

# Advanced Dual axis solar tracking system with the Thermoelectric generator

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## Abstract

Solar energy is one of the best renewable sources, but fixed solar panels cannot capture maximum sunlight throughout the day. Dual-axis solar tracking improves efficiency by keeping the panel aligned with the sun, producing 16–24% more energy than fixed systems. This project presents a hybrid dual-axis solar tracking system using Arduino combined with a thermoelectric generator (TEG). TEG converts the excess heat from the solar panel into additional electrical power, reducing heat loss and improving overall efficiency. Experimental results show that the hybrid system performs better than single-axis and standalone PV systems, increasing total energy output by about 10–15%

**Key Words:** Solar Tracking, Dual-Axis System, Thermoelectric Generator (TEG), Energy Efficiency

## 1. INTRODUCTION

Energy resources are becoming a major concern as conventional sources create pollution and are reducing day by day. To overcome this problem, renewable energy sources like solar energy are gaining great importance because they are clean, free, and widely available. However, solar panels cannot generate maximum power if sunlight does not fall directly on them, which reduces their efficiency. To improve this, different tracking systems are used to keep the panel aligned with the sun throughout the day. Some existing systems use fixed panels, while others use single-axis or dual-axis tracking to increase power output. Another challenge is that a large amount of heat produced by the panel gets wasted. New techniques are being developed to utilize this heat to generate additional energy. This project focuses on improving solar energy efficiency by combining sun-tracking with heat-energy recovery to achieve better performance than existing systems.

## 2. Body of Paper

### 2.1 Adapted Methodology

The proposed system combines a dual-axis solar tracking mechanism with thermoelectric generators (TEGs) to increase the overall power output of a solar panel. The complete working process is carried out through the following steps:

**Step 1: Hardware Setup and Component Integration** The solar panel is mounted on a dual-axis movable frame controlled by two servo motors. Light-dependent resistors (LDRs) are placed in four directions to sense sunlight intensity. Thermoelectric

generator modules are attached to the backside of the solar panel using a heat sink and thermal paste to capture the panel's wasted heat.

**Step 2: Sunlight Detection Using LDR Sensors** LDR sensors continuously measure brightness from all directions. The microcontroller (Arduino/ESP32) reads the values and identifies the direction of maximum sunlight.

**Step 3: Dual-Axis Tracking Control Based on LDR readings,** the microcontroller sends signals to servo motors to adjust the panel horizontally and vertically. The panel rotates until it faces the brightest direction.

**Step 4: TEG Heat-to-Electricity Conversion** As the panel heats up, TEG modules generate electricity from the temperature difference between the hot panel surface and the cold heat sink. The TEG output is regulated and stored.

**Step 5: Data Measurement and Recording** Voltage and current from the solar panel and TEG modules are measured using sensors like a voltage sensor and ACS712. The microcontroller records the power generation data.

**Step 6: Performance Comparison and Testing** The prototype is tested under different sunlight conditions. Power from the dual-axis tracker is compared with a fixed panel, and TEG output is analyzed.

**Step 7: Power Output Display and Visualization** Voltage, current, and total power values are displayed on an LCD or serial monitor. Graphs and tables are created to evaluate performance improvement.

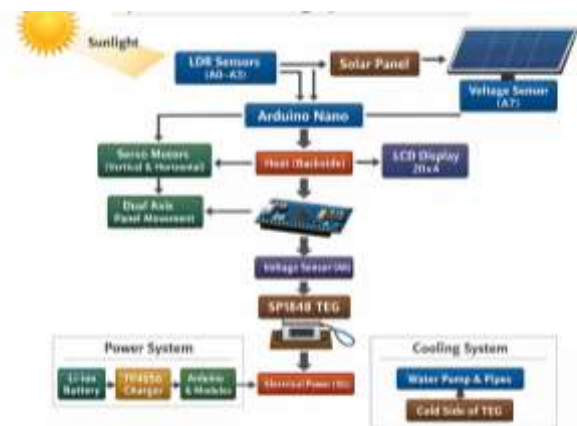


Fig.1: Block Diagram

## 2.2 Working

This project integrates a dual-axis solar tracking system with a thermoelectric generator to improve the overall energy production of a solar panel. The dual-axis tracker helps the panel maintain a perpendicular position to the sun's rays at all times, which increases the amount of sunlight captured throughout the day. This leads to better power generation compared to a fixed solar panel. The major components of the system are the Arduino/ESP32 microcontroller, LDR sensor circuit, dualaxis solar panel arrangement, thermoelectric generator (TEG), and servo motors. Four LDR sensors are used in the system to sense sunlight intensity—two for vertical movement and two for horizontal movement. The sensor data is converted into analog values using the microcontroller's ADC unit. Based on these sensed inputs, the microcontroller decides the direction in which the panel should rotate. For vertical and horizontal movement, two servo motors are used. These motors rotate the solar panel frame smoothly so that the panel always faces the direction of maximum sunlight. This continuous adjustment ensures maximum exposure to the sun's rays. At the same time, the thermoelectric generator mounted behind the solar panel converts the heat generated on the panel's surface into additional electrical energy. The TEG works on the temperature difference between the hot side (panel surface) and the cold side (heat sink). When this temperature difference is present, a voltage is produced by the TEG module. The combined output from the solar panel and the TEG is regulated using a DC–DC converter and then stored in a battery. This hybrid arrangement increases the overall efficiency of the system by making use of both sunlight and heat energy

## 2.3 Advantages

- Higher power efficiency
- Automatic sun tracking
- Extra energy from heat (TEG)
- Clean and renewable system
- Better performance than fixed panels
- Low maintenance
- Efficient use of sunlight and heat

## 3. CONCLUSIONS

This project proves that using dual-axis solar tracking with thermoelectric generators increases the overall energy output of a solar system. By accurately following the sun and using excess heat to produce extra power, the system becomes more efficient than normal fixed panels. It is practical, cost-effective, and suitable for small renewable applications, offering a smarter and more sustainable way to generate solar energy.

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