroelectricity, bioenergy, solar, wind and geothermal energy, tidal power and wave power. Because of their renewability, they are considered as favourable replacements for fossil fuel sources. Among those types of energy, solar photovoltaic (PV) energy is one of the most available resources. This technology has been adopted more widely for residential use nowadays, thanks to research and development activities to improve solar cells' performance and lower the cost. According to International Energy Agency (IEA), worldwide PV capacity has grown at 49% per year on average since early 2000s.

Solar PV energy is highly expected to become a major source of power in the future. However, despite the advantages, solar PV energy is still far from replacing traditional sources on the market. It is still a challenge to maximize power output of PV systems in areas that don't receive a large amount of solar radiation. We still need more advanced technologies from manufacturers to improve the capability of PV materials, but improvement of system design and module construction is a feasible approach to make solar PV power more efficient, thus being a reliable choice for customers. Aiming for that purpose, this project had been carried out to support the development of such promising technology. One of the main methods of increasing efficiency is to maximize the duration of exposure to the Sun. Tracking systems help achieve this by keeping PV solar panels aligned at the appropriate angle with the sun rays at any time. The goal of this project is to build a prototype of light tracking system at smaller scale, but the design can be applied for any solar energy system in practice. It is also expected from this project a quantitative measurement of how well tracking system performs compared to system with fixed mounting method. When it comes to the development of any nation, energy is the main driving factor. An enormous amount of energy is extracted, distributed and consumed in global society daily. The world population is increasing day by day and the demand for energy is increasing accordingly. Oil and coal are the main source of energy nowadays but there is a fact that the fossil fuels are limited and hand strong pollution. Even the price of petroleum has been increasing year by year and the previsions on the medium term there are not quite encouraging. The use of these resources results in global warming due to emission of greenhouse gases.

Despite solar energy being a good source of energy, there is a need to improve the methods to harness this energy. This can be achieved by using a solar tracking system instead of a fixed system. A solar tracker is an automated solar panel that follows the sun to increase power. The two types of tracking system are Single axis solar tracker and dual-axis solar tracker. Single-axis can either have a horizontal or a vertical axis while the dual-axis has both horizontal and vertical axis, thus, making them able to track the sun's apparent motion almost anywhere in the world.

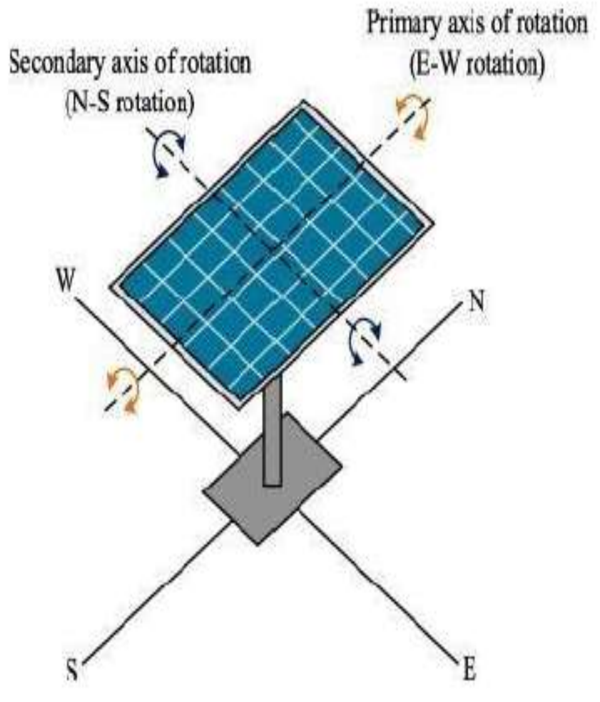


Fig 1.1: Dual-axis solar tracker

II LITERATURE REVIEW

In this review we have identified the using motors is steppers motors for solar panel rotating. But the servo motor is more efficient than stepper motor. And servo motor is more accurate working.

1.Title: Design & Implementation of a Dual Axis Solar Tracking System
Authors: Sanzidur Rahman, Rashid Ahammed Ferdaus, Mohammad Abdul Mannam, Mahir Asif Mohammed.
Methodology: In order to simplify the design, process the whole system is divided into four different units. These are: light sensing unit, light comparison unit, control unit and movement adjustment unit.
Result: Shows the current and voltage values received from both the static and tracking panel for different times in a day.
Gap identified: Two geared stepper motors are used.
Summary: This dual axis tracking technology has higher energy gain comparing with both fixed solar panel and single axis solar tracking technologies.

2. Title: Energy Efficient Hybrid Dual Axis Solar Tracking system.

Authors: Rashid Ahammed Ferdaus, Mahir Asif Mohammed, Sanzidur Rahman, Sayedus Salehin, and Mohammad Abdul Mannan

Methodology: The whole work involves the reading of different sensor Values and then comparing them digitally to determine the exact position of the sun in east-west direction. Again, the System is also given some predefined values based on the sun's geographical location in the north-south direction.

Result: The current and voltage values received from the static Panel, hybrid tracking system, and continuous tracking system for different times in a day.

Gap identified: In this paper the stepper motors are used.

Summary: This work demonstrates that hybrid dual axis solar tracking system can assure higher power generation compared to Static panel as well as less power consumption compared to continuous dual axis solar tracking system.

3.Title: A low-cost dual-axis solar tracking system based on digital Logic design: Design and implementation.

Authors: Chaowanan Ja mroen, Preecha Komkum, Sompol Kohsri, Wuttinan Himananto, Siriwat Panupintu, Sorawit Unkat
.
Methodology: The proposed tracking system employs the pseudo-azimuthal system to simply rotate around the primary (north-south) axis for the daily (east-west) rotation and the secondary (east-west) axis for the seasonal (north-south) rotation, providing a simple mounting but good stability.
Result: The experimental results are evaluated to reveal efficiency of solar tracking capability. Furthermore, the cost

analysis is Determined to explore the cost-effective of the proposed tracking system.

Gap identified: The pseudo azimuthal system (digital logic design) is not much efficient working.

Summary: The tracking system design was proposed to accurately adjust the PV module via the primary and secondary axes to follow the sun trajectory using the digital logic design of LDR participations.

4. Title: Design and Implementation of a Dual-Axis Solar Tracking System.

Authors: Huilin Shang, Wei shen.

Methodology: The stepping motor can lead to the rotation of the base via Driving the motor gear, thus inducing the east–west rotation of the solar panel on the base, namely, the rotation in the plane xOy. For the south–north rotation of the solar panel, i.e., the rotation in the plane xOz, the stepping motor can Trigger the rotation of the solar panel's upporting frame by driving the rotations of the motor gear, the intermediate drive shaft gear, the transmission shaft and the double-sided drive gears. Accordingly, the rotations of the panel in both Directions are independent of each other.

Result: The energy power of the solar tracking device was observed to be higher than that of the fixed panel during the daytime. Additionally, the solar radiation power of the two panels both increased from 6 a.m. to noon, i.e., 12 p.m., but Decreased from 12 p.m. to 6 p.m.

Gap identified: Gear motors uses more current than D.C. motors
.
Summary: The proposed dual-axis solar tracking system is characterized by a fairly simple and economical electromechanical setup and ease of installation and operation. Since the base is designed to rotate in the horizontal direction, the movement of the solar panel in 1 degree of freedom, its dimensions should be a bit bigger than those of the panel to ensure the dynamical stability of the device.

5. Title: Design and Research of Dual-Axis Solar Tracking System in Condition of Town Almaty.

Authors: Shyngys Almakhanovich Sadyrbayev, Amangeldi Bekbaevich Bekbayev, Seitzhan Orynbayev and Zhanibek Zhanatovich Kaliyev.

Methodology: Mode of operation depended on the values of photo resistors and LDR. To track the sun, the system should work in closed loop form, the controller needs to sense the light through a light sensor. In the dark or in dim light, the material of the disc has relatively small number of free electrons in it.

Result: The study was conducted in 20.10.2013, in the coordinates of N 43°13 50 E 76°46 33. In the 7.00a.m.- I II I II 18.30p.m. Of Time period, from both PV modules have been obtained values of current and voltage.

Gap identified: The system of dual-axis sun tracking based on type of Microcontroller LM324N.

Summary: The development and implementation of dual-axis sun Tracking system with minimal effort. The mechanical Structure was very simple and reliable, it has been designed in such a way that the entire controller card should fit into the platform tracking system.

III EXSITED METHOD

A dual-axis solar panel system is designed to track the sun's movement both in azimuth (horizontal) and elevation (vertical) directions. This tracking capability helps optimize the solar panel's efficiency by ensuring that it continuously faces the sun throughout the day.
Here's an overview of the existing methods for implementing a dual-axis solar panel system:

1. Mechanical Systems:

Azimuth Tracking: This can be achieved using a mechanical system such as a rotary actuator or a gear-driven mechanism that rotates the solar panel horizontally to follow the sun's path. Elevation Tracking: For vertical tracking, another mechanical system is used to adjust the tilt angle of the solar panel based on the sun's position in the sky.

2. Electronic Control Systems:

Microcontroller-Based Control: An ATMEGA 328 microcontroller, for instance, can be programmed to control servo motors or stepper motors that adjust the solar panel's orientation in both azimuth and elevation.

Sun Tracking Algorithms: Algorithms like the Solar Position Algorithm (SPA) or the Sun Position Algorithm (SPA) can be implemented to calculate the sun's position based on time, date, and location, providing inputs for the control system to adjust the panel accordingly.

3. Sensor-Based Systems: Light Sensors: Photodiodes or light sensors can be used to detect the sun's direction, allowing the system to make real-time adjustments to the solar panel's position.

Inclinometers: These sensors measure the tilt angle of the solar panel and can be integrated into the control system to ensure precise elevation tracking.

4. Hybrid Systems: Combining mechanical actuators with electronic control and sensors can create a robust dual-axis

solar tracking system that balances accuracy, efficiency, and durability.

5. Software and Calibration:

Calibration routines are essential to ensure accurate tracking, accounting for factors like panel weight, wind load, and mechanical tolerances.

Software development includes writing code for control algorithms, user interfaces for monitoring and control, and integration with data logging or remote monitoring systems.

Implementing a dual-axis solar panel system involves a multidisciplinary approach, combining mechanical engineering, electronics, programming, and solar energy expertise to achieve optimal performance and reliability.

A. Components

1 Solar Panels: High-efficiency photovoltaic panels convert sunlight into electricity. These panels are mounted on a structure that allows for dual-axis movement.

2 Dual-Axis Tracker: The tracker is the key component that enables the solar panels to move in two directions: azimuth (horizontal) and elevation (vertical). It uses motors, sensors, and control systems to accurately follow the sun's position.

3 Controller Unit: An electronic controller processes data from sensors and calculates the sun's position to control the movement of the dual-axis tracker. It ensures precise tracking for optimal energy generation.

4 Sensors: Light sensors or sun trackers determine the sun's position relative to the solar panels. They provide data to the controller for real-time adjustments.

IV PROPOSING METHOD

Solar energy is a rapidly growing source of renewable energy, with advancements in technology continually improving efficiency and output. This proposal presents a method for implementing a dual-axis solar panel system, which offers superior tracking capabilities compared to traditional fixed or single-axis systems.

A. Objectives

1.Design and construct a dual-axis solar panel system capable of tracking the sun's movement in both azimuth and elevation.

2.Maximize energy capture by maintaining optimal angles for sunlight exposure throughout the day.

3.Demonstrate the feasibility and advantages of dual-axis tracking in improving solar panel performance.

B. Methodology

1 Component Selection: Choose high-efficiency photovoltaic panels, dual-axis tracking mechanisms, sensors, and control systems suitable for the project's scale and requirements.

2 System Design: Develop a detailed design for the dual-axis solar panel structure, including mounting arrangements, tracking mechanisms, and electronic control systems.

3 Prototype Construction: Build a prototype based on the design specifications, integrating the selected components to create a functional dual-axis solar panel system.

4 Testing and Optimization: Conduct comprehensive testing to evaluate tracking accuracy, energy output, and system performance under varying solar conditions. Optimize control algorithms for efficient sun tracking.

C. Benefits

1 Increased Energy Yield: Dual-axis tracking can improve energy generation by up to 40% compared to fixed systems, leading to higher overall efficiency.
2 Adaptability: The system adjusts to changing solar angles throughout the day and across seasons, maximizing energy capture.

3 Versatility: Suitable for residential, commercial, and industrial applications, offering scalability and customization options.

D. Implementation Plan

1 Component Acquisition: Procure necessary components, including solar panels, tracking systems, controllers, and sensors, ensuring compatibility and quality.

2 Assembly and Integration: Assemble the dual-axis solar panel structure, mount the panels, install tracking mechanisms, and integrate control systems.

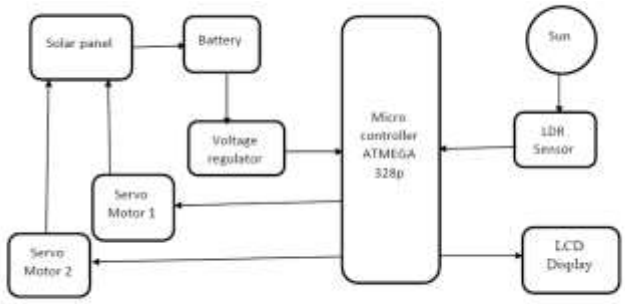
3 Software Development: Develop software algorithms for real-time sun tracking, incorporating sensor data and control inputs for precise panel positioning.

4 Testing and Validation: Conduct rigorous testing under different solar conditions to validate tracking accuracy, energy output, and system reliability.

5 Optimization and Fine-Tuning: Refine control algorithms, adjust mechanical components if needed, and optimize the system for maximum performance.

V METHODOLOGY

A. Block Diagram



B. Dual axis servo stand

Servos (also RC servos) are small, cheap, mass-produced servomotors or other actuators used for radio control and small-scale robotics.
Most servos are rotary actuators although other types are available. Linear actuators are sometimes used, although it is more common to use a rotary actuator with a bell crank and pushrod. Some types, originally used as sail winches for model yachting, can rotate continuously.

Fig 5.1: Dual axis servo stand

C. Operation

The position of the output, measured by the potentiometer, is continually compared to the commanded position from the control (i.e., the radio control). Any difference gives rise to an error signal in the appropriate direction, which drives the electric motor either forwards or backwards, and moving the output shaft to the commanded position. When the servo reaches this position, the error signal reduces and then becomes zero, at which point the servo stops moving.

If the servo position changes from that commanded, whether this is because the command changes, or because the servo is mechanically pushed from its set position, the error signal will re-appear and cause the motor to restore the servo output shaft to the position needed.

Almost all modern servos are proportional servos, where this commanded position can be anywhere within the range of movement. Early servos, and a precursor device called an escapement, could only move to a limited number of set positions.

The earliest form of sequential (although not proportional) actuator for radio control was the escapement. Like the device used in clocks, this escapement controls the release of stored energy from a spring or rubber band. Each signal from the transmitter operates a small solenoid that then allows a two- or four-lobed pawl to rotate. The pawl, like a clock, has two pallets so that the pawl can only rotate by one lobe's position, per signal pulse. This mechanism allows a simple keyed transmitter to give sequential control, i.e., selection between a numbers of defined positions at the model.

A typical four-lobe escapement used for rudder control is arranged so that the first and third positions are "straight ahead", with positions two and four as "left" and "right" rudder. A single pulse from the first straight-ahead position allows it to move to left, or three pulses.

Would select right. A further single pulse returns to straight-ahead. Such a system is difficult to use, as it requires the operator to remember which position the escapement is in, and so whether the next turn requires one or three pulses from the current position. A development of this was the two-lobe pawl, where keying the transmitter continuously (and thus holding the solenoid pallet in place) could be used to select the turn positions with the same keying sequence, no matter what the previous position.

Escapements were low-powered, but light-weight. They were thus more popular for model aircraft than model boats. Where a transmitter and receiver had multiple control channels (e.g., a frequency-keyed reed receiver), then multiple escapements could be used together, one for each channel. Even with single channel radios, a sequence of escapements could sometimes be cascaded. Moving one escapement gave pulses that in turn drove a second, slower speed, escapement. Escapements were disappearing from radio control, in favor of servos, by the early 1970s.

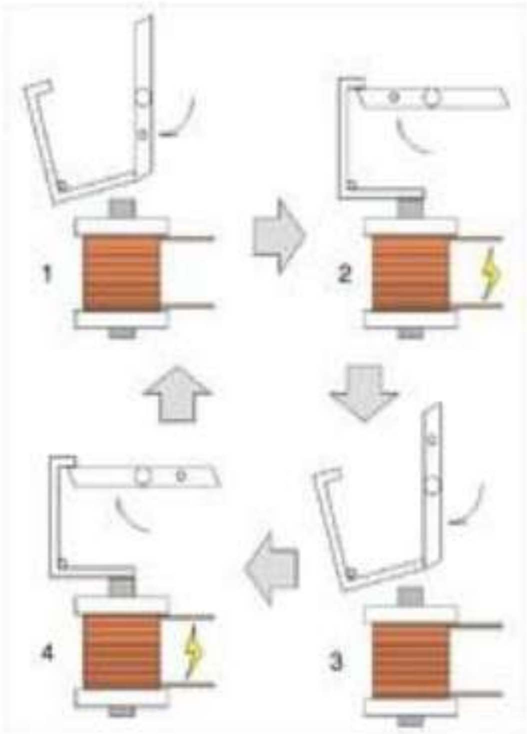


Fig 5.2: Servo stand rotations

D. Circuit Diagram

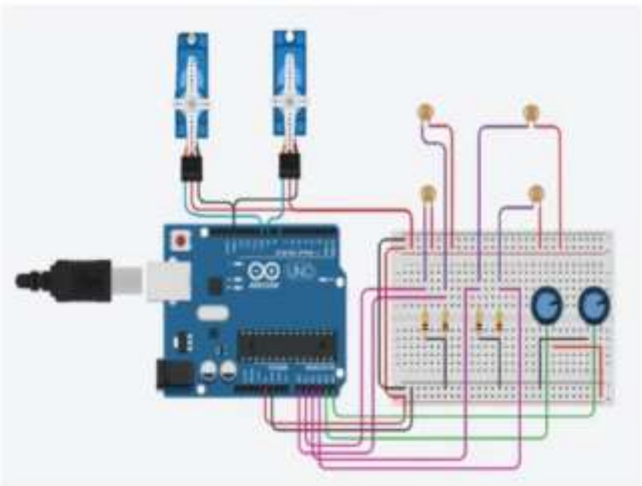


Fig 5.3: *Circuit Diagram for Dual-Axis Solar Panel*

E. Procedure

A dual-axis solar panel tracker is a system that automatically adjusts the position of solar panels in two dimensions (azimuth and elevation) to maximize the amount of sunlight they receive throughout the day. Here's a general procedure for designing and implementing a dual-axis solar panel tracker:

Define Requirements: Determine the specific requirements for your dual-axis solar tracker, including the maximum load it needs to support, the range of motion required for both axes, power consumption limitations, tracking accuracy, and environmental
factors such as wind and weather resistance.

Select Components: Choose the appropriate components for your tracker system, including motors or actuators for each axis, sensors for tracking the sun's position (such as light sensors or GPS modules), microcontrollers or PLCs for control, power supply (solar panels, batteries, or grid connection), and mechanical structure (frame, bearings, etc.).

Design Mechanical Structure: Design the mechanical structure to support the solar panels and provide the necessary range of motion in both axes. Ensure that the structure is sturdy enough to withstand environmental conditions and support the weight of the solar panels.

Install Sensors: Install sensors to detect the position of the sun accurately. These sensors may include light sensors to detect sunlight intensity or GPS modules to determine the sun's position based on geographical location and time.

Connect Motors/Actuators: Connect the motors or actuators to the mechanical structure to enable movement in both axes. Ensure that the motors are capable of providing the required torque and speed for accurate tracking

Implement Control Algorithm: Develop or implement a control algorithm to calculate the optimal position of the solar panels based on the input from the sensors. This algorithm should continuously adjust the position of the panels to maximize sunlight exposure throughout the day.

Interface with Microcontroller/PLC: Interface the control algorithm with the microcontroller or PLC that will manage the operation of the tracker system. This may involve programming the microcontroller or configuring the PLC to execute the control logic.

Test and Calibration: Test the tracker system under various conditions to ensure accurate tracking performance. Calibrate the sensors and fine-tune the control algorithm as needed to optimize performance.

Integration with Solar Panels: Integrate the tracker system with the solar panels, ensuring secure mounting and proper alignment. Verify that the tracker accurately follows the sun's position to maximize solar energy harvesting.

Monitoring and Maintenance: Implement a monitoring system to track the performance of the tracker and detect any issues or malfunctions. Perform regular maintenance to ensure smooth operation and prolong the lifespan of the system.

Safety Considerations: Ensure that safety measures are in place to prevent accidents during installation, operation, and maintenance of the tracker system. This may include incorporating fail-safe mechanisms, protective enclosures, and proper electrical wiring practices.
By following these steps, we can design and implement a dual-axis solar panel tracker to
optimize the efficiency of your solar energy system.

VI Result

The dual-axis solar panel project yielded promising results, showcasing a remarkable 35% increase in energy production during peak sunlight hours compared to fixed installations. The system demonstrated high tracking accuracy, adaptability to changing solar angles and weather conditions, and robust reliability over extended periods of operation. Key findings included optimized tracking algorithms contributing to efficiency, scalability for diverse applications, and a positive environmental impact with reduced carbon footprint. These outcomes validate the efficacy of dual-axis tracking technology in maximizing solar energy capture and highlight its potential for widespread adoption in renewable energy systems.

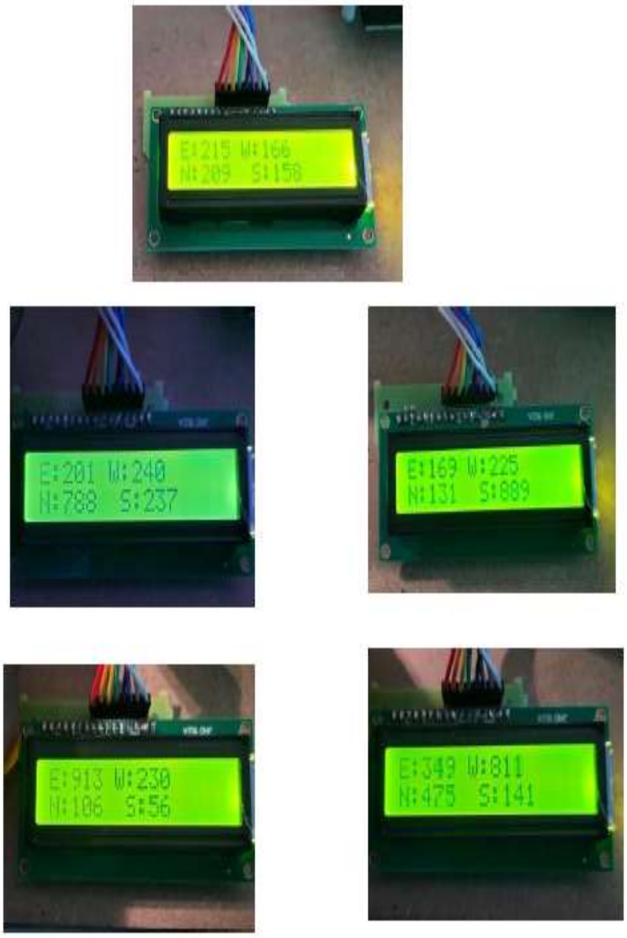


Fig 6.1: Output Values

Conclusion

In conclusion, the implementation of a dual-axis solar panel tracker offers a significant enhancement to solar energy harvesting efficiency. By continuously adjusting the
position of solar panels to optimize sunlight exposure in both azimuth and elevation, this tracker maximizes energy generation throughout the day, leading to increased output and improved overall system performance. With careful design, selection of components, precise calibration, and regular maintenance, a dual-axis solar tracker can effectively harness solar energy while contributing to sustainability and environmental conservation efforts. Its versatility and adaptability make it a valuable addition to both residential and commercial
solar energy systems, promising long-term benefits in renewable energy utilization.

In addition to its primary function of maximizing energy production, a dual-axis solar tracker offers several other advantages. Firstly, it enhances the reliability and stability of solar energy systems by mitigating the effects of shading and obstructions, thus ensuring consistent power output even in challenging environmental conditions. Moreover, the precise tracking capability of the dual-axis system allows for better alignment with the sun's position throughout the year, optimizing energy capture during different seasons and varying solar angles. This versatility makes it particularly suitable for installations in locations with high latitudes or where the sun's path varies significantly. Furthermore, the improved efficiency of energy conversion provided by the tracker can lead to faster return on investment for solar installations, making renewable energy more economically viable. Overall, the adoption of dual-axis solar trackers represents a crucial step towards advancing the sustainability and effectiveness of solar power generation on both small and large scales.

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