Energy Efficient Dual Axis Solar Tracker with Cleaning System

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ABSTRACT - Solar panels are devices convert light into electricity. Solar panels use sunlight to generate power. Solar panels work best when the sun is shining. As the angle of the sun varies throughout the day and seasons, this affects the amount of electricity a solar power system will generate. To make solar power systems work more efficiently, this project will include the design and construction of a microcontroller-based solar panel tracking system. Solar tracking allows more energy to be produced because the solar array can remain aligned to the sun. In this project, we will design a dual-axis solar tracker that allows solar panels to move on two axes, aligned both north-south and an east-west. This type of system is designed to maximize solar energy collection throughout the year. This project will make use of the Light Depending Resistor (LDR) which is important to detect the sunlight by following the source of the sunlight location. Arduino Uno microcontroller is used to control the motors based on LDR. The drastic improvement in power output from the solar panel can be seen on a LCD Display attached to the system. This project discusses the development of a prototype for a dual-axis solar tracking system.

Index: LDRs, Temperature Sensors, Servo-Driven wipers Solar Tracker, Enhance Energy Capture, Temperature Monitoring, Remote Monitoring, Blynk Platform.

I.INTRODUCTION

In the pursuit of sustainable energy solutions, solar power stands as a beacon of promise, offering clean and renewable electricity generation. However, traditional solar panel systems often fall short of realizing their full potential due to inefficiencies in capturing sunlight and challenges in maintenance. Toaddress these limitations, the integration of Internet of Things (IoT) technology with dual-axis solar panels presents a solution aimed for optimizing energy capture and enhanced panel lifespan. This paper introduces a self-optimizing dual-axis solar panel system empowered by IoT technology. By harnessing real-time data and automation,solar energy is produced continuously by tracking the sun's position and adjusting solar panel angles accordingly. This dynamic optimization ensures maximum exposure to sunlight throughout the day, significantly enhancing energy capture and system efficiency. Furthermore, the system goes beyond mere tracking capabilities to tackle another critical aspect of solar panel performance: maintenance. By incorporating temperature monitoring sensors, the system detects overheating conditions that can damage panels and reduce their efficiency. Moreover, regular cleaning is essential to mitigate losses caused by dust and debris accumulation. To this end, automated cleaning mechanisms are integrated into the system, ensuring that panels remain clean and free from obstructions. The benefits of this self-optimizing dual-axis solar panel system are many. It maximize energy capture and system efficiency, extends the lifespan of solar panels by reducing damage from overheating. Additionally, maintenance is simplified through remote monitoring and automated cleaning, minimizing the need for manual intervention and reducing operational costs.

Throughout this paper, we will search into the underlying principles, design considerations, and operational mechanisms of the proposed self-optimizing dual-axis solar panel system using IoT technology. Furthermore, we will explore its potential applications across various sectors, ranging from residential rooftops to large-scale solar farms, and assess its effectiveness in enhancing energy production, reducing maintenance efforts, and accelerating the transition towards a sustainable energy future.

II. LITERATURE SURVEY

The presented project by Moothedath et al. (2023) focuses on sustainability through a dual-axis solar tracker design for street lighting. Their research shows the importance of maximizing the efficiency of solar panel and to reduce reliance on conventional energy sources. The authors compares the benefits of dual-axis tracking systems with fixed panels. . By constantly adjusting solar panels faced towards the sun directly they see difference of increased energy capture. This method can significantly improve the overall efficiency of solar-powered systems.

The paper also explores the use of Light Dependent Resistors (LDRs) for sun tracking as a cost-effective. LDRs are light-sensitive resistors that change resistance based on the amount of light they receive. By placing LDRs around the solar panel, the system can determine the sun's position and adjust the panel's tilt accordingly using an Arduino microcontroller for control.

Finally, the research emphasizes the importance of integrating energy-efficient components. The paper discusses the use of TP-4056 Li-ion charging modules for safe battery management and Light Emitting Diodes (LEDs) for the street slighting system. LEDs are known for their low energy consumption and minimal heat generation, further contributing to the overall sustainability of the project.

III.PROPOSED SYSTEM

The proposed system for a self-optimizing dual-axis solar panel system utilizes IoT technology to revolutionize energy capture efficiency. By integrating real-time sun tracking and continuous panel angle adjustments, the system maximizes energy generation throughout the day. Additionally, the implementation of temperature monitoring and regular cleaning routines enhances panel lifespan by mitigating damage caused by overheating and dust accumulation. Maintenance becomes streamlined with automated cleaning processes and remote monitoring capabilities, ensuring optimal performance and longevity of the solar panel

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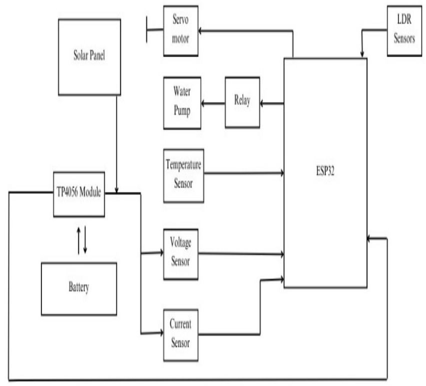
SYSTEM ARCHITECTURE



A. LDR SENSORS

Light dependent resistors (LDR), are light sensitive devices most often used to indicate the presence or absence of light, or to measure the light intensity. In the dark, their resistance is very high, sometimes up to 1 MΩ, but when the LDR sensor is exposed to light, the resistance drops dramatically, even down to a few ohms, depending on the light intensity. LDRs have a sensitivity that varies with the wavelength of the light applied and are nonlinear devices. They are used in many applications, but this light sensing function is often performed by other devices such as photodiodes and phototransistors. Some countries have banned LDRs made of lead or cadmium over environmental safety concerns.

B. ESP32 MICROCONTROLLER

The ESP32 is a family of low-cost, low-power System-on-a-Chip (SoC) microcontrollers that also have a dual-core CPU, Wi-Fi, and Bluetooth wireless connectivity. It can be used either as a standalone chip or as a comprehensive development board. There are two variants of this board, one with 30 GPIOs and the other with 36 GPIOs. In terms of wireless connectivity, the ESP32 supports Wi-Fi with a data rate of 150.0 Mbps using HT40 technology. It also supports both Bluetooth Low Energy (BLE) and Bluetooth Classic protocols. Furthermore, the ESP32 is compatible with the Arduino IDE, allowing programmers to use the familiar Arduino core to develop and program applications for the ESP32 microcontroller.

C. SERVO MOTORS

An exact form of motor recognized for its precise rotating capabilities is a servo motor. It often includes a control circuit that gives feedback on the motor shaft's present position. Servo motors may accomplish extremely exact rotations because of this feedback. Servo motors are

commonly used to rotate objects at specific angles or distances. They consist of a simple engine that drives a servo mechanism. When a DC power source drives the motor, it is called a DC servo motor, whereas an AC power source powers an AC servo motor. In addition to these major categories, there are several more servo motor types depending on gear configurations and operational characteristics. Servo motors often employ gear configurations that allow for high torque output in compact and lightweight packages. Due to these characteristics, servo motors are widely used in a variety of applications, including toy automobiles, RC helicopters and aircraft, robotics, and more. Hobby servo motors are typically categorized by their torque ratings, such as 3kg/cm, 6kg/cm, or 12kg/cm. These ratings indicate the weight the servo motor can lift at a specific distance, measured in kg/cm. For instance, a servo motor rated at 6 kg/cm should be able to raise a 6-

kilogram load hanging 1 centimeter above the ground.

D. SOLAR PANELS

A solar tracker is a device used for orienting a photovoltaic array solar panel or for concentrating solar reflector or lens toward the sun. The position of the sun in the sky is varied both with seasons and time of day as the sun moves across the sky. Solar powered equipment work best when they are pointed at the sun. Therefore, a solar tracker increases how efficient such equipment are over any fixed position at the cost of additional complexity to the system. There are different types of trackers. Extraction of usable electricity from the sun became possible with the discovery of the photoelectric mechanism and subsequent development of the solar cell. The solar cell is a semiconductor material which converts visible light into direct current. Through the use of solar arrays, a series of solar cells electrically connected; there is generation of a DC voltage that can be used on a load. There is an increased use of solar arrays as their efficiencies become higher.

E. TEMPERATURE SENSORS

Temperature sensors take heat readings and transform them into data you can read. They operate differently, measuring temperatures with varying precision for diverse uses. Thermocouples can withstand harsh conditions, suiting industrial settings. Their temperature range is wide. RTDs offer higher accuracy, ideal for labs and science. Stable and precise, they excel in controlled environments. Thermistor detect minute temperature shifts, making them useful for electronics and medical tools. Without direct contact, infrared sensors measure heat remotely, enabling thermal imaging cameras and non- contact thermometers to function Digital temperature sensors convey temperature data in a digital format.. They frequently incorporate analog to digital converters (ADCs) and interfaces like I2C or SPI for seamless integration.

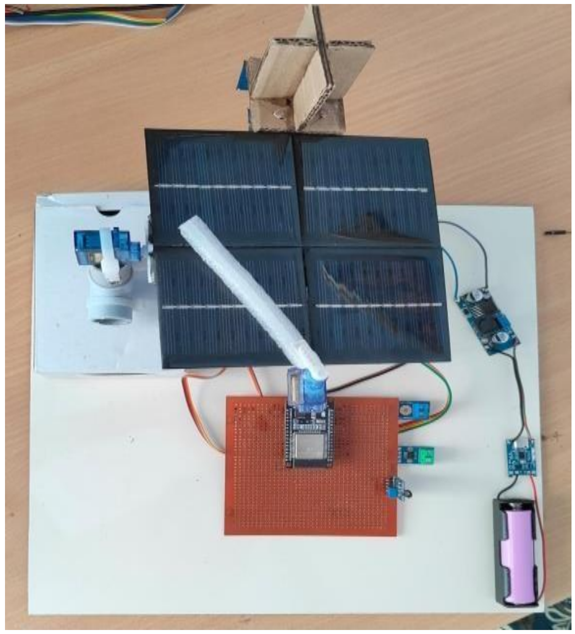
F. VOLTAGE AND CURRENT SENSOR

Voltage and current sensors are vital parts of electronic systems and power monitoring setups. They measure the voltage in a circuit or the current flowing through it, giving important data for things like control, protection, and monitoring. Here's a quick look at voltage and current sensors.

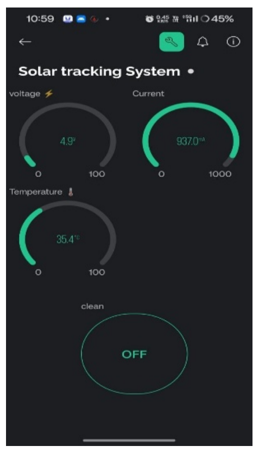
Measuring Voltage: Exploring Common Methods Voltage Divider Circuit: One popular way to measure voltage is through a voltage divider circuit. It uses resistive components that split the voltage proportionally, enabling measurement with analog or digital tools. Potential Transformers (PTs): PTs are employed to reduce high voltage levels to manageable levels for measurement and protection purposes in electrical power systems. Voltage Transducers: Voltage transducers convert voltage signals into proportional analog or digital outputs. They are frequently used in industrial control systems and instrumentation applications. Sensors for DC and AC Voltages: Different sensors are used for measuring direct current (DC) and alternating current (AC) voltages. For DC, voltage dividers, operational amplifiers, and analog- to-digital converters (ADCs) are commonly utilized. For AC, transformers, capacitors, and voltage transducers are employed.

HARDWARE AND SOFTWARE IMPLEMENTATION

A. HARDWARE IMPLEMENTATION



mplementing a self-optimizing dual-axis solar panel system using IoT technology involves integrating various hardware components for sun tracking, panel angle adjustments, temperature monitoring, cleaning mechanisms, and remote monitoring. Below is a hardware implementation overview:



SOFTWARE IMPLEMENTATION

The diagram showcases four graphs, each representing a key parameter of the solar panel system: voltage, current, temperature, and Light Dependent Resistor (LDR) reading. The x-axis (horizontal) represents time, and the y-axis (vertical) represents the measurement unit for each parameter. Voltage and Current: The voltage (V) and current (A) graphs depict the electrical output of the solar panel. These values likely fluctuate throughout the day, with higher values generally corresponding to periods of stronger sunlight. Temperature: The temperature (°C) graph displays the solar panel's temperature. During operation, the panel's temperature naturally rises due to sunlight absorption. This graph helps monitor thermal performance and identify any potential overheating issues.

By analyzing these combined graphs, we can gain valuable insights into the solar panel system's performance. This data can be used to optimize panel tilt angles for maximum sun exposure throughout the day and identify periods for cleaning. Additionally, temperature monitoring helps ensure the panel operates within a safe range.

RESULT AND DISCUSSION

Dual axis solar tracking and single-axis solar tracking are two methods of orienting solar panels towards the sun to increase energy output and efficiency. Dual-axis solar trackers use sensors and a control system to track the sun's path both horizontally and vertically, allowing the solar panels to constantly align to the sun through the sky. Dual axis solar tracking is more complex compared to single-axis solar tracking. Dual axis requires more components with a more sophisticated control system. But, the main advantage of dual-axis solar tracking is, it allows maximum collection sunlight throughout the day, resulting with higher energy output as shown in Table 1.Single-axis solar trackers, use sensors and a control system to track the sun's travel path horizontally only, allowing the solar-panels to constantly align to the sun's path across the sky rotate from east to west. This type of tracking system is complexity is less compared to dual-axis solar tracker with requirement of fewer components and a simpler control system.

TABLE I. COMPARISON OF SINGLE AND DUAL AXIS SOLAR TRACKING

Criteria	Single-axis solar tracking	Dual-axis solar tracking
Efficiency	Moderate to high	High
Range of movement	Narrow	Wide
Time of operation	Shorter	Longer
Tracking accuracy	Moderate	High
System complexity	Low to moderate	High
Cost	Low to moderate	High
Maintence require	Low to moderate	High

Dual axis solar tracking system optimize high output energy by capturing maximum amount of sunlight. Solar panels are always perpendicular to the sun's rays to track the sun's movement both horizontally and vertically. On the other hand, Single-axis solar tracker can only track the sun's traversal horizontally, which means that they are not always able to capture sunlight at optimal angles throughout the day, and therefore have a moderate energy output. Dual axis solar tracking system is more complex and in comparison of single axis solar tracker which requires more components results with high cost. Dual-axis solar tracker also has an advantage over single-axis systems. By constantly adjusting the position of the solar panels to face the sun, dual-axis systems are able to capture more sunlight, even during low-light conditions. Thus, there is a trade-off between both the trackers. Single - axis solar tracker has lower cost but the overall efficiency is low. Dual-axis solar tracker has higher cost but the overall efficiency is also high. The system produces high accuracy since four photo sensors are used.

VI . CONCLUSION

In conclusion, the implementation of a Energy efficient dual-axis solar tracker with cleaning system using IoT technology helps maximizing energy capture efficiency while simultaneously enhanced solar panel lifespan. By real-time sun tracking and continuous panel angle adjustments.The system optimizes energy capture by positioning solar panels and ensuring optimal to harness sunlight. The integration of temperature monitoring and regular cleaning avoids potential damage from overheating and dust accumulation, thereby extending the overall lifespan of the panels. Moreover, the system maintenance efforts through automated cleaning and remote monitoring capabilities, enhancing operational efficiency. This innovative approach boosts energy generation and reduces maintenance costs and environmental impact, making it a highly viable solution for sustainable energy production.

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