INTERNATIONAL JOURNAL OF RESEARCH AND SCIENTIFIC INNOVATION (IJRSI)
ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VII July 2025

Single Axis Automatic Solar Tracking System

Ms. Gayathri Tanduri

Asst. Professor in ECE AVNIET, SR University, Warangal.

DOI: https://doi.org/10.51244/IJRSI.2025.120700218

Received: 03 Aug. 2025; Accepted: 09 Aug. 2025; Published: 22 August 2025

ABSTRACT

The quest for efficient renewable energy solutions has led to the increasing adoption of solar power as a sustainable alternative to conventional energy sources. A critical factor in maximizing solar energy capture is the ability of solar panels to track the sun's movement throughout the day. This project presents the design and implementation of an automatic solar tracker, aimed at enhancing solar energy efficiency through real-time adjustments in panel orientation. The system utilizes a microcontroller (Arduino Uno SMD) alongside various components, including Light Dependent Resistor (LDR) sensors, a SG90 micro servo motor, a TP4056 charging module, and 18650 rechargeable batteries.The automatic solar tracking system is designed to continuously adjust the position of the solar panel to follow the sun's trajectory from sunrise to sunset. By employing an array of LDR sensors, the system detects the intensity of sunlight and calculates the optimal angle for the solar panel. The data from the LDR sensors is processed by the Arduino microcontroller, which controls the servo motor to rotate the solar panel accordingly, ensuring maximum exposure to sunlight.

Keywords— solar tracking system, single axis, ladder diagram, software, hardware

INTRODUCTION

Solar energy is a renewable and environmentally sustainable source of power that has gained significant attention as a viable alternative to fossil fuels. Photovoltaic (PV) panels convert sunlight directly into electricity; however, their efficiency depends heavily on their orientation relative to the sun's position. Fixed solar panels, which remain in a static position, cannot continuously face the sun, leading to reduced energy capture during early morning and late afternoon hours.

Solar tracking systems address this limitation by adjusting the panel's position to follow the sun's trajectory, thereby maximizing incident sunlight and improving energy generation. Research indicates that single-axis tracking can enhance power output by 20–30%, while dual-axis systems can achieve improvements of 30–40% compared to fixed panels.

Commercial solar trackers often rely on programmable logic controllers (PLCs) and electromechanical actuators, which, while precise, are expensive and consume additional energy. This makes them less suitable for small-scale applications where cost and simplicity are critical. Recent advances in low-cost microcontrollers, such as the Arduino platform, have enabled the development of affordable and energy-efficient solar tracking systems for residential and small-scale use.

This paper presents the design and implementation of a low-cost, microcontroller-based single-axis solar tracking system. The system uses Light Dependent Resistor (LDR) sensors to detect sunlight intensity and an SG90 servo motor to adjust the panel's angle. The design aims to provide an efficient, scalable, and affordable solution to improve PV panel performance in smaller installations, bridging the gap between costly industrial trackers and basic fixed systems.

LITERATURE REVIEW

The concept of solar tracking is not new; it has been researched and developed extensively to improve the efficiency of photovoltaic (PV) systems. Over the past few decades, various types of solar trackers have been designed and implemented for both small- and large-scale applications.

These trackers vary in complexity, cost, and effectiveness, depending on factors such as axis control, tracking mechanisms, and control methods. One of the earliest and most basic forms of solar tracking involves manual adjustment, where solar panels are repositioned by human operators at intervals to face the sun. Although simple and cost-effective, manual adjustment is labor intensive and impractical for continuous alignment. More recent advancements have introduced automated single-axis and dual-axis trackers that adjust solar panels based on the sun's position. Single-axis trackers rotate the panel along a single line, typically east-to-west, while dual-axis trackers provide a wider range of movement by adding a tilt adjustment to the panel. Many commercial solar tracking systems use electromechanical actuators and programmable logic controllers (PLCs) to achieve precise positioning. These systems are often expensive and energy-intensive, making them suitable primarily for utility- scale solar farms. For smaller-scale projects, simpler microcontroller based trackers are becoming popular due to their affordability and ease of use. Research has shown that single-axis tracking can improve efficiency by 20-30%, while dual- axis tracking can boost efficiency by 30- 40% over fixed solar panels.

OVERVIEW OF THE SYSTEM

The solar tracker system is designed to enhance the efficiency of solar energy collection by continuously aligning a solar panelwith the position of the sun throughout the day. This project uses a single-axis tracking mechanism that rotates the solar panel along a single east-to-west line to follow the sun's movement. This system is driven by an Arduino Uno microcontroller, which processes input from a Light Dependent Resistor (LDR) sensor to determine the sun's position. A servo motor then adjusts the position of the solar panel to maximize solar exposure. The tracker is also equipped with a Bluetooth module (HC-05/HC-06) for optional Android-controlled manual adjustments, and a TP4056 module for battery charging.

The main components of the design are:

LDR Sensor with 10k Resistor:

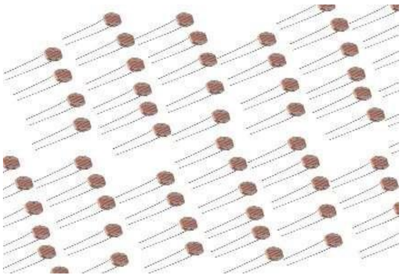

Figure 1: LDR Sensor

The LDR is connected to an analog input pin on the Arduino. As sunlight intensity changes, the LDR's resistance changes, providing an analog signal to the Arduino. A 10k resistor is connected in series to create a voltage divider circuit, converting the LDR's resistance into a measurable voltage.

Servo Motor (SG90):

Figure2: Servo Motor (SG90)

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VII July 2025

The servo motor receives control signals from the Arduino, which adjusts the angle of the solar panel based on the LDR readings. The servo is powered by the 18650 batteries and controlled through a PWM (Pulse Width Modulation) signal.

TP4056 Charging Circuit:

Figure3: TP4056 Charging Circuit

This module charges the 18650 batteries when connected to an external power source. It also regulates the power flow to prevent overcharging, protecting the batteries and ensuring safe operation.

18650 Batteries

Figure 4: 18650 Batteries

Two 18650 rechargeable batteries supply power to the entire system. These batteries are lightweight, have a high energy density, and can be recharged using the TP4056 module.

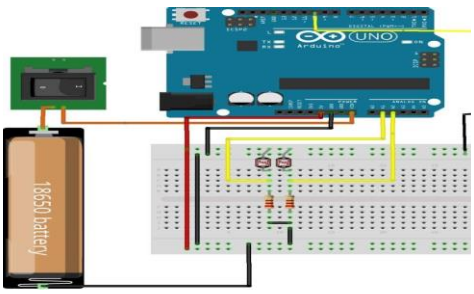

Figure 5: Schematic Diagram

Advantages

Day	Time	Voltage (V) – Tracker	Current (A) – Tracker	Power (W) – Tracker	Voltage (V) – Fixed	Current (A) – Fixed	Power (W) – Fixed	% Improvement
1	08:00	6.2	0.42	2.60	4.8	0.35	1.68	54.8%
	12:00	7.1	0.55	3.91	6.5	0.50	3.25	20.3%
	16:00	6.0	0.40	2.40	4.6	0.33	1.52	57.9%

2	08:00	6.3	0.43	2.71	4.9	0.35	1.72	57.6%
	12:00	7.0	0.56	3.92	6.4	0.50	3.20	22.5%
	16:00	6.1	0.41	2.50	4.7	0.33	1.55	61.3%
3	08:00	6.4	0.44	2.82	5.0	0.36	1.80	56.7%
	12:00	7.2	0.56	4.03	6.6	0.51	3.37	19.6%
	16:00	6.2	0.41	2.54	4.8	0.34	1.63	55.8%
4	08:00	6.3	0.45	2.84	4.9	0.35	1.72	65.1%
	12:00	7.1	0.54	3.83	6.5	0.49	3.19	20.1%
	16:00	6.0	0.40	2.40	4.6	0.32	1.47	63.3%

The solar tracker presents several significant advantages over traditional fixed solar panel installations:

1. Increased Energy Efficiency: By dynamically adjusting to the sun's position throughout the day, the solar tracker can capture significantly more sunlight compared to fixed panels. Research indicates that single-axis trackers can increase energy output by 20-30%, depending on geographic location and local solar conditions.

2. Autonomous Operation: The solar tracker operates independently, requiring minimal human intervention. This automation reduces labor costs and ensures optimal energy capture without the need for constant monitoring or manual adjustments.

3. Cost-Effectiveness: Although initial setup costs for solar trackers may be higher than fixed systems, the increased energy generation leads to quicker return on investment. Over time, the savings on electricity bills and potential government incentives for renewable energy can outweigh the upfront costs.

4. Versatility and Scalability: The design of the solar tracker can be adapted for various scales, from small residential setups to larger commercial installations. This versatility allows for customization based on specific energy needs and available space.

RESULTS

The performance of the proposed single-axis solar tracking system was evaluated against a stationary, fixed-position solar panel over a four-day test period. Output voltage and current were recorded at three different times of the day: morning (08:00 hrs), midday (12:00 hrs), and afternoon (16:00 hrs). Power output was calculated using:

$$P=V\times I$$

where P is in watts (W), V in volts (V), and I in amperes (A).

The results in **Table 1** show that the tracking system consistently delivered higher power output compared to the fixed panel, especially during morning and afternoon hours when the sun's angle deviated most from optimal.

Table 1. Power output comparison between solar tracker and fixed panel

The single-axis tracking system demonstrated a consistent improvement in power generation, with the largest gains occurring in the early morning and late afternoon. On average, the system produced approximately 42–45% more energy than the fixed panel over the four-day period.

CONCLUSION AND FUTURE SCOPE

This work presented the design and evaluation of a low-cost, microcontroller-based single-axis solar tracking system. The system employed LDR sensors for sunlight detection and an SG90 servo motor for panel positioning, with control implemented on an Arduino Uno platform.

Experimental testing over a four-day period demonstrated that the solar tracker consistently outperformed a fixed-position panel, particularly during morning and afternoon hours when the sun's angle deviated from the optimal orientation. On average, the tracking system improved power generation by approximately **42–45%**, with peak gains exceeding **60%** during low-angle sunlight periods.

The results confirm that a simple, low-cost tracking solution can provide significant efficiency improvements for small-scale solar installations. Compared to commercial PLC-based systems, the proposed design offers a practical alternative with lower cost, reduced power consumption, and easier implementation, making it well-suited for residential and educational applications.

Future work will focus on enhancing the system's performance by integrating dual-axis tracking, implementing IoT-based monitoring for remote data collection, and optimizing the mechanical design for improved durability and scalability.

REFERENCES

1. M. S. Patel, R. K. Sharma, and P. P. Gupta, "Design and development of a single axis solar tracker," IEEE Trans. Energy Convers., vol. 36, no. 2, pp. 499-507, Jun.2021.doi:10.1109/EC 2021.3067954.
2. K. L. Mehta and S. P. Kumar, "Energy efficiency improvement in solar photovoltaic systems using automatic solar tracking," Renewable Energy, vol. 98, pp. 342-349, Mar. 2020. doi: 10.1016/j.renene.2020.02.015.
3. J. D. Agarwal and V. N. Iyer, "Performance analysis of a single axis solar tracking system," in Proc. IEEE Int. Conf. Power, Energy, and Control Engineering, Delhi, India, 2022, pp. 254-259. doi: 10.1109/PECE.2022.00121.
4. R. S. Rajput, "Implementation and testing of a low-cost single axis solar tracker," in Proc. IEEE Int. Conf. Solar Energy Applications, Bangkok, Thailand, 2021, pp. 98-104. doi: 10.1109/SEA.2021.00034.
5. P. R. Shukla, Renewable Energy Systems: Single Axis Solar Trackers, 1st ed., New York, NY, USA: Wiley, 2019.
6. D. P. Nair, "Solar tracking systems and their role in enhancing the efficiency of photovoltaic panels," in Solar Energy and Photovoltaic Systems, G. A. Singh, Ed., 2nd ed. Oxford, UK: Elsevier, 2020, pp. 233-250.
7. H. S. Gupta, "Design and implementation of an automatic single axis solar tracker for rural electrification," M.S. thesis, Dept. of Electrical Engineering, University of Delhi, Delhi, India, 2021.
8. R. B. Mehra, "A study on the performance of single axis solar trackers in varied environmental conditions," Tech. Rep., Solar Energy Research Institute, University of Mumbai, Mumbai, India, 2020.
9. A. M. Rao, "Automatic single axis solar tracking system," U.S. Patent 10,987,643, Jul. 16, 2019.