

Solar Power Tracking System

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Abstract- The single-axis solar power tracker system is an efficient and cost-effective solution designed to enhance the energy harvesting capabilities of solar panels. This system operates by aligning the solar panel perpendicular to the sun's rays throughout the day, maximizing solar energy absorption. Unlike fixed solar panels, which only capture optimal sunlight during specific times, the single-axis tracker adjusts the panel's orientation along a single rotational axis, typically following the sun's east-to-west movement.

The system employs sensors, such as light-dependent resistors (LDRs), or pre-programmed algorithms to detect sunlight intensity and control a motorized mechanism for panel adjustment. By increasing energy capture by 20-30% compared to fixed systems, the single-axis solar tracker offers a balance between performance and cost-effectiveness. It is ideal for residential, agricultural, and industrial applications, contributing to sustainable energy production while reducing dependency on non-renewable resources. This project demonstrates the potential for innovative solar technology to meet growing energy demands with enhanced efficiency and affordability.

1. INTRODUCTION

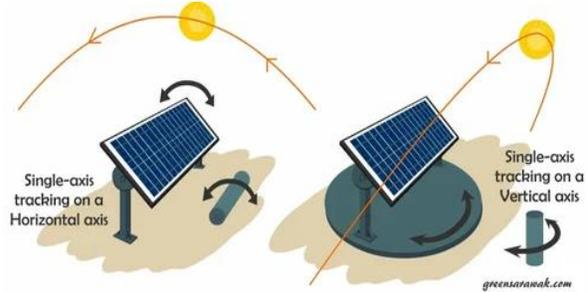
In 2017, India consumed approximately 470 million tons of coal in thermal power plants, contributing significantly to environmental pollution. During the 2017-18 period, the country's energy demand reached 915,123 million units (MU), while the actual energy availability was 908,650 MU, leading to a shortage of 6,473 MU (0.71%). Similarly, the peak electricity demand was 164,066 MW, but only 160,752 MW was met, resulting in a deficit of 2%. This shortage highlights the pressing need for efficient and sustainable energy solutions.

Developing countries like India face ongoing challenges in energy management due to over-reliance on fossil fuels, inefficient distribution, and environmental concerns. Fossil fuel reserves are depleting rapidly, and their continued use leads to severe pollution. To address these issues, renewable

energy sources, particularly solar power, offer a viable and sustainable alternative for electricity generation.

This project focuses on enhancing solar panel efficiency through a single-axis solar power tracking system, which dynamically adjusts the panel's orientation to maximize sunlight absorption throughout the day. Unlike static solar panels, which capture optimal sunlight only during certain hours, this automated tracking system continuously follows the sun's movement, increasing energy output. The system is powered by two DC geared motors, which control the panel's rotation along a single axis. Light-dependent resistors (LDRs) play a crucial role in detecting sunlight intensity, enabling the panel to adjust accordingly for better energy harvesting, even under varying weather conditions.

By implementing this single-axis solar tracking system, solar panels can significantly improve their efficiency, generating more electricity compared to fixed installations. This makes the system suitable for residential, commercial, and industrial applications, helping to reduce dependence on non-renewable energy sources while contributing to a cleaner and more sustainable future.



2. RELATED WORK

Solar tracking systems have been widely researched to enhance the efficiency of photovoltaic (PV) energy generation. Among the different tracking mechanisms, single-axis and dual-axis trackers have been extensively explored. While dual-axis trackers offer the highest efficiency by adjusting both azimuth and elevation

angles, they come with increased complexity and cost. Single-axis trackers, on the other hand, provide a cost-effective solution, improving solar energy capture by 20-30% compared to fixed panels. Their ability to follow the east-to-west movement of the sun ensures more consistent power generation throughout the day. Numerous studies have demonstrated the effectiveness of light-dependent resistors (LDRs) in detecting sunlight intensity and guiding solar panels for optimal positioning. Microcontrollers like Arduino are commonly used for automated control, processing real-time sensor data to adjust servo motors that reposition the solar panels accordingly. This setup minimizes manual intervention and increases energy output, making solar power more efficient and practical.

Beyond hardware improvements, research has also focused on Maximum Power Point Tracking (MPPT) algorithms and IoT-based monitoring systems to enhance solar tracking accuracy and automation. MPPT ensures that solar panels operate at their peak efficiency, while IoT integration enables remote monitoring and performance optimization. Comparative studies between fixed and tracking solar panels consistently show that tracking systems generate significantly more electricity, especially during mornings, evenings, and seasons with lower sun angles.

Building upon these advancements, this project incorporates sensor-based solar tracking with smart automation to ensure real-time adjustments for maximizing energy efficiency. By leveraging microcontroller-based control mechanisms, the system provides a reliable, automated, and cost-effective approach to solar power generation. As the demand for sustainable energy solutions grows, single-axis solar tracking technology plays a crucial role in improving solar energy utilization, making renewable power more accessible, efficient, and viable for diverse applications.

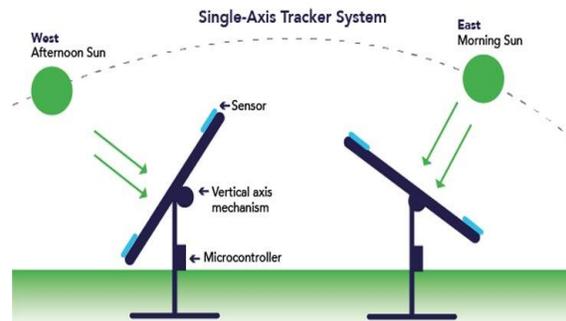
3. SYSTEM OVERVIEW

The traditional solar panel systems are fixed at a particular angle, limiting their efficiency as they cannot follow the sun's movement throughout the day. This results in suboptimal energy generation, with peak output occurring only when the sun is directly aligned with the panels. To address this limitation, the

Solar Power Tracker System is designed to dynamically adjust the panel's orientation using light-dependent resistors (LDRs) and an Arduino-based control system.

The LDR sensors detect the sun's position, and the Arduino microcontroller processes this data to control a servo motor, which adjusts the panel's angle accordingly. This mechanism ensures that the panel remains perpendicular to the sun, maximizing solar energy absorption and improving efficiency by 20-30% compared to conventional fixed panels. Additionally, a rechargeable battery is incorporated to store excess energy, making the system suitable for off-grid applications. While the tracking system enhances energy production, it also introduces some challenges, such as mechanical wear and tear, power consumption for motor operations, and weather dependency.

However, its benefits in terms of increased energy output, automation, and cost-effectiveness outweigh these limitations. Future enhancements may include dual-axis tracking, AI-driven predictive algorithms, and IoT-based remote monitoring, further optimizing energy efficiency and reliability. The Solar Power Tracker System represents a significant step toward sustainable energy solutions, improving the practicality and effectiveness of solar power utilization.



4. WORKING PRINCIPLE

The Single-Axis Solar Power System is designed to maximize solar energy absorption by dynamically adjusting the orientation of solar panels in response to the sun's movement. Unlike fixed solar panels, which receive optimal sunlight only at specific times of the day, this system continuously aligns itself to ensure the panel remains perpendicular to the sun, significantly increasing energy generation.

The system functions through the integration of Light Dependent Resistors (LDRs) and an Arduino UNO microcontroller, which work together to detect and

respond to changes in sunlight intensity. The LDR sensors continuously monitor the sun's position by measuring light intensity levels. This data is then processed by the Arduino UNO, which calculates the optimal panel orientation and sends signals to a servo motor or DC geared motor to adjust the solar panel accordingly. This dynamic movement ensures maximum sunlight absorption throughout the day, thereby improving efficiency.

The system operates automatically as soon as it is powered on. When the Arduino is connected to the battery, the solar panel immediately aligns itself towards the brightest light source, optimizing sunlight capture. The LDR sensors play a critical role in detecting variations in light intensity and guiding the panel's movement in the direction of the highest illumination. Throughout the day, as the sun changes position from east to west, the system continuously adjusts the panel's tilt and angle to maintain optimal energy absorption.

To ensure system stability and reliability, a switch mechanism is implemented. Once the panel completes its tracking process, the switch locks the panel in its final position, preventing unnecessary movements and minimizing wear and tear on the components. This feature also protects the system from damage due to excessive rotation or adverse weather conditions.

By using real-time tracking and automated control, the Single-Axis Solar Power System enhances solar energy efficiency while reducing dependency on manual adjustments. This makes it an ideal solution for residential, agricultural, and industrial applications, where consistent and efficient solar power generation is required.

5. RESULT AND ANALYSIS

The Single-Axis Solar Tracker System is designed to enhance energy efficiency by dynamically adjusting the orientation of solar panels to follow the sun's movement throughout the day. Unlike fixed solar panels, which only receive optimal sunlight during peak hours, the tracking system ensures that the panels remain perpendicular to the sun's rays at all times, significantly increasing the amount of energy harvested. This continuous adjustment reduces energy losses caused by indirect sunlight and maximizes power generation, making it a more effective solution for renewable energy production.

One of the key advantages of the system is its ability to adapt to varying sunlight conditions and different geographical locations. In regions with frequent changes in sun angles and shifting weather patterns, fixed solar panels often fail to maintain optimal efficiency. However, the Single-Axis Tracker compensates for these variations, ensuring steady and reliable energy production throughout the day. Studies have shown that single-axis trackers can increase energy output by 20-30% compared to fixed panels, making them a highly efficient and cost-effective alternative.

While the initial cost of installing a solar tracker system is higher than that of traditional fixed-panel setups due to the additional components such as motors, sensors, and control mechanisms, the long-term benefits outweigh the investment. The increased power generation over time leads to shorter payback periods and higher returns on investment. Additionally, advancements in sensor technology, automation, and AI-driven tracking algorithms are expected to further reduce costs and improve performance, making solar trackers more affordable and accessible in the future.

By ensuring consistent power generation, even under fluctuating sunlight conditions, the Single-Axis Solar Tracker System is a valuable technology for a wide range of applications, including residential solar systems, commercial solar farms, and off-grid energy solutions. As solar energy continues to play a crucial role in the global transition to renewable energy, solar tracking systems will become an essential component in maximizing efficiency and sustainability.

Power Generated by the Angle and corresponding Time of Day:

Angle (in degrees)	Time of Day	Power generated (in amps and voltage)
0 (horizontal)	06:00 AM to 08:00 AM	4V, 0.4 - 0.6A
10	08:00 AM to 10:00 AM	5V, 0.6 - 0.8A
30	10:00 AM to 02:00 PM	6V, 0.9 - 1A (peak power)
60	02:00 PM to 04:00 PM	5.5V, 0.8 - 0.9A
90(vertical)	04:00 PM to 06:00 PM	4V, 0.3 - 0.5A

These are approximate values, it can vary on specific solar panel & environmental conditions.

6. CONCLUSION AND FUTURE SCOPE

Solar power tracker systems, especially Single-Axis trackers, significantly improve solar energy generation by constantly adjusting the orientation of solar panels to face the sun. This ensures optimal sunlight exposure, leading to higher energy output compared to fixed panels, especially during mornings, evenings, and in seasons with low sun angles. Single-Axis trackers also adapt to changing weather conditions, maintaining consistent energy generation even when cloud cover or sun angles vary, ensuring reliable performance year-round.

While Single-Axis solar trackers have higher initial costs, their increased energy production leads to quicker payback periods and better long-term returns. This makes them an effective and cost-efficient solution for various applications, from residential rooftops to large-scale solar farms and off-grid systems. In conclusion, Single-Axis trackers offer a sustainable way to maximize solar energy use, helping to drive the transition to renewable energy and meet global energy demands efficiently.

Single-Axis solar power tracker systems are becoming an important technology in the shift towards sustainable energy. These trackers improve the efficiency of solar panels by constantly adjusting to follow the sun, increasing energy output. Future advancements in sensor technology, actuator mechanisms, and control algorithms will enhance the accuracy and performance of these systems. Additionally, the integration of artificial intelligence and machine learning could further improve tracking and solar energy prediction. These innovations are expected to lower costs, increase reliability, and make Single-Axis trackers more widely used in both utility-scale and smaller-scale solar installations.

As renewable energy sources, like solar power, continue to grow, combining solar trackers with energy storage systems will provide significant benefits. Excess energy generated during peak sunlight hours can be stored for later use, making the grid more stable and reliable. Solar trackers are not only useful for large solar farms but can also be applied to commercial and residential solar installations, especially in urban areas where space is limited. With technological advancements making trackers more affordable, they are expected to play a key role in increasing solar energy adoption,

contributing to a more sustainable and resilient energy future.

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