

A Survey of Dual-Axis Solar Tracker System Using Arduino PHASE-I

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Accepted 23-04-2026

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Abstract

Solar energy is clean and gives unlimited power sources, as per growing requirements of solar energy it should be utilised efficiently. The automated solar tracking system based on the Arduino prototype is mainly built using the Arduino Microcontroller, four LDRs and two servo motors. A mixture of hardware and programmed software is used to run the machine. Four Light Dependent Resistors (LDRs) are used to capture the maximum sunlight. LDRs helps to detect the strongest sunlight intensity. To shift the solar panel according to the LDRs instructions (where the sunlight is stronger), two servo motors are used. These motors are used to direct the solar panel's in both vertical and horizontal direction. Thus, according to the incident sunlight on the solar panel, it can follow the direction of the Sun, not only the vertical rotation, but also the horizontal rotation. This device can achieve maximum light and reduce the cost of generating energy by requiring a minimum number of solar panels. This device not only track the sunlight during days but also in different months and seasons, therefore this device requires a Real Time Clock (RTC) device for guiding the tracking system for seasonal changes in suns position, So the combination of this tracking system made it call as hybrid dual axis solar tracking system. The power gain and system power of hybrid dual axis solar tracking system is compared with the static and continuous dual axis solar tracking system. It is concluded that the power gain of hybrid dual axis solar tracking system is equals to the power gain of continuous dual axis system and the power saved in hybrid dual axis system is 44.44% compared to continuous tracking system.

1. Introduction

Due to the high and constantly increasing demands for energy throughout the world, the exploitation of various conventional energy sources has been induced. Considering the environmental issues, the non-renewable energy sources cause the greenhouse effect and the renewable energy sources like solar, wind, biomass and hydro are limited and are reduced to this degradation. Among these solar energy holds the most significant promise, as it is most clean, cost-free, and

inexhaustible resource of energy. To convert the solar energy into the electrical energy, Photovoltaic (PV) solar panels are used widely as important component in the solar tracking systems. A PV solar panel is made from a large number of solar cells composed of silicon like semiconductors. It works by transferring the energy of photons from sunlight that strikes the solar cells to silicon electrons, which then flow through the electrodes and the external circuit and electric current.

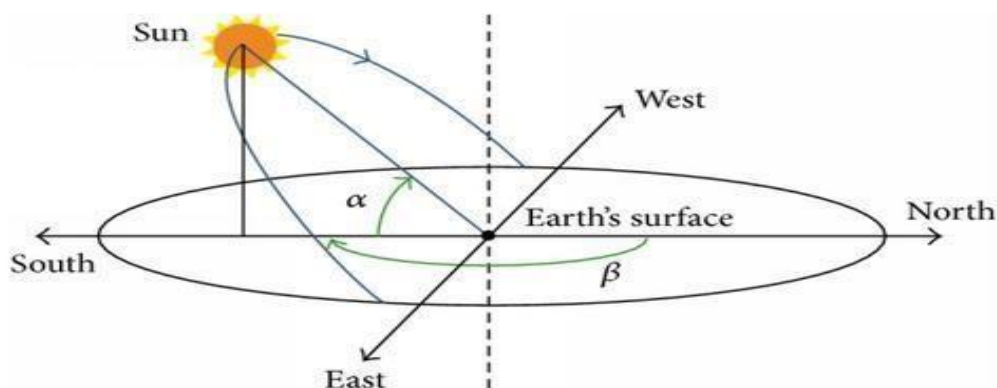


Fig.1: Sun Path Diagram With Different Angles

The diagram shows the vertical angle (α) and horizontal angle (β) used in the dual axis solar tracking system to track the movements of sun. Earlier the fixed solar panels are utilised largely as fixed tracking can easily accommodate harsh environmental conditions. There are three typical structural installations of fixed solar panels, they are: fixed-angle, vertical-angle and the seasonal-adjusted fixed-angle installations. Fixed angle solar panels has been extensively used in large solar power stations and roof top solar tracking systems, where the vertical panels are available for vertical structures with the limited space, such as the facades of high-rise buildings. With seasonal-adjusted fixed angle systems, the solar panels tilt angles in horizontal directions which can be modified for seasonal variations in order to maximise the amount of solar radiation. Although the angle adjustment is not convenient due to many site attributes, such as the security measures of working on rooftops or the high buildings and the human cost of adjusting a large of solar panels in solar power stations. Compared to fixed solar panels, solar tracking systems that can track the position of the sun based on both the season and the movement of each day have higher solar energy collection efficiency, thus it has broader applications and higher research value. Based on the different degrees of freedom of structures, there are two types of solar tracking systems, they are: single axis and dual-axis. The single axis is designed to track the sun according to the azimuth angle, whereas dual axis is designed to track the sun through the dual axes corresponding to azimuth and solar altitude angles. In recent years novel, technologies and designing for both types has been developed a lot to achieve high accuracy, efficiency and structural reliability for systems' practical performance.

2. Necessity of Dual-Axis Solar Tracker

1. Maximizing Solar Energy Capture

The primary necessity of dual-axis solar tracker is to maximize the amount of solar energy captured by a solar panel. A fixed solar panel receives

sunlight at varying angles throughout the day and across seasons, which reduces its energy output. A dual-axis tracker, can follow the sun's movement both horizontally and vertically. This ensures that the panel is almost always perpendicular to the sun rays, thereby increasing the incident sunlight and electrical output. Generally, the dual-axis tracking can increase 40% of energy capturing compared to other tracker system.

2. Improving System Efficiency

Solar panels are most efficient when sunlight strikes their surface **directly at a 90 degree angle**. A dual-axis solar tracker continuously adjusts the panel's orientation to maintain the optimal angle, thereby reducing energy losses and increasing the overall efficiency, which is difficult in regions with fluctuating sunlight when the sun's angle is low.

3. Adaptation to Seasonal Variations

The sun's position changes not only daily but also seasonally due to tilt of the Earth's axis. A dual-axis tracker compensates for these variations automatically. By adjusting both the tilt and rotation, the system maintains optimal solar exposure throughout the year. Where as in fixed panels, it may require manual adjustment or tilt correction, which is prone to error and is difficult.

4. Cost-Benefit Justification

Although dual-axis tracker involve higher initial costs and additional mechanical components that increase in energy output justifies the investment.

5. Supporting Renewable Energy Goal

Moving towards the renewable energy and carbon reduction, maximizing solar energy has become essential. **Dual-axis solar trackers increase energy without increasing the number of solar panels**, which make it more sustainable and efficient for solar installations.

Title	Authors and Year	Investigation	Advantages	Limitations

<p>“Dual-Axis Solar Tracker”</p>	<p>Priyam Bhattacharya in 2025</p>	<p>This research describes that a dual-axis tracking system keeps the solar panels according to the sun’s position throughout the day using sensors and microcontrollers to optimize the solar energy.</p>	<p>1.It gives continuous sun tracking 2.It provides higher energy output. 3.Also provides good efficiency.</p>	<p>1.It requires control algorithms 2.As more components used in the system the complexity increases.</p>
<p>“Solar Tracking System With Dual-Axis”</p>	<p>Kushal Y, Nithin M, Jagadeesh B, Vinith J. Samson in 2023</p>	<p>This describes the developed automated solar tracking system using sensors and microcontrollers, which is used to track both daily and seasonal movements.</p>	<p>1.It supports Automatic tracking. 2.It gives increased solar energy.</p>	<p>1.More power consumption by motors.</p>
<p>“Design And Implementation Of Dual-Axis Solar Tracking System”</p>	<p>Huilin Shang and Wei Shen in 2023</p>	<p>These authors designed a dual-axis solar tracker using a photoelectric tracking method to follow the sun’s movement. This system compares the radiation between a fixed panel and tracking panel.</p>	<p>1.It has higher efficiency than fixed panels. 2.It provides improved energy collection.</p>	<p>1. High installation cost. 2.It requires regular maintenance.</p>
<p>“Solar Tracking System Using Stepper Motor”</p>	<p>Ankit Anuraj and Rahul in 2018</p>	<p>The authors proposed a solar tracking system using a stepper motor, LDR sensors, and an ATmega16 microcontroller. The system is used to detect sunlight using the photo resistors and rotates the solar panel using a stepper motor.</p>	<p>1.It has high tracking accuracy 2.It provides improved solar energy output.</p>	<p>1.Stepper motor speed limitation 2.It is generally expensive.</p>

3. Literature Survey

The major technologies in the field of Dual axis solar tracking system are briefly reviewed.

Title	Authors and Year	Investigation	Advantages	Limitations
“Dual Axis Solar Tracker”	Abhishek Surti, Hanan Mansoori, Sameer Salunke in 2017	This paper presents a solar tracker controlled by a microcontroller and photo sensors that adjust the panel position towards the sun to obtain the maximum power.	1.It has Simple control system, 2.Provides increased solar power.	1.It has limited scalability.
“Maximum solar power tracker using Dual Axis Tracker”	B. Balaji, A. Arulvizhi, J. Jayashree in 2017	The paper presents a mechanical Solar tracking in two axes to obtain maximum solar radiation	1.Reduced energy loss. 2.This system is used to improve solar output.	1.The system faces the mechanical complexity. 2.It requires regular maintenance.
“Design and Implementation of a Sun Tracker with Dual Axis”	Jing-Min Wang and Chia-Liang Lu in 2013	Here the authors developed an optical sensor-based dual-axis tracker to improve solar power by maintaining the panel in perpendicular direction to sun.	1.The system has high tracking accuracy. 2.And also has improved energy production.	1. The system is made up of expensive sensors. 2. It has complex control design.
“Sliding Mode Control for Sensorless Solar Tracker”	Ahmed Rhif in 2012	This research introduced a control system for a solar tracker that predicts sun’s position without sensors and increases energy production.	1.The system is built without any sensors. 2.The system has good efficiency.	1.The programming is complex for the tracker. 2.It requires high level controlling design.

“Dual-Axis Solar Tracker” describes that a dual-axis tracking system keeps the solar panels according to the sun’s position throughout the day using sensors and microcontrollers to optimize the solar energy.

“Solar Tracking System With Dual-Axis” This paper of 2023 describes the developed automated solar tracking system using sensors and microcontrollers, which is used to track both daily and seasonal movements.

“Design And Implementation Of Dual-Axis Solar Tracking System” The paper represented a dual-axis solar tracker using a photoelectric tracking method to follow the sun’s movement. This system compares the radiation between a fixed panel and tracking panel.

“Solar Tracking System Using Stepper Motor” Here the authors proposed a solar tracking system using a stepper motor, LDR sensors, and an ATmega16 microcontroller. This system is used to detect sunlight using the photo resistors and rotates the solar panel using a stepper motor.

“Dual Axis Solar Tracker” This paper presents a solar tracker controlled by a microcontroller and

photo sensors that adjust the panel position towards the sun to obtain the maximum power.

“Maximum solar power tracker using Dual Axis Tracker” This paper presents a mechanical solar tracking in two axes to obtain maximum solar radiation.

“Design and Implementation of a Sun Tracker with Dual Axis” Here the authors developed an optical sensor-based dual-axis tracker to improve solar power by maintaining the panel in perpendicular direction to sun.

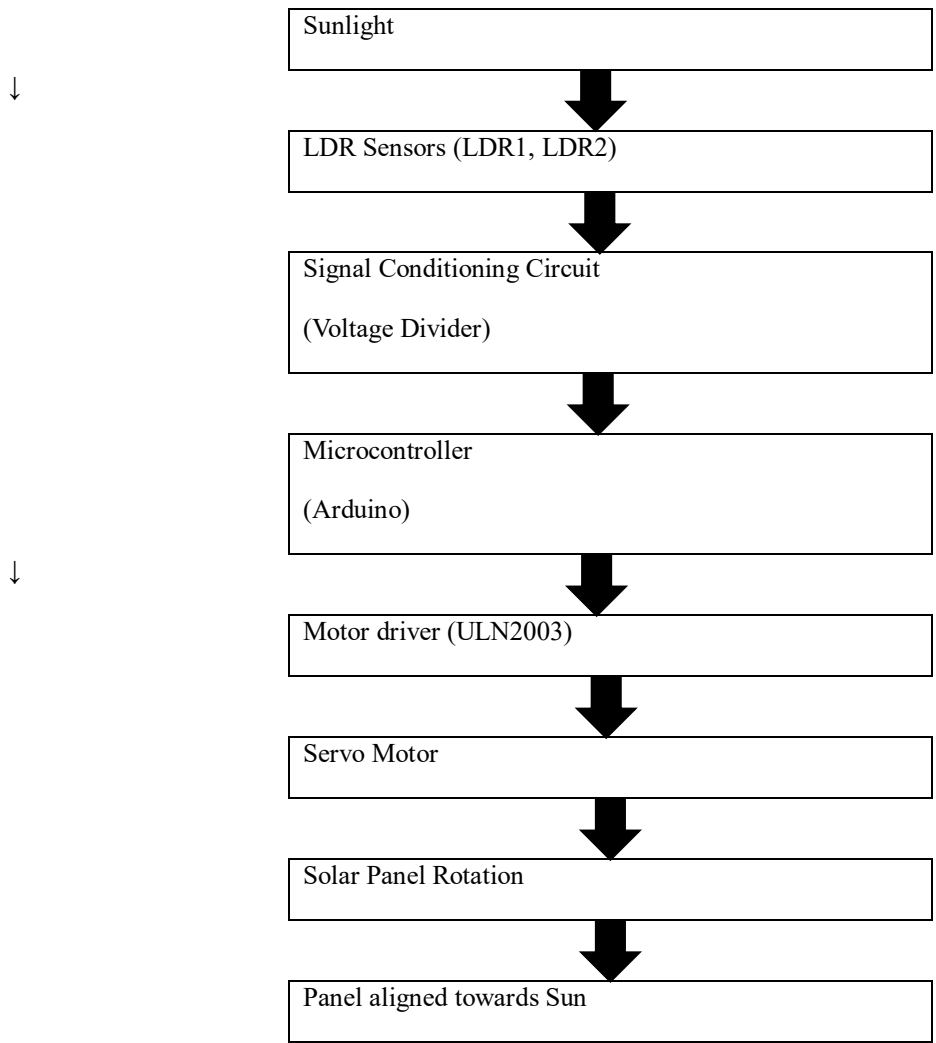
“Sliding Mode Control for Sensorless Solar Tracker” This research introduced a control system for a solar tracker that predicts sun’s position without sensors and increases energy production.

4.Methodology

In this solar tracking system, LDRs (Light Dependent Resistor) are known as photo resistors plays a major role. These are sensitive to light, so these are used in Light or Dark detector circuit. Two LDRs are installed and the servo motor used to move towards solar power. The servo motor

moves towards the LDR on which the light is falling, and will continue to obey the sun. If both the LDRs had the same amount of light falling, then

the servo motor will not rotate. This method is done by using Arduino microcontroller to interface with other components.



The system uses **LDR sensors** to detect sunlight intensity from different directions. The sensor signals are processed by a **microcontroller**, which compares light levels to determine the sun’s position. Based on this comparison, control signals are sent through a **motor driver** to a **servo motor**, which rotates the solar panel in small steps. This continuous process ensures that the panel remains aligned with the sun, improving energy output compared to a fixed system.

5.Components

A. Arduino UNO



The **Arduino Uno** serves as the “central processing unit” or “brain”. It manages the closed loop feedback system by interpreting sensor data and commanding mechanical actuators to keep the solar panel perpendicular to the sun.

1.Azimuth Axis (Horizontal / East-West) – rotates the panel towards the sun as it moves across the sky.

2.Elevation Axis (Vertical / North-South) – tilt the panel up or down to follow the sun’s height.

B. LDR (5 MM)



A **Light Dependent Resistor (LDR)**, also called a **photoresistor**, is a resistor whose resistance decrease as the intensity of incident light increases. In bright light, the resistance is low, allowing more current to pass; in darkness, the resistance is high, allowing less current. In a dual axis solar tracking system, the LDRs are used as sunlight sensors to determine the sun’s position along both azimuth(horizontal) and elevation(vertical) directions.

C. Solar Panel



A **solar panel**, also called a **photovoltaic (PV) module**, is a device that converts sunlight directly into electricity using the photovoltaic effect. It is the main energy source component of solar tracking system. In a dual-axis solar tracker, the solar panel is mounted on a movable frame controlled by motors.

The panel’s orientation changes along two axes.

D. Servo Motor



A **Servo Motor** is a small, light-weight actuator that rotate to a specific angular position when controlled by a pulse-width modulated (PWM) signal. It is widely used in robotics, hobby electronics, and automated systems due to its compact size, protection, ease of control.

In a dual-axis solar tracker system, servo motors are used to adjust the position of the solar panel along two axes:

1.Tilt/Elevation Axis (Vertical Movement) – Adjusts the panel up or down according to the sun’s height in the sky.

2.Rotation/Azimuth Axis (Horizontal Movement) – Rotates the panel left or right to follow the sun from east to west.

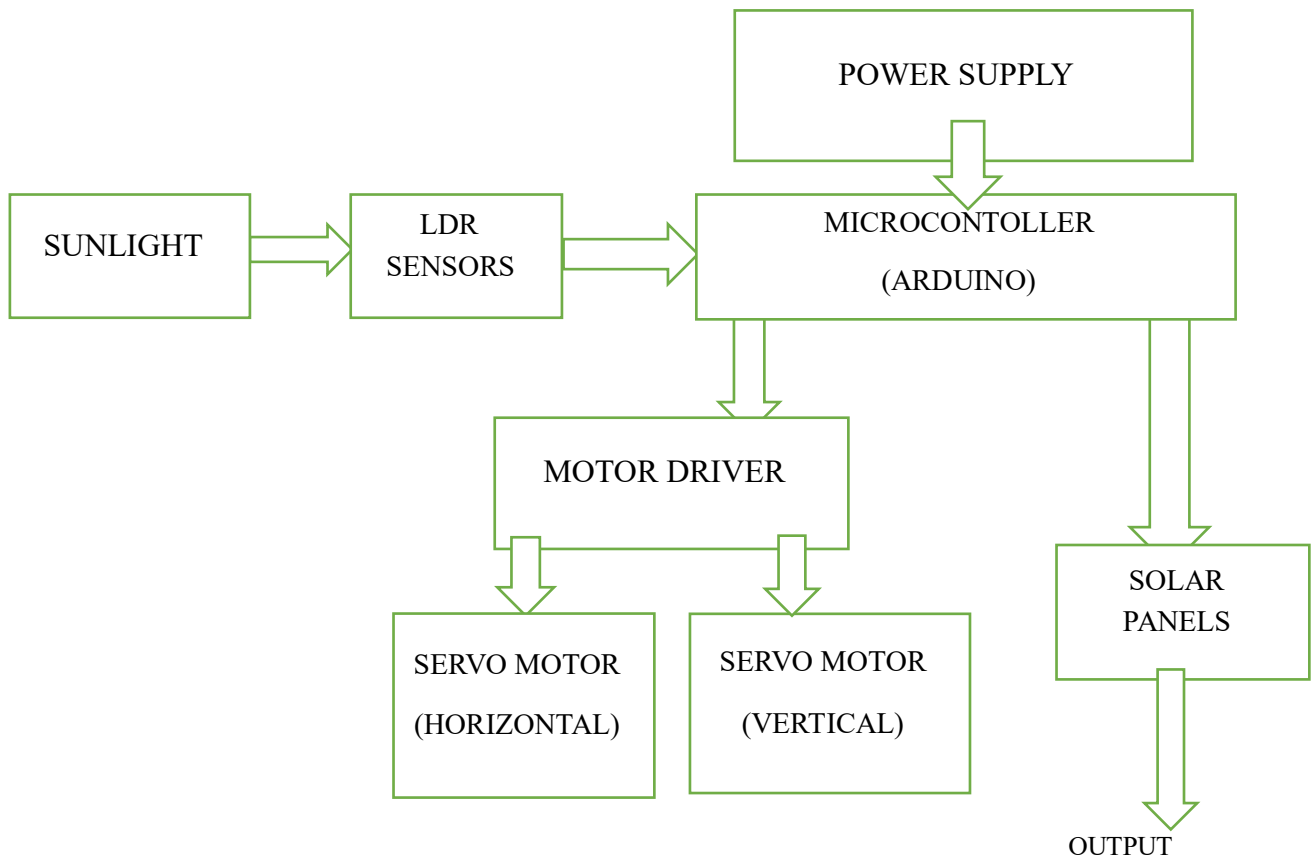
6. System Overview of Dual-Axis Solar Tracker

A dual-Axis solar tracker (DAST) is a mechanical and electronic system designed to continuously orient a solar panel towards the sun throughout the day. Unlike fixed solar panels, which remain stationary, dual axis tracker can move along two axes:

1 Azimuth axis (horizontal movement): Rotates the panel east to west following the sun daily path.

2.Elevation axis(vertical movement): Adjusts the panel’s angle up and down to track the sun’s changing height in the sky.

7.Key components:



- **Solar panel:** Captures sunlight and converts it into electrical energy.
- **LDR sensors:** Detect the direction of maximum sunlight. Typically four sensors are placed around the panel in a cross pattern.
 - **Microcontroller:** Processes sensor data and calculates the necessary panel orientation.
 - **Actuators (Micro-Servo Motors):** Adjust the panel along both axes based on control signals.
 - **Power Supply and Driver Circuits:** provide regulated power to motors and microcontroller.

8.System Performance

1. Energy Output improvement:

- Dual-axis tracking systems typically produce 25% - 40% more energy than static panels.
- The system ensure the maximum incident sun light even during early morning and late afternoon hours.

2. Accuracy:

- The use of LDR sensors and precise servo motor used for accurate positioning.
 - Positional error is usually within 1-3 degrees, which is sufficient for optimal energy capture.

3.Efficiency:

- Maintains high panel efficiency throughout the day by minimizing energy losses due to angular changes.

- More effective in regions with varying sun angles and seasonal variations.

4.Reliability:

- Simple sensor-based feedback reduces system complexity compared to GPS-based.
 - With proper maintenance, the system can operate continuously for year with minimal downtime.

5.Limitations:

- Higher initial cost compared to static panels due to motors and control circuits.
 - Requires structural stability to withstand when environmental factors affect.

9.Conclusion

The dual-axis solar tracker system **significantly increases solar energy harvesting** by keeping the panel aligned with the sun. its combination of sensors, microcontroller, and motors ensures improved energy efficiency and system reliability. Though the initial investment is higher, the **increase in energy output and adaptability to seasonal and daily sun movement** justifies the implementation of such systems in residential, commercial, and industrial solar installations.

10.Future Scope

Dual-axis solar tracker system has potential to increase the efficiency of solar energy by following the sun's position in both horizontal and vertical

directions. We conclude from the project that dual axis solar tracker can increase the energy generation by 25-40% as compared to fixed systems.

The main future scopes can be as following:

- Integrating with smart grid
- Installing hybrid energy systems
- Using the artificial intelligence
- Using the IoT(Internet Of Things)
- Integration of advanced energy storage
- Using improved sensors and control systems

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