

# DESIGN AND IMPLEMENTATION OF A DUAL AXIS SOLAR TRACKER

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**Abstract:** - A dual-axis solar tracking system controlled by a Real-Time Clock (RTC) is presented in this paper, Without the need for light sensors, the proposed system uses an Arduino microcontroller interfaced with an RTC module to determine the sun's position based on time and date. Two motors control the panel's movement in azimuth (east–west) and elevation (north– south) directions, ensuring optimal alignment throughout the day and across seasons. The performance of photovoltaic (PV) systems is highly dependent on the orientation of solar panels with respect to the sun. When compared to fixed-panel systems, experimental results show a notable improvement in energy output. The suggested system is dependable, reasonably priced, and appropriate for stand-alone solar applications.

**Index Terms:** Photovoltaic System, RTC, Arduino, Dual Axis Tracker, Solar Tracking, Renewable Energy

## I INTRODUCTION

Solar energy's abundance, sustainability, and low environmental impact make it one of the most promising renewable energy sources. The effectiveness of photovoltaic (PV) panels, which directly convert sunlight into electrical energy, is highly dependent on the angle at which sunlight strikes the panel surface. When solar energy strikes the panel perpendicularly, the maximum power is produced. Because conventional fixed solar panels are positioned at a fixed tilt angle and are unable to adapt to the sun's movement across the sky, they only produce electricity at its best for a small portion of the day and are less efficient overall.

By automatically reorienting the panel to maintain better alignment with the sun, solar tracking devices overcome this issue. Single-axis trackers follow the sun's daily journey by rotating the panel in a single direction, usually from east to west. By modifying both the horizontal (azimuth) and vertical (elevation) angles, dual-axis trackers allow for more accurate tracking, allowing the panel to follow the sun all day long as well as during seasonal variations. When compared to fixed installations, this leads to a noticeably higher energy generation.

Many tracking systems currently in use light sensors, such as LDRs, to determine the direction of sunlight, but clouds, dust, shade, and reflections can all have an impact on how well they work. A more dependable option is a time-based tracking technique that makes use of a Real-Time Clock (RTC). The controller can determine the sun's position without depending on outside light conditions thanks to the precise time and date information provided by the RTC. In order to obtain accurate, reliable, and effective solar tracking appropriate for realistic renewable energy applications, a dual-axis solar tracker utilizing

an RTC module and an Arduino microcontroller is suggested in this work.

## II PROPOSED METHODOLOGY

### A. System Overview

To achieve precise solar tracking, the suggested system is made up of a number of essential parts. These consist of a mechanical support structure, two motors for dual-axis movement, an Arduino Uno microcontroller, a Real-Time Clock (RTC) module (DS3231 or DS1307), a motor driver circuit, a photovoltaic solar panel, and a regulated power supply unit. The Arduino acts as the primary controller that coordinates all activities, and the solar panel is mounted on a mobile frame powered by the motors.

The controller can predict the sun's position throughout the day and orient the panel appropriately thanks to the exact time and date information provided by the RTC module. The technology guarantees dependable functioning regardless of weather, shade, or dust accumulation by employing time-based positioning in place of light sensors.

### B. Real-Time Clock (RTC) Module

Accurate timekeeping within the system is maintained by the Real-Time Clock (RTC) module. It has a backup battery that enables it to function even in the event that the primary power source is cut off, and it has an internal crystal oscillator to produce accurate timing signals. With just two data lines needed for synchronization, the RTC and Arduino microcontroller interact via the I<sup>2</sup>C protocol.

The module allows the controller to apply a time-based solar tracking algorithm by continuously supplying the current

time and date. By using this method, reliance on light sensors—which may yield erroneous readings in foggy or darkened environments—is eliminated. Furthermore, the RTC guarantees accuracy and stability over time, which makes the system appropriate for unsupervised use in remote areas.

#### C. Control Unit (Arduino Microcontroller)

The solar tracking system's central processing unit is the Arduino Uno microcontroller. In order to ascertain the necessary orientation of the solar panel, it processes real-time data received from the RTC module. The Arduino determines the proper angular coordinates for both axis using preset algorithms that connect time with the apparent motion of the sun. In order to move the panel appropriately, it then transmits control signals to the motor driver. In order to reduce mechanical stress, the controller also controls system logic, which includes guaranteeing smooth, progressive motion and returning the panel to its original east-facing orientation after sunset. The Arduino Uno is ideal for embedded renewable energy applications because of its low power consumption, ease of programming, and interoperability with a variety of hardware modules.

#### D. Dual-Axis Motion Mechanism

The solar panel can follow the sun's path in both horizontal and vertical directions thanks to the dual-axis motion mechanism. The panel can track the sun from sunrise in the east to sunset in the west thanks to the azimuth control system, which spins it along the east-west axis. The sun's apparent daily journey across the sky is explained by this horizontal movement. In order to correct for seasonal variations in solar altitude brought on by the Earth's axial tilt, the elevation control system modifies the panel's tilt along the north-south axis. These two degrees of freedom work together to maximize energy absorption by ensuring that the panel is always almost perpendicular to incoming sunlight. Servo motors or geared DC motors are commonly used for precise movement because they give the tracking mechanism enough torque and positional control.

#### E. Motor Driver Circuit

The Arduino cannot directly deliver the higher current and voltage levels needed by the motors used to move the panels. An interface between the microprocessor and the motors is thus provided by a motor driver circuit, such as the L298N dual Hbridge driver. The Arduino sends low-power control signals to the driver, which amplifies them to run the motors effectively and safely. The panel can travel forward or backward along each axis thanks to its bidirectional rotation capability. Furthermore, the motor driver uses pulse-width modulation (PWM) to regulate speed and shields the microcontroller from electrical harm brought on by the motors' back electromotive force (EMF). Under various

load scenarios, this configuration guarantees the tracking system's dependable and controlled performance.

### III. MATHEMATICAL MODELLING

#### A. Solar Panel Output Power

The current supplied to the load and the voltage across the panel determine how much electricity a solar panel can produce. This relationship is represented by the basic power equation  $P=V \times I$ , where  $I$  is the output current in amperes,  $V$  is the panel voltage in volts, and  $P$  is the output power in watts. Higher power is produced when voltage or current is maximized while ideal operating conditions are maintained.

#### B. Effect of Incidence Angle

The amount of solar energy that a panel receives is greatly influenced by the angle at which sunlight strikes its surface. Maximum power is generated when incident rays are perpendicular to the panel, or when the angle between the panel's normal and the sun's direction is zero. The formula for the power received, which is proportional to the cosine of this angle, is  $P \propto \cos(\theta)$ , where  $\theta$  is the incidence angle. As this angle increases, the effective irradiance decreases, resulting in lower power generation. A dual-axis monitoring system continuously adjusts the panel orientation to reduce  $\theta$  in order to guarantee nearoptimal energy capture throughout the day.

#### C. Solar Motion

The Earth's rotation is what causes the sun to appear to move across the sky. The sun completes an angular displacement of roughly 180 degrees between sunrise and sunset, moving from east to west at an average speed of 15 degrees per hour. Timebased solar tracking devices are based on this predictable motion. The controller can determine the sun's location at any given time and modify the panel orientation by using precise time data from the RTC module. This technique ensures consistent performance in a variety of environmental circumstances by providing dependable tracking without the need for optical sensors.

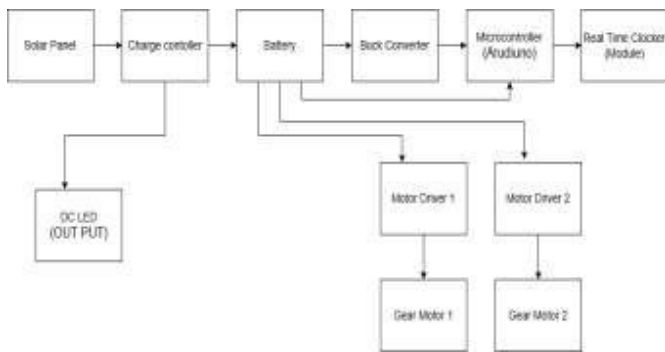


Fig.1. Block Diagram

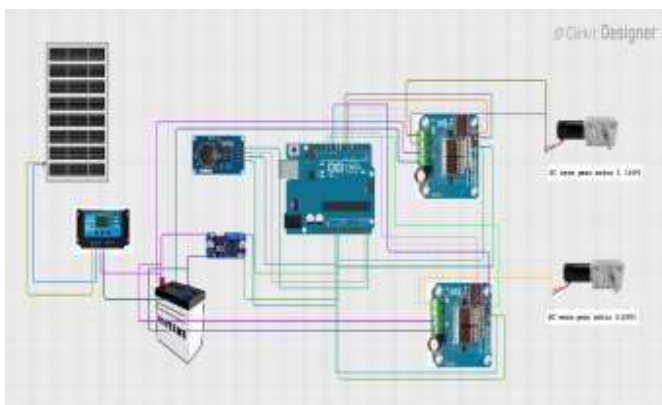


Fig.2. Circuit Diagram

#### IV WORKING

As the sun appears to move across the sky, the dual-axis solar tracking device continuously modifies the solar panel's orientation. The panel is oriented toward the east at the start of the day in order to catch the first rays of sunlight when the sun rises. The Arduino microcontroller uses precise time and date information from the Real-Time Clock (RTC) module to determine the sun's position at any given time. The controller creates the proper control signals to drive the motors attached to the azimuth and elevation axes based on predetermined time intervals.

During daylight hours, the azimuth motor rotates the panel horizontally from east to west, following the sun's daily path. Simultaneously, the elevation motor adjusts the vertical tilt of the panel to account for changes in solar altitude throughout the day and across different seasons. This coordinated motion ensures that the panel surface remains nearly perpendicular to incoming solar radiation, thereby maximizing energy absorption. The movement is typically implemented in small incremental steps to ensure smooth operation and reduce mechanical stress on the structure.

As sunset approaches, the controller gradually returns the panel to its initial east-facing position in preparation for the next day's operation. During nighttime, the tracking mechanism remains inactive to conserve energy and prevent unnecessary motor wear.

Because the system relies on precise time data rather than light sensors, it maintains consistent performance regardless of weather conditions such as cloud cover, haze, or temporary shading. This time-based approach enhances reliability and makes the system suitable for unattended operation in remote environments.

#### V CONCLUSION

The design and implementation of a dual-axis solar tracker with a Real-Time Clock (RTC) module are presented in this work. In comparison to fixed panels, the technology improves energy capture and ensures dependable performance in all-weather circumstances by synchronizing the solar panel with the sun depending on time. According to experimental data, the design is simple, affordable, and appropriate for remote applications because it produces more power while using less energy.

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