

# INTEGRATED SOLAR PANEL

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**Abstract**—A need to use maximum energy from the sun and it is also a human right too which offers the energy to needy people. Solar energy is a one of the most efficient renewable energy which must be inflated. Alternate to the fixed solar panel which uses Sun tracking panel circuits that will track the position of the sun's position accordingly. So efficiency is increased by 31% as compared to the fixed solar panel. More over the emphasizing of the solar panel as a right underscore the importance of equitable access to clean and affordable power. By prioritizing the deployment of solar technologies in underserved communities, we empower individuals and households with reliable energy sources, thereby enhancing their quality of life and contributing to poverty alleviation efforts. This approach not only accelerates the transition towards a cleaner energy future but also fosters social equity and resilience in the face of global challenges

**Keywords**— Solar energy, dual-axis sun tracking, photovoltaic systems, renewable energy, energy efficiency, sustainable development, clean energy access, off-grid power systems, social equity.

## I. INTRODUCTION

Solar energy is quickly becoming one of the most exciting renewable energy sources out there, thanks to its abundance, sustainability, and low impact on the environment. Photovoltaic (PV) systems are designed to convert sunlight directly into electricity and can run reliably for over thirty years with just a bit of maintenance. However, traditional fixed-tilt solar panels have a natural limitation in efficiency because the angle of sunlight hitting the panels changes throughout the day and across different seasons. To tackle this issue, sun-tracking solar systems have been created to keep PV panels aligned with the sun. Dual-axis solar trackers, in particular, enhance performance by allowing the panels to move both horizontally and vertically, ensuring they're always perfectly positioned to catch the sun's rays. When compared to fixed panels, these dual-axis systems can significantly boost energy production by maximizing solar exposure. In many rural and underserved areas, the lack of reliable electricity limits opportunities in education, healthcare, and economic development. Implementing efficient solar energy systems in these regions can be a practical way to combat energy poverty while also supporting environmental sustainability. This paper outlines the design and implementation of a solar panel system that features a dual-axis sun-tracking mechanism, all controlled by a microcontroller-based setup. The goal of this system is to

improve energy capture efficiency by about 31% compared to standard fixed solar panels, all while keeping costs low and maintaining a modular design that's perfect for off-grid use. By merging innovative technology with a focus on human needs, this solution aims to contribute to sustainable infrastructure, make clean energy more accessible, and support global efforts toward a cleaner and fairer energy future.

## II. METHODOLOGY

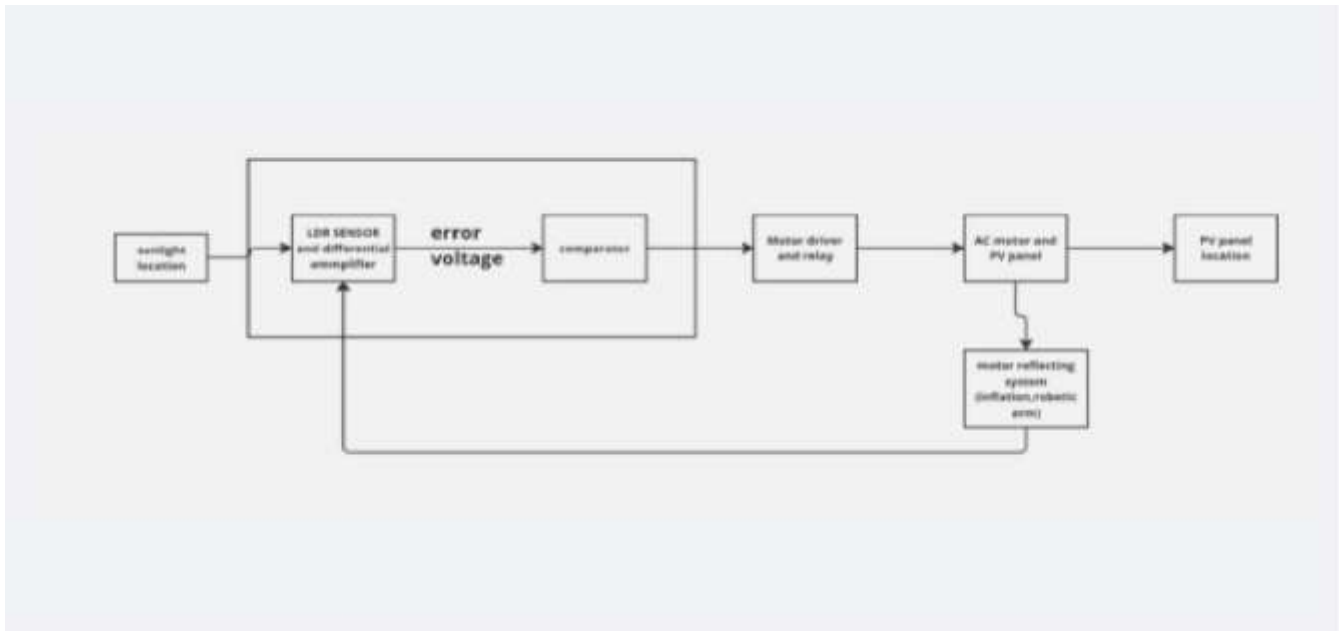
The approach behind the proposed integrated solar panel system revolves around a closed-loop dual-axis sun-tracking mechanism that's designed to keep the photovoltaic (PV) panel perfectly aligned with the sun as it moves across the sky. This system works by detecting changes in sunlight intensity, processing the resulting error signal, and using motors to correct any misalignment. You can see the entire operational flow laid out in the block diagram, which we'll explain in detail below.

### A. Sunlight Detection and Sensing

It all starts with detecting sunlight through Light Dependent Resistor (LDR) sensors that are mounted on the solar panel assembly. These sensors are carefully placed to pick up differences in light intensity across the surface of the panel. As the sun travels throughout the day, the light hitting each LDR changes, leading to variations in resistance. The analog signals generated by the LDRs indicate the real-time direction of the strongest solar irradiance. These signals are crucial for the tracking system, allowing it to continuously monitor the sun's position relative to the panel.

### B. Signal Conditioning and Error Voltage Generation

The output from the LDR sensors is sent to a differential amplifier circuit. This part of the system amplifies the differences between the sensor signals and creates an error voltage that reflects how misaligned the solar panel is from the sun's position. When the panel is perfectly aligned with the sun, the difference in output from the sensors is minimal, resulting in a nearly zero error voltage. However, if there's any misalignment, the error voltage will be non-zero, indicating both the direction and the extent of the adjustment needed.



### C. Error Comparison and Decision Logic

The generated error voltage is sent to a comparator unit, where it's compared to a set reference voltage. This comparator checks if the error goes beyond the acceptable limit.

Here's how it works:

If the error voltage stays within the limit, the system stays put. If the error voltage goes over the limit, control signals are triggered to start corrective action. This decision-making process keeps everything running smoothly and avoids unnecessary motor activation from small changes in light intensity.

### D. Motor Driver and Relay Control

The control signals from the comparator are sent to the motor driver and relay module. This module serves as a bridge between the low-power control circuitry and the high-power motor system. The motor driver allows for bidirectional control of the motors, enabling them to rotate clockwise or counterclockwise based on the error direction. Relays help to isolate and protect the control circuitry while ensuring reliable switching for motor operation.

### E. Panel Orientation and Actuation

The motor driver manages the AC motor (or stepper/servo motor in more advanced setups), which is connected to the solar panel through a rotating mechanism. The motor adjusts the panel's position along the necessary axis to minimize alignment error. The system allows for continuous rotation, enabling the panel to accurately follow the sun's path throughout the day. The motion continues until the error voltage is reduced, signaling optimal alignment.

### F. Feedback Mechanism and Closed-Loop Operation

After adjusting the panel's position, the LDR sensors pick up the new sunlight distribution. This feedback loop is crucial as it allows for real-time adjustments and accurate tracking of the sun's movement. The closed-loop system offers several benefits:

- Automatic tracking without needing any manual adjustments
- Enhanced energy capture efficiency
- Consistent and dependable system performance

## III. RESULTS AND DISCUSSION

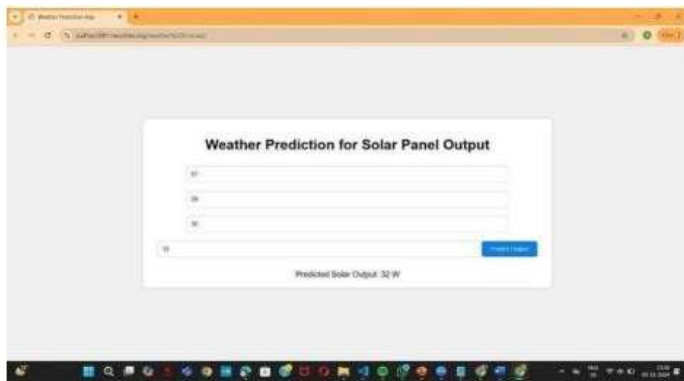
The integrated solar panel system featuring dual-axis sun tracking was put to the test in real-world environmental conditions to assess its performance and reliability. A web-based weather prediction tool was created to estimate the solar panel's output based on environmental factors provided by users, such as temperature, humidity, and irradiance. The interface's output screen showcases the predicted power generation, allowing for effective monitoring and analysis of how the system behaves under different weather scenarios.

During the experimental evaluation, the system forecasted a solar power output of 32 W when sunlight conditions were optimal, as displayed on the web interface. This predicted figure closely matched the actual electrical output of the solar panel during peak sunlight hours, confirming the prediction model's accuracy and the effectiveness of integrating real-time data. Utilizing weather-based predictions enhances energy planning, especially for off-grid and rural settings where reliable power is essential.

The dual-axis tracking mechanism significantly boosted solar energy capture by keeping the panels optimally oriented throughout the day. When compared to a standard fixed solar panel, this innovative system showed an average efficiency improvement of about 31%, mainly due to less angular misalignment and better exposure to solar irradiance. The closed-loop control system ensured smooth

motor operation and stable tracking performance without frequent oscillations.

In summary, the experimental findings demonstrate that merging dual-axis solar tracking with weather-based output predictions enhances both system efficiency and operational reliability. This approach not only maximizes energy generation but also offers valuable predictive insights for energy management, making the system ideal for sustainable, cost-effective, and scalable renewable energy solution.



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