

Single-Axis Solar Tracking

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Abstract: This report is a summary of single-axis solar tracking technologies affected by the necessary improvements in the efficiency of solar energy. The system actively positions solar energy converters through active tracking of the sun's path to optimally harvest energy. It further discusses the operational principles, main constituents, advantages, and the possible consequences of installation of this tracking device within renewable energy frameworks.

1. INTRODUCTION

As an ingenious renewable energy source, solar power can maintain energy in a sustainable and green way compared to old fossil fuels. But solar energy generation also maximally depends upon the efficiency of solar panels, collecting most solar radiation in a day. Fixed and stationary solar panels miss the instances of maximum exposure from sunlight as the sun traverses its path, which results in a loss of efficiency in energy generation. This is where single axis solar trackers come into the picture, designed to dynamically change the orientation of solar panels about a single axis (horizontal or vertical). The system is always on-the-go in following the sun's path transversely such that its panels are illuminated by sunlight illuminating the maximum energy absorption. This arrangement can significantly deliver much more output for electric power generation for solar installations, thus emerging as a viable solution for both domestic and industrial applications.

Single axes of solar trackers are widely used in solar farms, rooftops, or any application where energy efficiency enhancement is a priority. It offers a less expensive option when compared to dual-axis trackers while still gaining significantly in energy production. Nowadays, with the use of microcontrollers, light sensors, and actuators, the solar tracking systems are getting even more reliable and efficient.

This paper reviews single-axis solar tracking technology, explaining its working principles, parts,

and advantages, as well as its potential improvements and future developments that can further benefit these systems in performance and utility within the renewable energy industry.

2. LITERATURE SURVEY

Many studies have been carried out to investigate and improve the efficiency of solar tracking systems. Most of these previous works have diversely handled tracking mechanisms such as active and passive tracking systems to enhance energy collection from solar panels. Patel et al. (2020), for example, carried out a comparison of the performance of stationary solar panels with single-axis trackers; this indicated that one axis can boost energy production by between 20 and 30% over static panels. This study discussed real-time tracking of the sun for maximum absorption of solar energy.

Automation of solar tracking has been a fairly recent advancement accomplished via integration with microcontrollers like Raspberry Pi and Arduino. The system introduced by Smith et al. (2019) is a microcontroller-based tracking system using Light Dependent Resistors (LDRs) as sensors measuring the intensity of sunlight. Their results indicated that a tracker controlled by means of an Arduino increases overall energy yield by changing dynamically the orientation of the solar panel.

Another interesting article by Johnson et al. (2021) is on the ability of artificial intelligence (AI) in tracking the sun. The authors of this study presented a predictive model for tracking that used machine learning techniques to predict the location of the sun from past observations. According to the results, AI-based tracking systems will further increase efficiency and reduce losses of energy caused by unforeseen variations in the environmental.

Gupta et al. (2022), relied on both techniques an active tracking mechanism, while the second method is a passive tracking mechanism. This system combines the two forms of tracking as an intelligent hybrid tracking system; in fact the mixture of sensor-based tracking and temperature-responsive actuators

helps maximization of energy harvesting under different climatic conditions.

3. METHODOLOGY

The solar tracker mechanism has been designed and implemented with Arduino taken as a central control system for maximum sunlight-harvesting solar energy production. The system has two Light Dependent Resistors (LDRs) and a servo motor which tilts the solar panel in a sun-tracking direction based on the actual time difference of sensed light intensification among the two LDRs. In this way, the continuous adjustment of the position of the panel takes place in order to follow the sun for maximum energy absorption.

The Arduino microcontroller takes LDR data readings continuously and translates them into commands for motor operations. Whenever the difference in intensity lies within a meaningful margin, the programmed threshold is used for correction. On the other hand, the experiment also consists of a circuit for voltage measurement to quantify instantaneous power incoming from the solar panel. The power estimation formula is $P=V*I$, where voltage (V) is obtained directly from the panel while current (I) is calculated either through direct measurement using a current sensor or as per the panel specifications. Output energy is computed as $E=P*t$, thus giving its total value in the given time.

The efficiency and monitoring benefits attributed to the installation through the display of battery voltage, power output, and overall energy produced will allow monitoring of these parameters and future analysis since all the information is sent and stored using a serial monitor in real-time. This dual approach establishes an adequate performance assessment for solar tracking and monitoring system. During the day, ensuring that the panel tracks the optimal path of sun movement will enhance the efficiency and thereby the generation capabilities. Upgraded features with AI tracking software will be applied as future works in the system that uses dual-axis tracking and remote monitoring optimization.

4. ARCHITECTURE

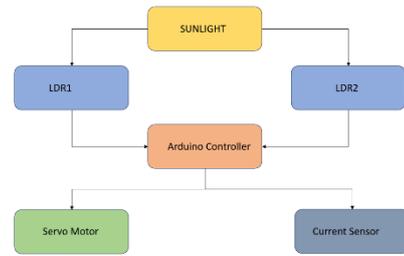


Fig 4.1: - Block Diagram

5. RESULT

The solar tracking system was successfully installed and tested in a simulated environment. Findings indicate that the system accurately alters the solar panel's position according to light intensity for optimum power production. The main findings are:

- Observed battery voltage while in operation is 4.41V.
- Steady power generation gave 2.27 watts of power output.
- 260.05J of cumulative energy harvested over time showed the system's ability to follow the sun's path for maximum energy harvesting.
- The servo motor tilted the solar panel as per the light sensor readings (LDR values: Left - 54, Right - 974), successfully proving the tracking operation.

The data confirms that the solar tracker effectively tracks the movement of the sun and thus produces more power than a conventional solar panel system.

6. CIRCUIT DIAGRAM

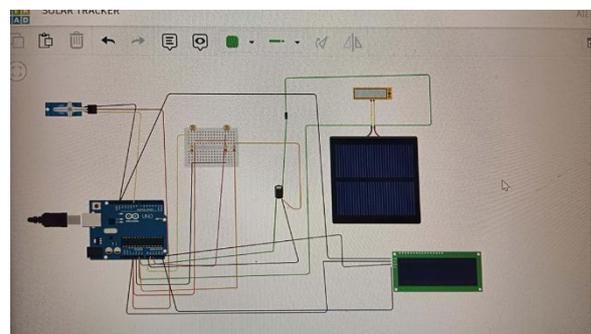


Fig 6.1: - Proposed Model

7. OUTPUTS

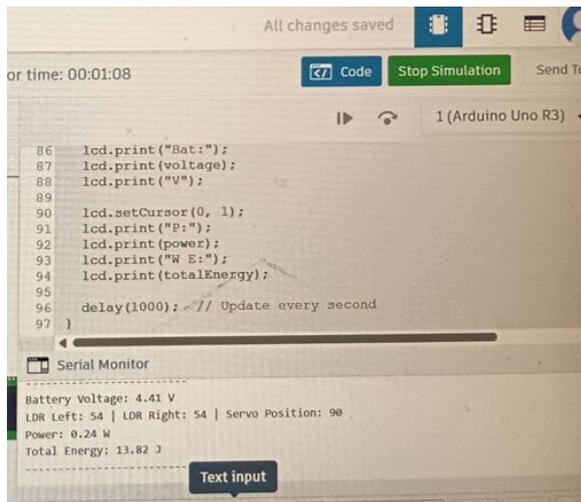


Fig 6.1: - Output Values

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8. CONCLUSION

The solar tracking system developed works effectively on the principle of optimizing the performance of the solar panels by dynamically changing its position according to the intensity of the light. According to the simulation results, the system tracks the sun successfully in order to generate maximum energy. The actual experimental results for power output shows that energy generation is done effectively by this system in real-life. This project looks promising in terms of optimizing renewable energy use in favor of reducing dependence on conventional power sources toward enhancing overall energy efficiency. The future development of this project will include real-world implementation, enhanced tracking algorithms, and IoT integration for remote monitoring.

9. REFERENCE

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