Solar Tracking System: From Traditional to AI-Integrated Solutions

Harsh Suresh
Department of Computer Science(ADS)
Vimal Jyothi Engineering College harshsrh0@gmail.com

Prithviraj K
Department of Computer Science(ADS)
Vimal Jyothi Engineering College
iprithvi2003@gmail.com

Vinayakrishnan C
Department of Computer Science(ADS)
Vimal Jyothi Engineering College
vinayakrishnanc@gmail.com

Jasim KT
Department of Computer Science(ADS)
Vimal Jyothi Engineering College
jasimkt771@gmail.com

Anit Thomas M
Assistant Professor
Department of Computer Science(ADS)
Vimal Jyothi Engineering College
anitthomasm@vjec.ac.in

***Abstract*—The performance of solar panels is highly dependent on their alignment with the sun. Fixed solar panel systems do not increase energy absorption, while traditional tracking methods often depend on mechanical sensors and predefined algorithms, which may lack pre- cision and adaptability. Different types of solar tracker available are studied and the best mechanism is chosen to built the solar tracker that makes use of machine learn- ing. The proposed model uses historical solar position data, weather parameters, and real-time power output to determine the optimal tilt and azimuth angles. By contin- uously adapting to environmental conditions, the system enhances energy capture, minimizes reliance on costly sensors, and surpasses conventional tracking techniques in performance. Experimental evaluations indicate that ML-driven tracking significantly improves energy effi- ciency and adaptability. This research underscores the role of artificial intelligence in optimizing renewable energy systems and contributes to the development of better renewable energy sources.**

I. Introduction

As the global demand for renewable energy in- creases, solar power has emerged as a key sustainable energy source. However, the efficiency of solar panels is highly dependent on their orientation relative to the sun. Fixed solar panel systems fail to increase energy absorption throughout the day due to the sun's continuous movement. To resolve this limitation, solar tracking systems have been developed to adjust panel angles dynamically, thereby improving energy capture. Traditional solar tracking techniques often utilize me- chanical sensors or pre-programmed data to follow the sun's movement. While these methods offer improve- ments over static panels, they come with limitations such as sensor inaccuracies, mechanical wear, and an inability to adapt to sudden environmental changes like cloud cover or shading. These solar tracking approaches may not effectively respond to real-time variations in solar position and weather conditions, leading to energy losses. The advancement in the field of artificial intelligence and machine learning has opened a new way to track the position of sun more accurately without the use of expensive sensors. Unlike conventional systems, machine learning based tracking continuously learns from data and adapts to changing environmental conditions, improving decision-making for maximum energy absorption. By incorporating AI into solar tracking, this research contributes to the advancement of intelligent, data-driven renewable energy technologies.

II. LITERATURE SURVEY

The type of solar tracker that uses single axis tracking system [1] is proven more efficient compared to the conventional solar panels. An experiment conducted, shows an increase in the efficiency of solar panels [1].

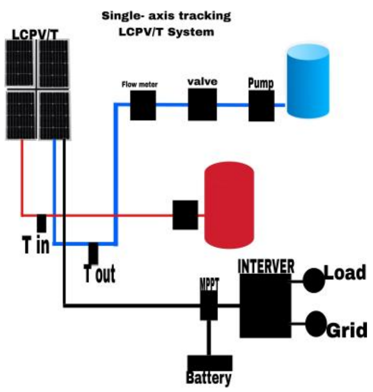


Fig 1: Schematic diagram of the single-axis tracking LCPV/T system .

It also uses a low concentration photovoltaic /thermal system. Advantages of this model are, increased efficiency, the amount of energy output and

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 03 | March - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

adaptability of the solar panels. Limiting factors of this model are, complexity of construction, economic feasibility as it uses expensive components and heat management.

The experiment conducted on a model that incor- porates two Light Dependent Resistor (LDR) sensors for sun position detection and an Arduino Uno 3 microcontroller to regulate a servo motor, ensuring that the SPV panel follows the sun's movement from east to west is mentioned in paper ,"Analysis of Single Axis Sun Tracker System to Increase Solar Photovoltaic Energy Production in the Tropics"[3]. Comparative analysis with fixed-tilt SPV systems indicates a 22 percentage increase in energy output when using the tracking system. This enhancement demonstrates the potential of single-axis tracking technology, particu- larly in tropical regions, where it can significantly improve solar energy generation.

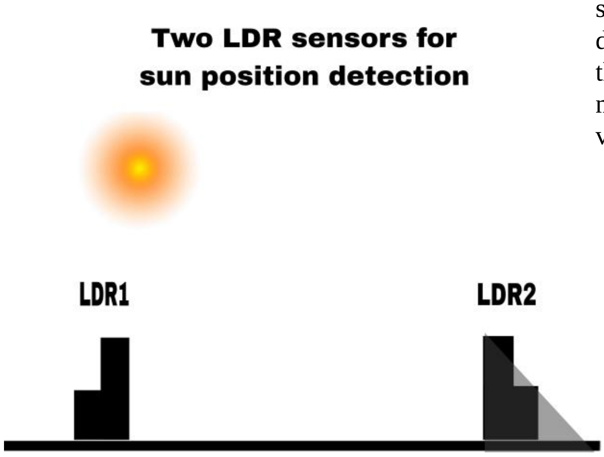


Fig 2: Two LDR sensors for sun postion detection

[3] This model provides increased energy output, adaptability to tropical climates and a cost effective solution. Limiting factors of this model are, limited tracking capability unlike dual axis tracker, increased power consumption, mechanical wear and tear and initial calibration complexity.

The model that uses Arduino Atmega328p micro- controller and Light Dependent Resistors (LDR) to dynamically adjust solar panel positioning through servo motors, is mentioned in paper "Single axis solar tracking system"[2]. By ensuring the panel remains perpendicular to incident sunlight, the system enhances energy capture. A thorough construction and testing phase highlight the efficiency gains compared to fixed solar panels, reinforcing the role of single-axis tracking in promoting renewable energy adoption.

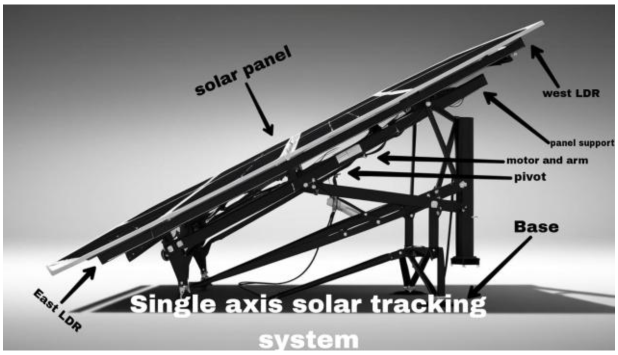


Fig 3: Single axis solar tracking system

[2] this model provides increased enhanced efficiency, cost effectiveness, sustainability. Disadvantages of this model are initial setup complexity, energy consumption and mechanical wear and maintenance.

"Performance Analysis of Dual-Axis Solar Tracking System"[4],states a way to evaluate the effectiveness of a dual axis solar tracking system using Arduino tech- nology. The system integrates five Light Dependent Resistors (LDRs) to detect optimal sunlight exposure, alongside two servo motors that adjust panel orienta- tion accordingly. The control mechanism is developed using C programming and executed via an Arduino UNO microcontroller.

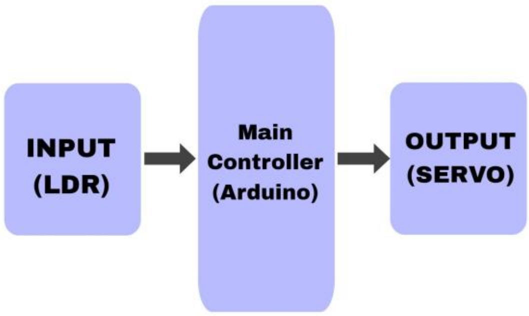


Fig 4: Control mechanism with Arduino

[4] The results indicate that the dual-axis tracking system achieves greater voltage, current, and power output than a stationary panel, proving its effectiveness in increasing solar energy capture. Advantages of dual axis solar tracker are, enhanced energy capture, improved efficiency and automated control. disadvantages are increased complexity, higher energy consumption, maintenance requirements and cost considerations

A solar tracking system that enhances energy absorption by at least 15 percentage compared to static panels, is mentioned in The paper "Design of a Solar Tracking System for Renewable Energy"[5]. The system is designed for both standard homes and remote areas, with the ability to autonomously collect solar energy, convert it into usable AC power, and monitor in real-time through an integrated LCD display. It is semi-portable, weighing under 100 lbs, cost-effective, and resistant to environmental factors such as wind and temperature variations. The system improves efficiency through real-time tracking and a power inverter, making it a sustainable alternative to fossil fuels. However, it has some drawbacks, including high initial costs, mechanical wear and tear, system complexity, and dependence on battery storage and weather conditions. Another is that moving parts need maintenance and tracking failures incur efficiency losses. Still, with all these restrictions, the system remains reliable, eco-friendly, and efficient, and can definitely be a means of supplementing traditional power sources.

”Solar Tracking System Using Microcontroller,”[6] demonstrates how a solar tracking system can help enhance the efficiency of solar panels by ensuring alignment with the position of the sun as determined for various daytime positions. The system implements continuous solar tracking using MSP430 microcontrollers, a stepper motor, and a motor driver like ULN2003A without relying on LDRs. It uses a time-based system and provides tracking that is independent of cloudy weather. The stepper motor turns the solar panel by 7.5° each hour between sunrise and sunset, and it resets to its position at the beginning of the following day. According to the research, a tracking system outperforms fixed photovoltaic systems as the conversion efficiency increases by 30-40 percentage. The current prototype is a miniature model but could include two-axis rotation or a more robust motor setup in future improvements toward practical applications. The project was developed at BNMIT, Bangalore, by faculty members and their support

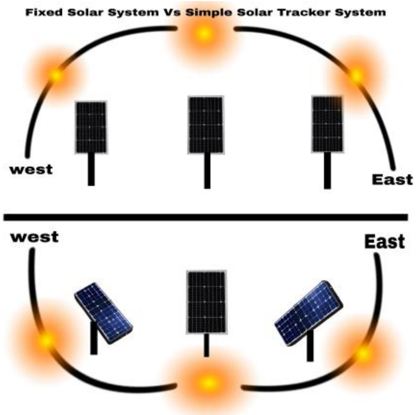


Fig 5: Fixed Solar Tracker System Vs Simple Solar Tracker System

”Design and Fabrication of Automatic Single Axis Solar Tracker for Solar Panel”[7] is a research paper that focuses on the development and fabrication of an automatic single-axis solar tracking system designed to increase the efficiency of solar panels. This model uses a DC motor controlled by an Arduino microcontroller [6] and LDR sensors. This model offers enhanced energy efficiency, automated operations, cost effective design and simple constructions. Disadvantages of this model are mechanical wear and tear, environment sen- sitivity, limited axis movement, power consumption.

[7] static solar panel and solar tracker system comparison is based on The development of an automatic single axis solar tracker is mentioned in the paper ”Design of Low Power Single Axis Solar Tracking System Regardless of Motor Speed”[8]. Hardwares used for this model are, LDR sensors [2][3], a PIC16F877A microcontroller,and DC geared motor. This model uses C programming language to programming the microcontroller. advantages of this model are , improved efficiency, low power consumption, cost effectiveness and simple control mechanism. disadvantagges are, sensitivity to environment, mechanical wear and tear, limited axis movement, dependency on motor efficiency. This model consumes less power compared to other solar tracking models.

The survey named ”Solar tracking system – a review” [9] states the different methods that can be used to track the sun to increase the energy harnessing capacity of solar panels. The main mechanism of the solar tracking system consists of the tracking device, tracking algorithm, control unit, positioning system, driving mechanism and sensing devices [9]. Power output of a solar panel depends on the cosine angle of incidence of the sun, solar tracking system maintains the optimal cosine angle throughout the day. Different types of solar tracker based on the axis are, single axis tracker, horizontal axis tracker, vertical single axis tracker, tilted single axis tracker, polar aligned single axis tracker, dual axis trackers, tip tilt dual axis tracker and azimuth-altitude dual axis tracker [9].This paper provides a review on all the major types of solar tracker.

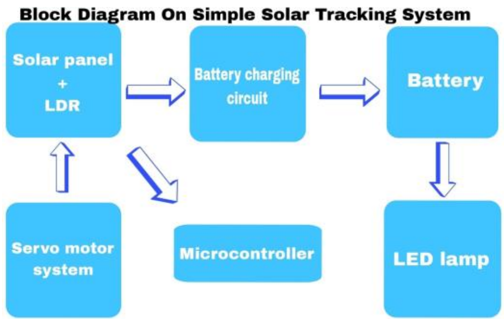
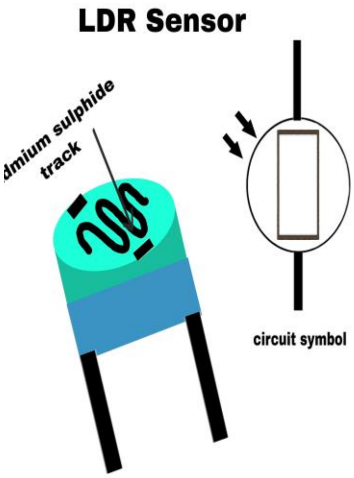


Fig 6: Block diagram of Simple solar tracker system

Comparison table		
Methodology	Advantages	Disadvantages
[1]Uses single-axis tracking with different orientations (EW, NS, SE-18°) and Light Tools software for simulation.	Increased energy output, better adaptability.	Complexity in construction, high cost, heat management issues.
[2]Uses two LDR sensors and an Arduino Uno 3 microcontroller to regulate a servo motor	22 percentage increased energy output, cost-effective, adaptable to tropical climates.	Limited tracking capability, increased power consumption, mechanical wear, calibration complexity.
[3]Uses Arduino Atmega328p and LDRs to adjust positioning through servo motors.	Enhanced efficiency, cost-effective, sustainable.	Initial setup complexity, energy consumption, mechanical maintenance.
[4]Uses five LDRs and two servo motors controlled by an Arduino UNO.	Enhanced energy capture, improved efficiency, automated control.	Increased complexity, higher energy consumption, maintenance needs, high cost.
[5]Uses a real-time tracking system with an LCD display, converting solar energy into AC power.	No additional power needed	15 percentage efficiency increase, semi-portable, resistant to environmental factors. Around 70-75 percentage of total possible sunlight and High initial cost, mechanical wear.

LDR SENSOR
LDR sensor or Light Dependent Sensor is a type of sensor that senses the presence of light. This sensor is a type of resistor whose resistance waries when light hits on the sensor. We can use this sensor in the solar tracker to identify the direction of sun by placing LDR sensors on different part of the solar panels. The intensity of light falling on the sensors are taken and the panel is rotated to the direction of the sensor which recorded the maximum intensity of sunlight

Fig 7: LDR sensor schematic diagram



ARDUINO UNO
Arduino Uno 3 is a microcontroler that can be programmed to perform certain task. these micro controller is used to control the servo motors that helps in rotating the solar panels. Arduino Uno can be programmed to take the reading from the LDR sensors as input and decide on which direction to move the solar panel by sending signal to the drive circuit corresponding the the specific servo motor

SERVO MOTOR
Servo Motor is a type of motor that is used for precise movements. These type of motors are capable of rotating the solar panel to the precise direction in which the solar panels can harness maximum sunlight. It is controlled by a drive circuit that receives signal from the main processor.

III. Conclusion

This study emphasizes the way to increase the input of renewable energy production by increasing the solar energy harnessing capability of solar panels. This is done by using sustainable and cost effective technique like machine learning to understand the position of the sun from prehistoric data and the data collected daily to increase the accuracy of the model and energy harnessing capability of the solar panel day by day. this approach contributes to the increase in renewable energy sources. by implementing this method we can increase the production of solar energy and thereby decreasing the pollution caused by during the production of energy in the conventional method like burning of coal.

IV. REFERENCES

[1] YANG LIU, YONG ZHANG, YANG ZHAO, HAN YUE, DAN GAO, HENG ZHANG AND HAIPING CHEN "Per-
formance Comparison of Solar Single-Axis Tracking Low- Concentrating Photovoltaic/Thermal System With Different Axes" (2021).
[2] Second IEEE International Conference on Advances in In- formation Technology (ICAIT-24) "Single axis solar tracking system" (2021)
[3] 2018 2nd International Conference on Electrical Engineering and Informatics"'Analysis of Single Axis Sun Tracker Sys- tem to Increase Solar Photovoltaic Energy Production in the Tropics"" (2018).
[4] 2013 IEEE International Conference on Control System, Com- puting and Engineering, 29 Nov. - 1 Dec. 2013, Penang, Malaysia"Performance Analysis Of Dual Axis Solar Tracking System".(2013).
[5] Proceedings of 2014 Zone 1 Conference of the American Society for Engineering Education (ASEE Zone 1) "Design of a Solar Tracking System for Renewable Energy"
[6] Amogha Lokesh, Anup Surahonne, Adithya N Simha, Arjuna C Reddy "Solar Tracking System Using Microcontroller"
[7] 2019 International Conference on Computing, Mathematics and Engineering Technologies "Design and Fabrication of Automatic Single Axis Solar Tracker for Solar Panel"(2019)
[8] International Journal of Integrated Engineering "A Design of Low Power Single Axis Solar Tracking System Regardless of Motor Speed"(2011)
[9] International Journal of Sustainable Engineering, "Solar track- ing system – a review"(2017)
[10] Design of real time efficient sun tracking system for smart irrigation using raspberry pi(2021)
[11] A Smart Solar Photovoltaic Remote Monitoring and Control- ling,IEEE (2018)
[12] Design and Control of an Actuated Solar Panel for Solar Tracking Windows (2024)
[13] Development of Solar Tracking Robot for Improving Solar Photovoltaic (PV) Module Efficiency (2019)
[14] Design of an Automated System to Optimize the Capture of Solar Energy in Photovoltaic Panels
[15] Automation of solar system for Maximum Power Point track- ing using Artificial Neural Networks and IoT(2016)
[16] IEEE, "An Accurate and Efficient Solar Tracking System Using Image Processing and LDR Sensor"(2015)
[17] IEEE, "The Improvement of LDR Based Solar Tracker's Action using Machine Learning"(2017)
[18] IOP Conference Series: Materials Science and Engineering, "Increasing the efficiency of solar panel by solar tracking system"(2020)
[19] mdpi, "Design and Implementation of a Sun Tracker with a Dual-Axis Single Motor for an Optical Sensor Based Photo- voltaic System"(2013)
[20] International Conference on Renewable Energies and Power Quality (ICREPQ'10) Granada (Spain), "TWO AXES SUN TRACKING SYSTEM: COMPARSION with a FIXED SYS- TEM"(2010)
[21] Robert Pitz-Paal, "Concentrating Solar Power in Europe, the Middle East and North Africa: A Review of Development Issues and Potential to 2050"(2010)