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Single Axis Solar Tracker

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Abstract*: The pace of electricity consumption is rising every day, and people's reliance on traditional energy sources is growing. If it persists, use of traditional energy sources will cease quickly. Therefore, the timing is right to combine conventional and renewable energy sources. The cleanest and most sustainable renewable energy source is solar power. The conversion of solar energy into electrical power is possible using a solar photovoltaic (PV) panel.*
Several variables, including sun irradiation, solar cell composition, surface temperature, and others, affect how quickly a solar photovoltaic panel produces energy. The solar cell generates more power the more sunshine it receives. Due to variations in the sun's location in the sky, a fixed state solar panel cannot receive the most sunlight during the daylight hour

Keywords: Renewable Energy, Automatic Single Axis Solar Tracking System, Microcontroller, Solar Photovoltaic Panel, Solar Irradiance

I. INTRODUCTION

As the world seeks sustainable and environmentally friendly alternatives to conventional energy sources the demand for renewable energy sources has been on the rise. Among the diverse renewable energy technologies solar energy among them stands out as one of the most promising due to its abundant and availability. However, the efficiency of solar energy systems heavily depends on its ability to effectively capture and convert sunlight into usable energy. To address this challenge a number of solar tracking systems have been developed to optimize the alignment of solar panels with the sun's movement across the sky.

A single-axis solar tracking system is a mechanical and electronic system designed to maximize the efficiency of solar panels by continuously adjusting their orientation to follow the sun's movement along a single axis Unlike fixed solar panels which are stationary and capture sunlight at fixed angles, a single-axis tracker adjusts the angle of the panels throughout the day to ensure that they face the sun as directly as possible.

This dynamic positioning significantly increases the amount of solar energy captured significantly enhancing the overall performance of the solar energy system.

The concept of single axis tracking revolves around the principle that the sun moves in an arc from east to west during daylight. By aligning the solar panels along this east-west path the tracker can tilt the panels to match the changing position of the sun. The axis of rotation may be horizontal vertical or tilted depending on the design with horizontal single axis trackers (HSAT) being the most common in large-scale solar farms.

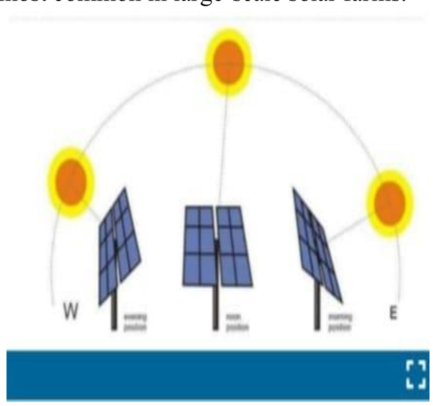

Fig 1: rotation of solar panel according to sunlight

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Despite their numerous advantages, single-axis trackers come with challenges such as higher initial capital costs, increased mechanical complexity, and maintenance requirements. Additionally, their performance is highly dependent on geographical factors such as latitude, cloud cover, and weather conditions, making them more suitable for certain regions. Nevertheless, with ongoing innovations in tracking algorithms, material science, and system integration, single-axis solar trackers are expected to play an increasingly important role in the future of solar energy, helping to maximize the efficiency of solar power generation and contribute to the global transition to renewable energy.

Solar Panel

Fig 2: Solar panel

Solar panels, also known as photovoltaic panels or PV panels are devices which convert sunlight into electricity using the photovoltaic effect. Its use has become a key technology in harnessing solar energy as a renewable and sustainable energy source.

Solar panels are widely used in residential, commercial, industrial and large-scale solar farms to produce clean renewable electricity in residential and commercial buildings. The development of solar panels has improved considerably over the years with improvements in efficiency, cost and durability.

Servo Motor

Fig 3: Servo motor

A servo motor is a highly specialized type of motor which allows the control of angular position, speed, and acceleration. It is an essential part of systems that require very accurate and controlled movements. Servo motors work within a closed-loop feedback system which means that they continuously monitor their own position and adjust their movement in order keep it accurate. They are widely used for applications like robotics, CNC machines, and solar tracking systems because of their precision.

A Single-Axis Solar Tracking System is used to track the sun movement on one axis, generally along the east-west axis from morning till afternoon. It's not a fixed solar panel, where the panels don't move and are angled at one position.

In a single axis tracking system, the servo motor is used to adjust the position of the solar panel along the horizontal axis or sometimes the vertical axis, depending on the design. The motor moves the solar panel from one position in the morning (facing the east) to another in the evening (facing the west), ensuring that the panel is always oriented toward the sun for maximum energy capture.

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II. LDR SENSOR

Fig 4: LDR Sensor

LDR is a resistor whose resistance decreases with an increase in the intensity of light hitting it. LDRs are widely used in applications where the light level needs to be measured or detected. In a Single-Axis Solar Tracking System, LDR sensors play a crucial role in detecting the amount of sunlight falling on different parts of the solar panel and hence the system can make necessary adjustments to the panel's position to track the sun's movement across the sky and maximize energy absorption.

In a single-axis solar tracker, usually two LDR sensors are used to detect the difference in light intensity on either side of the panel:

LDR1 on the East side and LDR2 on the West side are mounted oppositely.

2.1 How LDR Detects Sunlight

- Exposure to Sunlight: The solar panel changes the angle of its orientation; then the LDR measures how much sunlight is falling on every sensor.
- Sun's Position: When the solar panel is perfectly aligned with the sun, both LDRs have equal light intensity. The panel is misaligned if one LDR has higher light intensity than the other.

2.2 Measurement of Light Intensity

- East vs. West Sensors: If LDR1 (East) gets more sunlight than LDR2 (West), then the solar panel is too far to the West and the tracker has to move the panel to the East.
- If LDR2 (West) gets more sunlight than LDR1 (East), then the panel is too far to the East and has to move West.
- The difference in light intensity forms the basis for deciding how much and in which direction the solar panel should shift.

Arduino UNO

Fig 5: Arduino uno programming board

The Arduino Uno is an open-source microcontroller board based on the ATmega328P microchip and is used to develop interactive electronic projects. In a Single-Axis Solar Tracking System, the Arduino Uno board acts as the central controller that takes input from the light sensors (LDRs), calculates the position of the solar panel, and then controls the

movement of the solar panel with a motor usually a servo motor. The use of Arduino Uno makes the solar tracking system flexible, easy to program, and cost-effective.
Role of Arduino Uno in a Single-Axis Solar Tracking System
The Single-Axis Solar Tracking System makes the Arduino Uno the main controller of the system, as it carries out some critical tasks in the entire operation.

TP4056 Charging Modulo

Fig 6: TP4056 charging Modulo

TP4060 is one of the popular Li-ion/Li-polymer battery charging modules that can be used particularly for charging single-cell lithium-ion or lithium-polymer batteries. It integrates all functions required to charge the cell, including constant current charging, constant voltage charging, and overcharge protection. In the Single-Axis Solar Tracking System, the TP4060 module will be responsible for regulating the charging of the battery that is used to store the energy gained from the solar panels. This reserve energy powers the electronics, sensors, and motors in the tracking system if it encounters insufficient sunlight or nightfall operation.

18615 Battery

Fig 7: 18715 Battery

The 18615 battery more accurately, the 18650 battery-is a type of lithium-ion rechargeable battery widely applied in multiple applications, such as solar tracking
systems, which is recognized for its high energy density, long cycle life, and relatively compact size.
In a single-axis solar tracking system, the 18650 battery is the key component in storing and supplying energy for the system's operational needs. It provides backup power to the motors, sensors, and control systems, ensuring continuous tracking performance and optimizing energy capture throughout the day and night.

III. METHODOLOGY

A methodology for one-axis solar tracking is used to position the solar panels dynamically along one axis that orients the panels with maximum capture of solar energy. Below is the theoretical approach in how such a system may be implemented:

1. Concept and Design of the System
Selecting the Tracking Axis:
The system applies one axis for rotation usually horizontal or vertical, which traces the movement of the sun in a day. The chosen axis is dependent on the geographical location of the site, latitude, as well as the requirement and desired energy optimization.

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Orientation of the Panels

In the structure of a framework that mounts the solar panel, the mechanism enables free rotation along the selected axis; it accommodates the motion with ease, thereby enhancing stability and durability.

2. Solar Tracking Mechanism

Light Sensing (Photodiodes or LDRs):

Measure the intensity of light hitting the solar panel using Photodiodes or Light dependent resistors, which measure the intensity of the light from different points. Light-intensity difference at various sensor points is taken by the system to find direction movement.

Pre-programmed Algorithms (Timer-Based):

In the absence of real-time sensors, it is also possible for the system to use pre-programmed algorithms based on the position of the sun at any specific time of day and year. These algorithms calculate the azimuth (horizontal angle) and elevation (vertical angle) of the sun as a function of latitude and longitude

3. Control System

Microcontroller Integration:

A microcontroller (e.g., Arduino or Raspberry Pi) processes the inputs from sensors or the pre-programmed algorithm. It calculates the correct position for the solar panel based on the input data and sends commands to the motor system to adjust the orientation accordingly.

Motorized Adjustment

A stepper motor or DC motor is employed to rotate the solar panel. The microcontroller controls the motor to make sure that the panel moves into the correct position, based on sensor feedback or calculation of sun position.

4. Power Supply and Energy Optimization

Power Supply to Tracking System:

The use of motors and sensors by the tracking system is where power consumption comes from. Ideally, such a system consumes a very minor fraction of the energy being produced by the solar panels, and the net gain in energy is always positive. Reducing Power Consumption. To optimize efficiency, it is desirable to reduce power consumption in the tracking mechanism. This can be achieved by using efficient motors and low-power electronics, ensuring that the overall consumption does not offset the gains in energy from tracking.

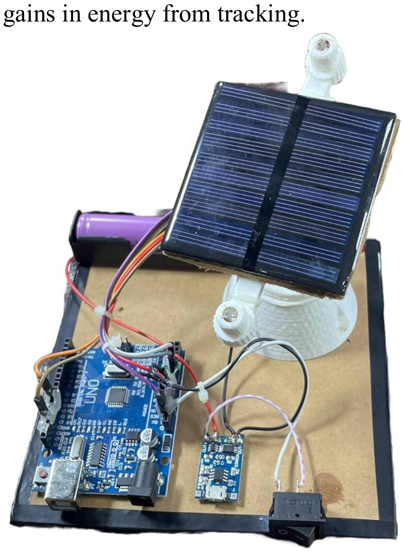

Fig 8: Model of single axis of solar tracker

IV. LITERATURE SURVEY

In recent years, single-axis solar trackers have gained considerable attention due to the potential to enhance the efficiency of photovoltaic (PV) systems by tracking the sun's path. Unlike fixed-tilt systems, single-axis trackers can adjust the orientation of solar panels along a single axis, usually east-west, and maximize solar irradiance capture throughout the day. Research shows that these systems can enhance the energy output by 25–35% more than fixed systems, especially in locations with high solar insolation. Single-axis trackers can be divided into two types: horizontal and vertical, but horizontal trackers are used more because they are cost-effective and applicable to a larger geographic area. The design of single-axis trackers includes critical factors like motorized actuators, tracking algorithms, and structural integrity, with recent innovations concentrating on reducing mechanical failures and improving durability. Single-axis trackers have their own merits but pose challenges like increased capital and maintenance costs as well as reliance on moving parts that may increase the likelihood of mechanical failure. Such factors as latitude, as well as the local solar resource availability, significantly impact the economic feasibility of such systems, thus indicating them as more appropriate to large power projects in the areas of predictable sun movement. While continuing research into more sophisticated tracking algorithms, hybrid tracking systems, and even the merging of smart grid technology provides significant promise for improvements in both performance and economics of the single-axis trackers, both large-scale and commercial applications are becoming a highly attractive option.

V. CONCLUSION

A single-axis solar tracker is an effective solution to enhance the efficiency of solar panels by continuously adjusting their orientation to follow the sun. This increases energy output by 15-25% compared to fixed systems, making it ideal for large-scale solar farms, commercial applications, and even some residential setups. Even though they involve higher initial investment and higher maintenance costs, their advantages of optimizing the capture of solar energy, optimizing land use, and maximizing the performance throughout the day and year make it a worthy investment, especially in sun-rich regions and high-demand areas.

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