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IOT-BASED DYNAMIC TRACKING FOR SMART ENERGY SYSTEMS

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ABSTRACT

The rising global energy demand, fueled by population expansion and improved living conditions, underscores the urgent need to transition from diminishing fossil fuels to renewable energy sources. Solar power, being an abundant and eco-friendly alternative, offers a promising solution. This study introduces a solar energy tracking system designed to enhance electricity generation by continuously adjusting its orientation to follow the sun. The system integrates four essential components: a solar panel, light-dependent resistors (LDRs), an Arduino microcontroller, and a motor. The LDRs sense variations in sunlight intensity, prompting the Arduino to activate the motor, ensuring optimal panel alignment for maximum energy absorption. This dynamic system not only boosts power efficiency but also serves as an educational resource for engineering students, offering practical insights into renewable energy technologies. By optimizing solar energy utilization, this project supports sustainable development and strengthens knowledge of alternative energy solutions in modern engineering applications.

Keywords: Renewable Energy,Solar Tracking System,Photovoltaic Efficiency,Arduino Microcontroller,Energy Optimization,Power Generation,Solar Panel Rotation.

I. INTRODUCTION

Solar energy is a widely available, sustainable, and highly adaptable resource, making it one of the fastest-growing renewable energy sources. It is utilized in various applications, including electricity generation, heating, and lighting, through two primary methods: active and passive solar technologies. Active solar systems use mechanical and electrical components to capture, store, and convert solar energy, while passive systems rely on architectural designs to naturally optimize heat distribution and light absorption .

A significant challenge in solar energy utilization is its inconsistency, influenced by factors such as seasonal changes, geographic location, and time of day.

This variability can reduce the efficiency of solar panels. To address this, solar tracking systems have been developed to continuously adjust the orientation of solar panels, ensuring they remain aligned with the sun's position throughout the day. These systems can increase energy efficiency by up to 50% and typically consist of sensors, a control unit, motors, or actuators that automatically reposition the panels for optimal energy absorption .

With the growing global demand for renewable energy, the adoption of solar tracking technology is expanding rapidly. These systems are now widely integrated into concentrated solar power plants, residential rooftops, and commercial solar installations, significantly

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boostenergy output and contributing to a more sustainable future.

II. EXISTING METHOD

In conventional solar power systems, solar panels are fixed in a stationary position, which significantly limits their ability to capture sunlight efficiently throughout the day. Since the sun's position constantly changes from sunrise to sunset, stationary panels often fail to receive maximum solar radiation, leading to energy losses and reduced efficiency. To counteract this problem, some setups involve manual adjustment of the panels at different times of the day or during seasonal change but this approach is labor-intensive, time-consuming, and impractical for large-scale installations. Furthermore, fixed panels only achieve optimal efficiency for a few hours each day, as they cannot dynamically respond to real-time changes in sunlight direction or intensity.

Another limitation of existing solar systems is their lack of automated monitoring and feedback mechanisms. Since traditional panels do not include real-time tracking or IoT- based monitoring, users have limited visibility into their system's performance. In the event of misalignment, dust accumulation, or efficiency losses, users remain unaware until they manually inspect the system, leading to reduced energy output and higher maintenance costs. Additionally, environmental factors such as cloud cover, shading, or panel obstructions further decrease efficiency, but traditional solar setups to the lack adaptive mechanisms to adjust for these variations.

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While some advanced solar systems use single-axis or dual-axis tracking mechanisms, these systems are often complex, expensive, and require high energy consumption for operation. Additionally, most existing solar tracking systems are not IoT-enabled, meaning users cannot remotely monitor or control their system's orientation and performance.The absence of real-time alerts or feedback mechanisms results in delayed detection of inefficiencies, reducing overall power generation capabilities. Therefore, the need for an automated, intelligent, and IoT-based solar tracking system is critical to maximizing solar energy efficiency while reducing manual effort and maintenance costs.

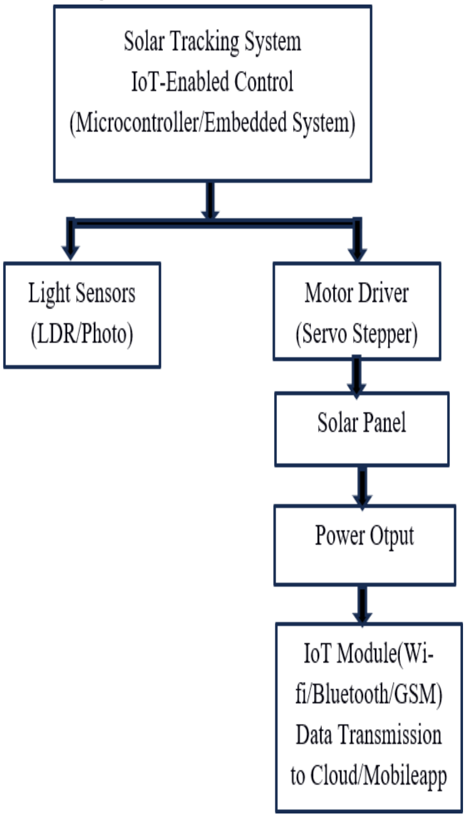

Fig1:IoT Enabled Solar Tracking System

III PROPOSED METHOD

To overcome the limitations of traditional solar panels, the Solar Sense system integrates IoT-enabled solar tracking with automated positioning mechanisms to ensure that solar panels continuously align with the sun's position for maximum energy absorption. The system consists of a solar panel, four LDRs, a servo motor, a 16×2 LCD display,buzzer.The four LDR sensors are strategically placed at different corners of the solar panel to detect sunlight intensity from multiple angles. These sensors send data to the control unit, which then analyzes the brightest light source and determines the optimal angle for the panel. The servo motor receives this data and adjusts the panel's position accordingly, ensuring that it always faces the sun for maximum energy collection. Unlike traditional systems that remain fixed, this automated movement eliminates energy

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losses caused by misalignment and significantly to the increases power output.The 16×2 LCD display provides real-time updates on panel orientation, sunlight intensity, and tracking status, ensuring that users can monitor performance at all times. The buzzer serves as an alert mechanism, notifying users in case of misalignment, servo motor failure, or tracking malfunctions, thereby enabling timely maintenance and system adjustments.

One of the most significant advancements of the Solar Sense system is its IoT-based remote monitoring capability. By integrating wireless connectivity, users can access real-time data on solar panel performance through a mobile application or web interface. This feature allows for remote tracking, diagnostics, and optimization, eliminating the need for physical inspections. Additionally, the IoT system can send alerts and notifications in case of efficiency drops, system errors, or required maintenance, ensuring that the panel operates at peak performance without unnecessary downtime.Unlike existing solar tracking solutions that are expensive and energy-consuming, the Solar Sense system utilizes an energy-efficient servo motor that consumes minimal power while ensuring precise and smooth adjustments. he Solar Sense system is designed with energy efficiency and cost-effectiveness in mind, making it a viable solution for both residential and commercial applications. It operates on low power and can be integrated with battery storage systemscontinuous functionality even in low-light conditions.

Another important aspect of the Solar Sense system is its emphasis on safety, durability, and reliability in real-world conditions.

The components used—such as weather- resistant LDR sensors, a robust servo motor, and a sealed control unit designed to withstand varying environmental factors like dust, rain, and extreme temperatures. This ensures long-term operation with minimal wear and tear.

Additionally, the system includes built-in fail-safe protocols that automatically revert the solar panel to a default safe position in the event of sensor failure or communication loss. The use of durable materials and protective enclosures enhances the lifespan of the system, making it suitable for outdoor installations. These safety features, combined with real-time monitoring and alert mechanisms, offer users confidence in the system’s reliability and make it a practical solution for continuous solar power generation under different weather conditions. Moreover,the system can be configured to support to the dual-axis tracking ,allowing even greater precision.

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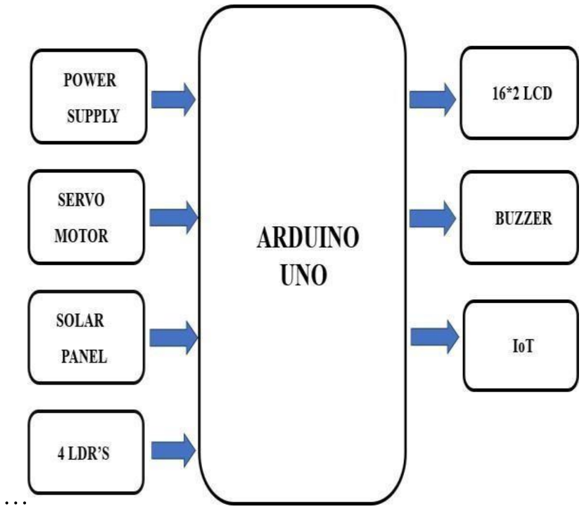

Fig 2. Arduino-Based Solar Tracking System

III. RESULTS

An LDR (Light Dependent Resistor) sensor is a part whose resistance varies in direct proportion to the amount of light it receives. According to, the amount of light can be described using the equation: R = R0 * I/I0. The LEDs depict the LDR's resistance in ohms (R), resistance in darkness (R0), illuminance in lux (I), and constant I0, which represents the illuminance at which the LDR's resistance equals R0. The LDR's resistance-illuminance characteristic curve is represented by this equation. As the illuminance rises, the LDR's resistance falls, and vice versa. This characteristic is used by the solar tracking system to ascertain the sun's position in relation to the LDR sensors and, consequently, to control the servo motor's movement, which modifies the solar panel's position.

The literature contains a wealth of information about the application of LDRs in sun tracking systems. Solar tracking systems utilize this property of LDRs to determine the position of the sun and adjust the orientation of solar panels accordingly.A typical solar tracker consists of multiple LDR sensors placed at different angles to monitor sunlight intensity from various directions.

The system continuously compares the light intensities detected by these sensors, identifying the direction where the light is most intense.

A microcontroller processes this information and signals a servo motor to adjust the solar panel's position, ensuring it remains aligned with the sun for maximum energy absorption. By dynamically adjusting the orientation of solar panels, solar tracking systems can significantly improve energy efficiency compared to fixed solar panels.Beyond solar tracking, LDRs are widely used in various applications, such as automatic street lighting, where they help turn streetlights on at night and off during daylight, and in camera exposure control, where they assist in adjusting shutter speed and aperture based on ambient lighting. Additionally, they play a crucial role in smart home automation by controlling indoor lighting based on room brightness and in security systems by detecting motion and unauthorized.LDRs are widely used in various fields due to their simple design, low cost, and reliability. One of their key advantages is their ability to function without direct electrical control, making them highly energy- efficient. They are often made from materials such as cadmium sulfide (CdS) or lead sulfide (PbS), which have photoconductive properties. The response time of an LDR can vary depending on the material used; some respond almost instantaneously to changes in light, while others may have a slight delay.

In industrial applications, LDRs are used in optical switching circuits, where they help in detecting objects and controlling machinery based on light levels. In agriculture, they are integrated into smart irrigation systems to monitor sunlight levels and optimize water distribution for crops. LDRs are also used in automotive applications, such as automatic headlamp systems, where headlights adjust their brightness based on ambient light conditions.

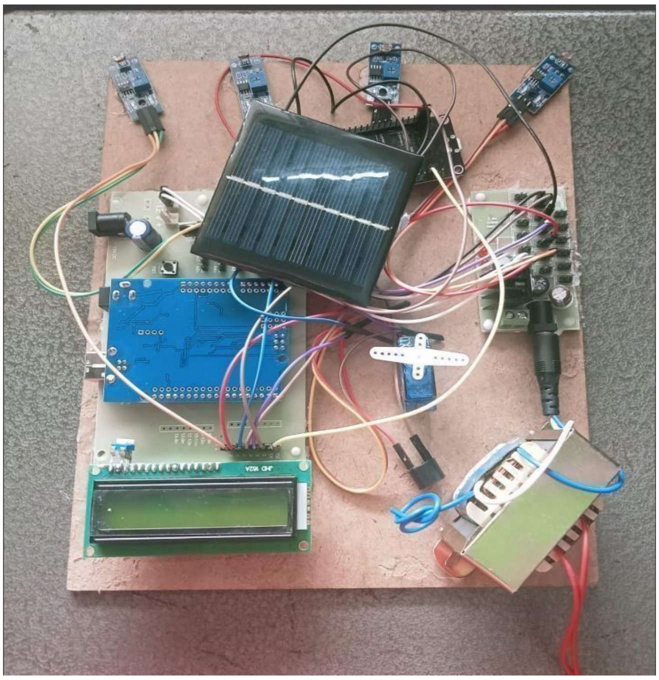

Fig 3.Working model of IoT based dynamic tracking for Smart energy systems.

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TABLE.1
Comparison of Fixed Axis and Single Axis Over Time

Sr.No	Time	Fixed Axis	Single Axis
1	1	0.60	0.63
2	4	0	0
3	5	0.46	0.48

As the day Progresses,we can see that the power output of both systems in Table 1.

The graphical representation of above data is in below.

Fixed Axis vs.Single Axis Power Output

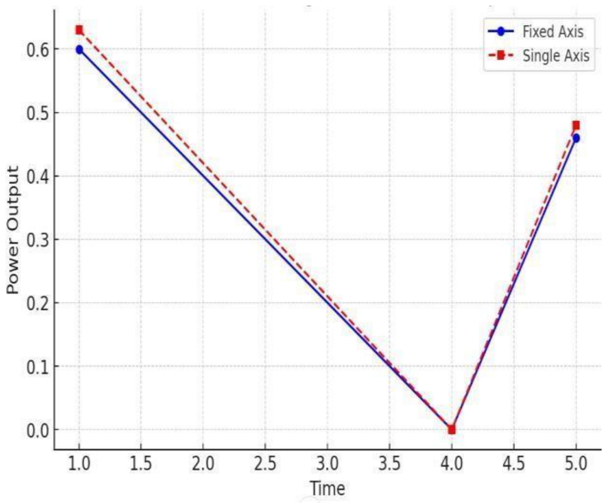

Fig 4: A line graph comparing the power output of the Fixed Axis and Single Axis systems over time.

IV. CONCLUSION

The Solarsense system exemplifies the fusion of IoT and solar tracking technology to enhance energy efficiency and sustainability. By dynamically adjusting solar panels to follow the sun's movement, Solarsense maximizes energy capture, reduces waste, and improves overall system performance. Its integration with IoT enables real-time monitoring, predictive analytics, and remote control, making it an intelligent and cost- effective solution for residential, commercial,and the industrial applications.

As advancements in AI and automation continue, future iterations of Solarsense could further refine energy optimization, making solar power even more accessible and efficient. Ultimately, adopting IoT-enabled solar tracking solutions like Solarsense plays a vital role in reducing reliance on fossil fuels, promoting environmental conservation, and shaping a more sustainable future.

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