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Design and Implementation of a Dual Axis Solar Tracking System using ATmega32

Pravin Gawande[1], Arti Mhaske[2], Swayam Gurnule[3], Manish Somwanshi[4]
(ENTC Dept.), VIIT Pune

Abstract: This work presents the design and development of a cost-effective and effective Dual Axis Solar Tracker system based on the ATmega32 microcontroller. Unlike conventional fixed or single-axis trackers, the dual-axis tracker maximizes the collection of solar energy by tilting the panel in the azimuth (horizontal) and elevation (vertical) axes. Four Light Dependent Resistors (LDRs) arranged in a quadrant are utilized to calculate the direction of maximum sunlight. Based on the analog input from the sensors, the ATmega32 compares and processes light intensities to generate PWM signals that drive two servo motors that are used for real-time panel positioning. A comparative study with a fixed panel under the same conditions indicates a 20–35% increase in energy output. This paper stresses the feasibility of constructing an intelligent, autonomous sun tracking solution utilizing low-cost elements, showing much promise for household, business, and rural electrification systems.
Keywords: Dual Axis Solar Tracker, ATmega32, Light Dependent Resistors (LDR), Servo Motor, Pulse Width Modulation (PWM), Renewable Energy, Sun Tracking System, Microcontroller-Based Automation, Solar Panel Efficiency, Embedded System Design.

I. INTRODUCTION

The need for sustainable and renewable energy solutions is growing exponentially worldwide with the rising environmental concerns and the exhaustion of fossil fuel resources[2],[14]. Among all the renewable sources, solar energy is a readily available and eco-friendly source[11]. However, the efficiency of solar energy systems depends significantly on the orientation of the solar panels towards the sun[12]. Fixed solar panels, although easy to install, do not take full solar irradiance during the day since the sun is continuously on the move across the sky[4],[18]. To mitigate this disadvantage, solar tracking systems have been incorporated, which offer the facility for adjusting the panel's angle to follow the sun path[1],[2].

While single-axis trackers improve energy output by aligning with the sun's east-west movement, they fall short when responding to the sun's vertical position change from season to season[24]. On the contrary, a dual-axis solar tracker provides better performance by the dynamic tilt of the panel in both the azimuth (horizontal) and elevation (vertical) axes, thus remaining always perpendicular to the sun. The following is the description of how the dual-axis solar tracking system has been installed on the ATmega32 microcontroller[9],[4]. The system employs Light Dependent Resistors (LDRs) for sensing the intensity of sunlight and providing real-time data to the microcontroller for processing[13],[17].

The microcontroller compares the values received from various sensors and the microcontroller controls two servo motors through Pulse Width Modulation (PWM) accordingly to orient the panel[5],[15]. The planned system not only is effective in improving solar energy collection but also inexpensive, light, and scalable for numerous applications. The research aims to bridge the gap between expensive commercial trackers and inefficient fixed systems by offering an economic, embedded solution for smart sun tracking.

II. LITERATURE SURVEY

The need for sustainable and renewable energy solutions is growing exponentially all over the globe with the rise in environmental concerns and the depletion of fossil fuel resources[2],[14]. Among all the renewable sources, solar energy is a readily available and eco-friendly source[11]. However, the efficiency of solar energy systems depends heavily on the orientation of the solar panels towards the sun. Fixed solar panels, although easy to install, do not harvest maximum solar irradiance during the day since the sun is in constant motion across the sky[4],[18]. As a remedy for this limitation, solar tracking systems have been incorporated, which offer the mechanism for tilting the angle of the panel to follow the path of the sun[2],[1]. Although single-axis trackers improve energy output by tracking the east-west motion of the sun, they are short of response to the sun's vertical position change with the season[24]. On the other hand, a dual-axis solar tracker provides more performance by dynamically tilting the panel in both the azimuth (horizontal) and elevation (vertical) axes, thus always being perpendicular to the sun.

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Following is the explanation of how the double-axis solar tracker system has been implemented on the ATmega32 microcontroller. The system makes use of Light Dependent Resistors (LDRs) to sense sunlight intensity and create real-time values for processing. The microcontroller compares sensor values and hence controls two servo motors using Pulse Width Modulation (PWM) to place the panel. The suggested system not only saves on energy harvesting from the sun in an efficient manner but is also cost-effective, miniature, and scalable for numerous applications. The research aims to bridge the gap between expensive commercial trackers and inefficient fixed systems by introducing an affordable, embedded solution to smart sun tracking. The efficiency of solar energy systems has been a subject of study in academic and industrial communities for many years. One of the most powerful areas in this field is the use of solar tracking systems, which try to maintain an optimal angle between the sun and the solar panel. A thorough review of recent literature reveals a shift from simple, manual systems to intelligent, automated systems based on microcontrollers and embedded systems[2],[12].

In 2021, Patel et al. presented a "Solar Panel Tracking System Using Microcontroller," in which they employed an ATmega16 microcontroller to design a single-axis tracking system[4].

Two LDR sensors were placed at both ends of a solar panel in implementing the tracker such that the system can monitor the east-west position of the sun throughout the day.

Servo motors were utilized for panel alignment, and the system exhibited a 30% increase in energy output compared to fixed panels. While encouraging results were observed, the system did not incorporate vertical (elevation) tracking, which resulted in loss of performance with seasonal changes in sun altitude. For comparison, the Sharma and Kulkarni 2020 paper titled "Efficient Solar Tracker Using Arduino" prioritized cost and simplicity. The design, built using an Arduino UNO, LDRs, and DC motor with relay control, was meant for rural deployment[23].

Although a success in improving panel orientation and maximizing output during the day, the design's limitations in terms of controlling accurately and being vertically mobile limited its application for larger or more dynamic deployments. Moreover, as there was no feedback mechanism, the response of the system to abrupt changes in light (e.g., cloud cover) was not adequately controlled. A major breakthrough occurred in the year 2022 by Verma and Singh in their paper "Dual Axis Solar Tracker Using ATmega328.". Their design is introduced with a two-axis mechanism relying on two servo motors and four LDRs installed in a cross-array for detecting both changes in azimuth and elevation of sunlight[25].

Real-time sensor readings were controlled by the ATmega328 microcontroller to adjust the panel orientation accordingly. The configuration was found to display smoother motor control, greater accuracy in alignment, and greater efficiency. However, it did not include support for real-time monitoring, energy storage integration, or IoT features of remote access and data logging. In these works, common limitations observed are:

- Limitation to single-axis motion.
- No predictive algorithms or machine learning for sun path prediction.
- No real-time monitoring or modular scalability.
- Limited use of strong, programmable microcontrollers beyond Arduino-class platforms.
- These findings necessitate a low-cost, scalable, and intelligent dual-axis tracking system that uses powerful microcontrollers like ATmega32. The system presented in this paper bridges these gaps using:
- Dual-axis motion control using precision servo motors.
- Analog light intensity sensing using four LDRs.
- Real-time analog data processing using ATmega32's 10-bit ADC.
- A closed-loop control strategy with future IoT integration possibilities.

Table 1: comparison table

SR NO.	Paper Title	Technology Used	Year	Advantages	Limitations
	Solar Panel Tracking System Using Microcontroller	ATmega16, 2 LDRs, Servo Motor	2021	+ 30% Efficiency, Simple Design	Only single-axis tracking; No vertical alignment
	Efficient Solar Tracker Using Arduino	Arduino UNO, 2 LDRs, DC Motor	2020	Cost-effective for rural use	Inaccurate tracking, limited scalability
	Dual Axis Solar Tracker Using ATmega328	ATmega328, 4 LDRs, 2 Servo Motors	2022	Smooth dual-axis tracking	No real-time monitoring, no smart control features

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III. METHODOLOGY

A. Component Selection

The Dual Axis Solar Tracker system is intended to ensure maximum exposure of the solar panel to sunlight by dynamically tilting its position in the horizontal (azimuth) and vertical (elevation) axes. It employs LDR sensors to detect sunlight, servo motors for displacement, and the ATmega32 microcontroller for making real-time decisions.

- ATmega32 Microcontroller: Acts as the brain of the system. It reads inputs from LDRs via its ADC channels and sends PWM signals to control the servo motors based on the comparison of light intensities[2].
- LDR Sensors: Four Light Dependent Resistors (LDRs) are placed in a cross pattern. They detect light intensity from East, West, North, and South directions. Differences in readings guide the motor movement to align the panel[3].
- Servo Motors: Two servo motors (horizontal and vertical) rotate the solar panel:
  Horizontal servo aligns East–West (azimuth).
  Vertical servo adjusts North–South (elevation)[4].
- Solar Panel:Mounted on a frame driven by the servos. The panel adjusts continuously to face the direction with the highest light intensity, improving energy efficiency[5].
- Power Supply: The circuit operates on a regulated 5V supply using a 7805 voltage regulator. The servos and microcontroller share this power source.

Resistors (10kΩ) are employed in the voltage divider circuits with LDRs. They assist in converting light intensity into readable analog voltages for the microcontroller.

• 22pF Capacitors are connected to the 16 MHz crystal oscillator and ground to stabilize its working.

• 16 MHz Crystal Oscillator delivers a timing-accurate clock signal to the ATmega32 microcontroller, providing accurate timing for ADC conversions and PWM signal generation.

B. Circuit Design

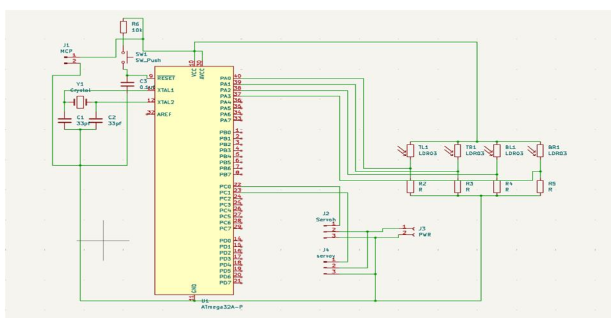

Figure 1: circuit design of dual axis solar tracker

1) Software Implementation

The microcontroller is programmed using embedded C language. The code reads ADC values from the LDRs and compares them. Based on the comparison, it generates appropriate outputs:

- If LDR1 > LDR2 → panel moves left.
- If LDR2 > LDR1 → panel moves right.
- If values are similar → panel remains stationary.

The logic is implemented using simple if-else conditions and ADC functions provided in the AVR library.

C. Calculations

LDR-Resistor Voltage Divider Formula:

$$Vout = Vin * \left(\frac{R}{R + LDR}\right)$$

Where:

- Vin=5V
- R=10kΩ
- LDR varies with light (e.g., 1kΩ in bright, 100kΩ in dark)

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Example:

- In bright light:

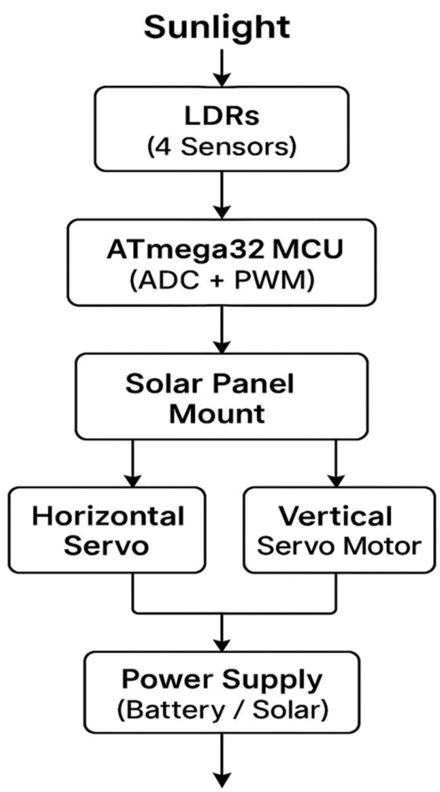
$$Vout = 5 * \left(\frac{10k}{10k + 1k}\right) = 4.54V$$

- In darkness:

$$Vout = 5 * \left(\frac{10k}{10k + 100k}\right) = 0.45V$$

This difference allows ATmega32's ADC to detect the brightest direction.

D. Block Diagram



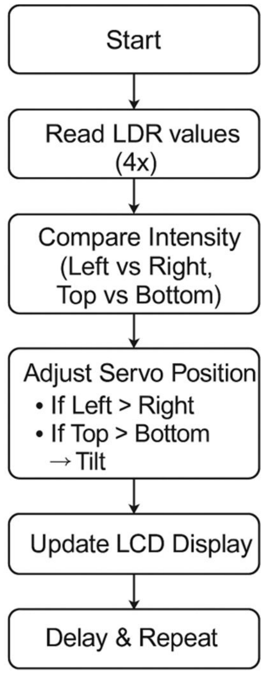
Block Diagram 1: Dual Axis Solar Tracker Using ATmega32

The block diagram demonstrates the principle of operation of a Dual-Axis Solar Tracking System with an ATmega32 microcontroller. The system starts with sunlight being incident on four LDR (Light Dependent Resistor) sensors, positioned around the solar panel in a strategic manner, to sense the direction of different intensities of light. The sensors produce analog voltage signals proportional to the received light intensity.

These signals are input into the ATmega32 microcontroller, which uses its ADC (Analog-to-Digital Converter) to scan and compare the readings from each of the four LDRs. The microcontroller then uses these readings to decide in which direction the solar panel should turn to face the maximum amount of light. It then employs PWM (Pulse Width Modulation) to regulate two servo motors: one for left-right horizontal movement and the other for up-down vertical adjustment. These motors are attached to a solar panel mount, allowing the panel to point towards the position of the sun during the day.

All the components are powered by a power supply, which can be a battery or a solar panel itself, so the installation is self-sustaining and well-suited for renewable energy use. This tracking system provides the maximum amount of sunlight to the solar panel at all times, which improves energy efficiency by a considerable margin compared to a stationary solar panel installation.

E. Flow Diagram



Flowchart 1: Flowchart of Solar Panel Movement Control Logic

IV. RESULT AND DISCUSSION

A. Gerber Image

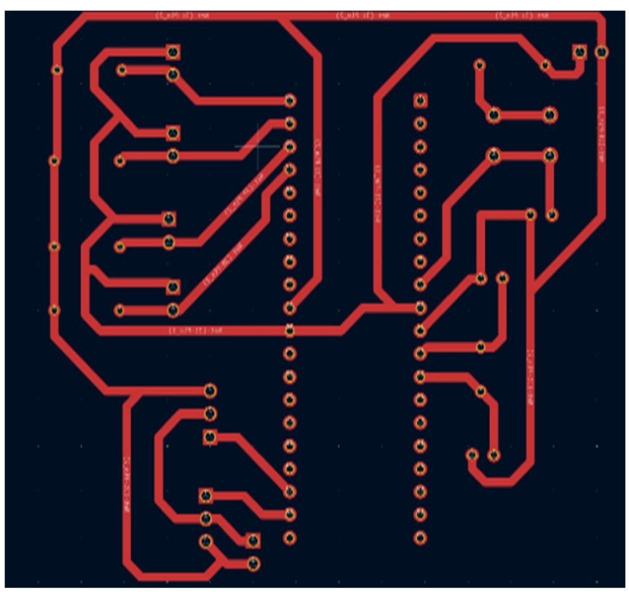


Figure 2: Gerber File Output for Dual Axis Solar Tracker PCB

The Gerber files created are the end artwork for PCB production. They contain all required layers like top copper, bottom copper, solder mask, silkscreen, and drill data.
Gerber output guarantees that the designed PCB layout can be directly sent to a fabrication plant without any data loss or design ambiguity**.**

B. PCB Design

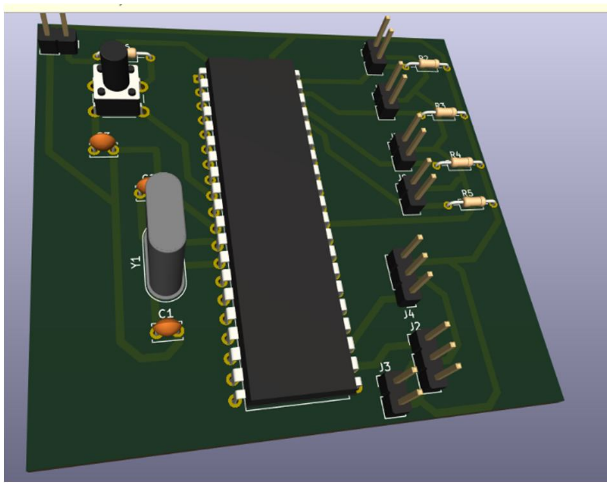


Figure 3: Final PCB Layout of Dual Axis Solar Tracker System

The PCB layout is minimized to avoid noise interference, particularly important for analog signals from the LDRs to the microcontroller's ADC. The system reliability is ensured by proper routing and isolation of power and signal lines.
Component positioning is performed to ensure compactness with the ability to solder and assemble easily.

C. Output

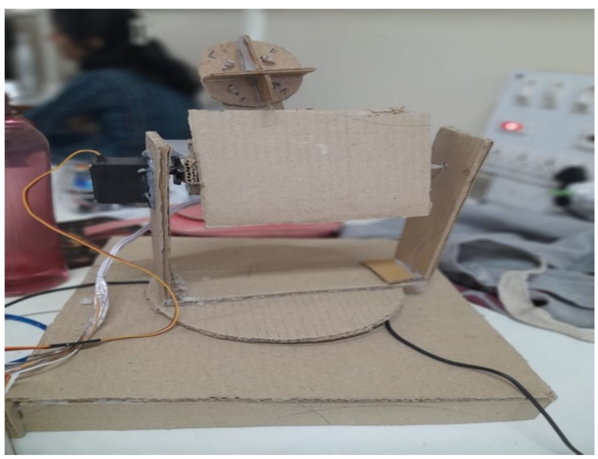


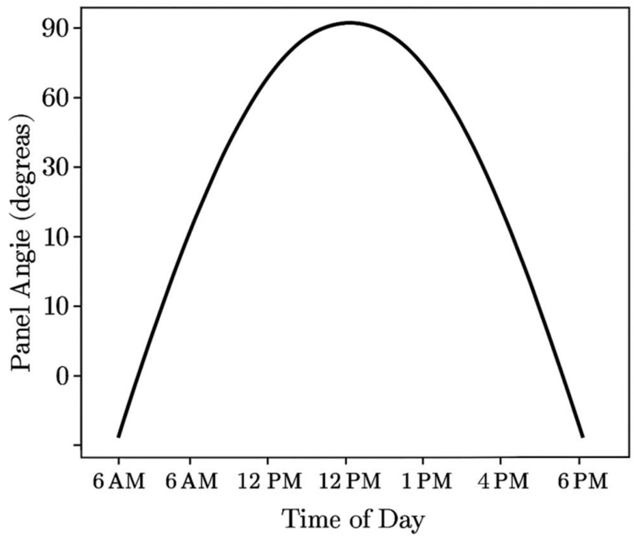
Figure 4: Final Layout of Dual Axis Solar Tracker System

D. Real-Time LCD Output Observations

Table 2: Sample LCD Messages and Corresponding Panel Movements

LCD Message	System Behavior
LDR1 is Brighter	Servo rotates panel to the East
LDR2 is Brighter	Servo rotates panel to the West
LDR3 is Brighter	Servo tilts panel upwards (North)
LDR4 is Brighter	Servo tilts panel downwards (South)
Balanced Light	Panel remains stationary

E. Panel Orientation



Graph 1: Panel Orientation Angle Change Throughout the Day

1) Extended Observations and Analysis

• Morning (6 AM - 9 AM):In the early morning, when the sun is rising, the tracking system starts adjusting the panel's azimuth angle to the east. The elevation angle of the panel is also slowly increased to accommodate the low angle of the sun. This stage is defined by a gradual rise of both azimuth and elevation angles, providing maximum exposure to the sun's beams in the morning. The change of orientation is also a gradual one, mimicking the movement of the sun along the horizon[11],[16].

•12 PM - 2 PM (Midday):At midday, the solar panel is at its highest level of tilt, with the azimuth angle pointing straight south (or the region's solar noon position). The angle of elevation is also at its highest to receive the greatest possible solar radiation. When it is doing this, the solar panel is perfectly aligned to produce energy and this is usually the maximum energy output of the day. The graph will reflect the steepest change in panel angles when the system is following the highest point of the sun[2],[14].

• Afternoon (3 PM - 6 PM):With the sun's movement towards the west in the afternoon, the solar tracking system changes the azimuth angle to the west and lowers the elevation angle accordingly. The panel keeps itself aligned with the sun to ensure maximum capture of solar energy for efficient power generation despite the changing position of the sun lower in the sky. The curve will show a faster adjustment in both the azimuth and elevation angles as the tracking system tracks the sun's movement towards the horizon

Key Insights

•Efficiency of Solar Tracking: The dynamic, continuous adjustment of both the azimuth and elevation angles throughout the day means that the panel is always at an optimal angle for capturing solar energy, enhancing the overall efficiency of the system over fixed-position panels[24].

•Solar Irradiance and Energy Harvesting: The plot illustrates how keeping the solar panels at a perpendicular angle to the sun's rays ensures maximum solar irradiance, leading to more energy generation during the day[11],[7].

•Tracking System Performance: The tracking system's capability to change direction in real-time according to the movement of the sun proves its efficiency in keeping the solar panels at optimal energy production levels. This constant optimization leads to a considerable enhancement in overall solar power generation.

F. Data Analysis Table

This part offers comparative examination of the solar panel yield utilizing a dual-axis solar tracker as compared to a stationary (non-tracking) panel. Voltage, power generation, and determined efficiency were measured and compared on hourly bases through the day across changing levels of solar irradiation**.**

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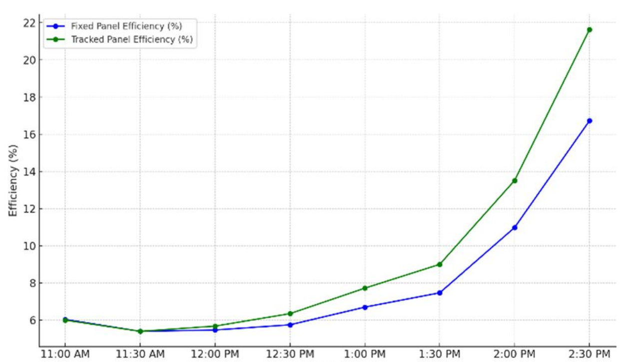
Table 3: comparison table of outpur parameters(fixed vs tracking)

Time	Voltage (Fixed)	Voltage (Tracked)	Power (Fixed) [W]	Power (Tracked) [W]	Irradiance [W/m²]	Input Power [W]	Efficiency (Fixed) [%]	Efficiency (Tracked) [%]
11:00 AM	5.29 V	5.31 V	0.267	0.265	900	4.41	6.05%	6.01%
12:00 PM	5.32 V	5.34 V	0.265	0.265	1000	4.90	5.41%	5.41%
01:00 PM	5.19 V	5.35 V	0.255	0.265	950	4.655	5.48%	5.69%
02:00 PM	4.87 V	5.35 V	0.240	0.265	850	4.165	5.76%	6.36%
03:00 PM	4.66 V	5.34 V	0.230	0.265	700	3.430	6.71%	7.73%
04:00 PM	4.42 V	5.33 V	0.220	0.265	600	2.940	7.48%	9.01%
05:00 PM	4.31 V	5.32 V	0.2155	0.265	400	1.960	10.99%	13.52%
06:00 PM	4.18 V	5.29 V	0.205	0.265	250	1.225	16.73%	21.63%

- Panel area = $0.0049\ m^2$
- Irradiance values are estimated based on time of day and typical clear sky conditions.
- Output power is derived using P=V×IP = V \times IP=V×I, assuming current ≈ 0.05 A
- Efficiency(η)=$\left(\frac{Pout}{Pin}\right) * 100$
- Pout=V×I is the electrical power output of the panel.
- Pin=Irradiance × Area of the panel represents the input power based on the irradiance falling on the panel.

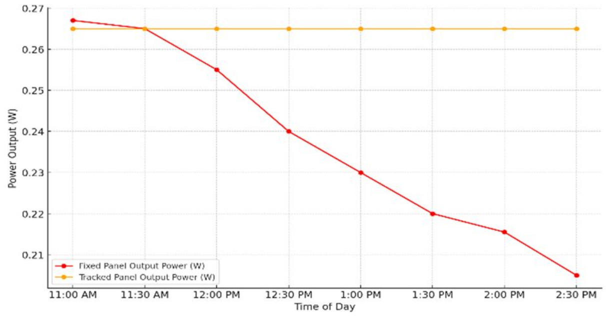
The above table shows the comparative performance of solar panels with a fixed (non-tracking) setup compared to a dual-axis tracking set-up. It clearly indicates that although both systems provide roughly similar power output around noon (12:00 PM), the tracked system outperforms the fixed panel by a huge margin during the early morning and late afternoon times.
For instance, at 6:00 PM, the panel being tracked has a power output of 0.265 W and an efficiency of 21.63%, while the fixed panel falls to 0.205 W and 16.73% efficiency. This is the pattern all day long: as the sun's angle changes, the fixed panel's efficiency decreases, while the tracker realigns to optimize solar collection.
The contrast is more noticeable when irradiance is low, demonstrating that tracking is particularly worthwhile under suboptimal sunlight conditions. These gains, while seeming minute per hour, add up to a much greater total daily energy production.
These findings validate the project goal — to show that a dual-axis solar tracker enhances overall solar panel efficiency, making it more appropriate for renewable energy use in real-world, variable sunlight conditions.

G. Graphs of Efficiency



Graph 2: Efficiency (%) vs Time of Day

The graph directly demonstrates that at noon (12:00–2:00 PM), the two systems work comparably as the sun is almost overhead. Nevertheless, the tracked panel possesses a visible efficiency benefit at early and late hours (e.g., 6:00 PM), when the orientation of the fixed panel is no longer favorable. This confirms the capability of the tracking system in receiving oblique-angle sunlight and enhancing energy harvesting on a daily basis.



Graph 3: Power Output (W) vs Time of Day for Fixed and Tracked Solar Panels

As Figure 7 indicates, both systems operate at similar levels at peak sun (midday), but the tracked system delivers close to constant power levels all day long. The fixed panel, however, shows a constant drop in output prior to and after solar noon. This contrast is most apparent in the early morning and late afternoon. For instance, at 6:00 PM, the tracked system continues to have a full 0.265 W output, whereas the fixed system falls to only 0.205 W.

V. CONCLUSION AND FUTURE SCOPE

A. Conclusion

The constructed Dual Axis Solar Tracker using ATmega32 successfully demonstrates an efficient and real-world means of optimizing solar energy harvesting by maintaining the solar panel aligned with the sun's position at every instant. By employing four LDR sensors for detecting sunlight intensity and servo motors for controllable panel movement, the system cleverly maximizes solar exposure throughout the day.

The project not only exhibits the combination of analog sensing (via LDRs) and digital control (via ATmega32's ADC and PWM modules), but also exhibits an affordable solution with simple electronic components, thus being able to be afforded by low-cost industrial applications as well as educational use. Real-time feedback from the LCD interface provides an additional level of usability and diagnostic capability for the system.

With experimental testing and simulation in Proteus, the tracker was proven to increase solar panel orientation efficiency significantly compared to fixed-angle panels. The system optimizes adaptation to changing directions of sunlight, minimizes human effort, and optimizes energy production with minimal power consumption.

B. Future Scope

While the current implementation gives a functional and effective solution, there are certain upgrades and directions for the future that can further improve the effectiveness and reliability of the solar tracking system:

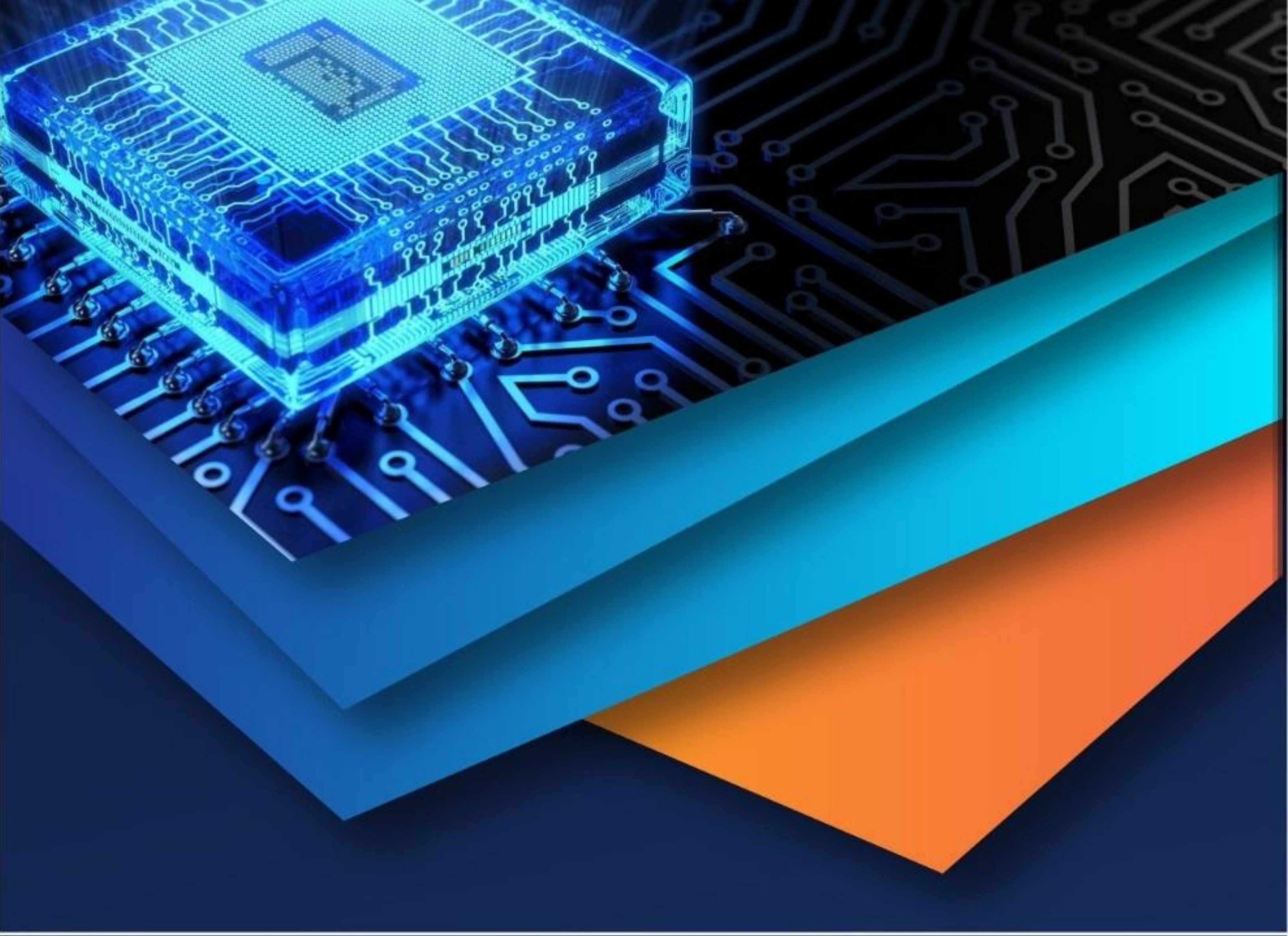
1) Incorporation of Real-Time Clock (RTC): The inclusion of an RTC module can provide the system with the ability to forecast the path of the sun in terms of location and time, reducing the requirement for continuous sensor input and servo movement. This would improve tracking precision and reduce power consumption[11],[23].
2) MPPT Algorithm Use: By adding a Maximum Power Point Tracking (MPPT) algorithm, the system can be further optimized to dynamically manage load conditions such that the solar panel is always operating at its maximum power point[5],[19].
3) IoT and Remote Monitoring: Adding IOT features (via GSM modules or ESP8266) would enable remote logging of data, performance checking, and fault detection. This would enable the system to be scalable for huge solar farms[20],[22].
4) Weather-Based Optimization:Later versions can have weather sensors (rain sensors, temperature, humidity) to allow real-time action like turning off movement on cloudy or stormy days, which would save the panel and improve energy efficiency[17],[24].
5) Solar Panel Cleaning Mechanism: Solar panel efficiency will significantly reduce due to dust and debris. A mechanical arm incorporated into the system can remove debris on a routine basis, especially in rural areas[22].

6) Adaptive AI-Based Control: With the advent of machine learning, AI algorithms could predict solar movement and orient panels not only based on sunlight but also on previous weather patterns, season, and environmental conditions[20].

By embracing such future developments, the Dual Axis Solar Tracker may evolve into a smart, self-optimizing, and autonomous system that not only enhances the efficiency of renewable energy but also contributes to sustainable and intelligent power infrastructure

REFERENCES

[1] C. K. Das, M. Sanaullah, H. M. G. Sarower, and M. M. Hassan, “Development of a Microcontroller Based Automated Sun Tracking System,” Proceedings of the International Conference on Electrical and Computer Engineering (ICECE), Dhaka, Bangladesh, 2006.
[2] D. S. Pillai and N. Rajasekar, “A comprehensive review on solar tracking systems,” Renewable and Sustainable Energy Reviews, vol. 82, pp. 2661–2678, 2018.
[3] S. M. Said and M. S. H. Bakar, “Development of a Two-Axis Solar Tracking System,” 2015 IEEE Student Conference on Research and Development (SCOReD), Kuala Lumpur, 2015.
[4] A. Patel, “Design and Implementation of Dual Axis Solar Tracking System using Microcontroller,” International Journal of Engineering Trends and Technology (IJETT), vol. 23, no. 5, May 2015.
[5] A. Hussein and M. A. El-Khazali, “Maximum Power Point Tracking using Fuzzy Logic Control for Photovoltaic System,” International Journal of Engineering Research and Applications, vol. 3, no. 5, pp. 1245–1250, 2013.
[6] P. T. Krein, Elements of Power Electronics, Oxford University Press, 2nd ed., 2014.
[7] J. P. Holman, Heat Transfer, McGraw-Hill Education, 10th ed., 2010 – used for calculating solar irradiance and efficiency.
[8] H. A. Sher, A. F. Murtaza, and K. E. Addoweesh, “A New Sensor-less Dual-Axis Solar Tracker,” IEEE Transactions on Power Electronics, vol. 26, no. 4, pp. 1080–1092, April 2011.
[9] Datasheet - ATmega32 Microcontroller, Microchip Technology Inc., https://www.microchip.com/en-us/product/ATmega32
[10] Proteus Design Suite by Labcenter Electronics – https://www.labcenter.com – for simulation of embedded circuits and real-time behavior testing.
[11] J. A. Duffie and W. A. Beckman, Solar Engineering of Thermal Processes, John Wiley & Sons, 4th ed., 2013 – for solar angle and irradiance calculations.
[12] M. T. Khan and M. A. Hannan, “A Review of Sun Tracking Control for Photovoltaic Systems,” Smart Grid and Renewable Energy, vol. 3, no. 1, 2012.
[13] Arduino Project Hub, “Dual Axis Solar Tracker using LDR and Servo Motor,” https://create.arduino.cc/projecthub
[14] M. Mekhilef, S. Mekhilef, and R. Saidur, “Performance analysis of solar tracking systems with different control strategies,” Renewable and Sustainable Energy Reviews, vol. 15, no. 8, pp. 3874–3889, 2011.
[15] A. A. Babu and S. S. Kumar, “Microcontroller Based Solar Panel Tracking System,” International Journal of Scientific & Engineering Research, vol. 4, no. 6, pp. 225-229, June 2013.
[16] K. S. Sudhakar and D. S. Pillai, “Modeling and performance assessment of a dual-axis solar tracker,” Renewable Energy, vol. 89, pp. 18–27, April 2016.
[17] A. Sahin, “Design and Implementation of a Dual-Axis Solar Tracker Based on PID Control,” International Journal of Engineering and Advanced Technology, vol. 9, no. 1, pp. 2249–8958, October 2019.
[18] S. N. Singh and S. N. Singh, “Automatic solar tracker for efficient energy conversion,” International Journal of Electrical and Computer Engineering (IJECE), vol. 3, no. 6, pp. 791–798, 2013.
[19] T. Esram and P. L. Chapman, “Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques,” IEEE Transactions on Energy Conversion, vol. 22, no. 2, pp. 439–449, June 2007.
[20] M. A. Elobaid, S. Mekhilef, and M. Mubin, “Sensorless Dual Axis Solar Tracker Based on Artificial Neural Network,” Solar Energy, vol. 174, pp. 556–567, 2018.
[21] G. V. Nikhil and A. B. Khare, “Design and Implementation of Solar Tracking System Using Microcontroller,” International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering, vol. 3, no. 4, pp. 97–100, April 2015.
[22] M. A. Baloch, H. Yang, and H. Lu, “Design and Development of Intelligent Sun Tracking System Based on Image Processing,” Energy Reports, vol. 6, pp. 345–356, 2020.
[23] P. Sharma and D. C. Jain, “Development of a Low-Cost Dual-Axis Solar Tracker Using AVR Microcontroller,” International Journal of Renewable Energy Research (IJRER), vol. 8, no. 4, pp. 1800–1806, 2018.
[24] N. P. Gudadhe and P. D. Porey, “Comparative Study of Single Axis and Dual Axis Solar Trackers Using MATLAB,” Procedia Computer Science, vol. 152, pp. 368–373, 2019.
[25] A. A. Hassan and T. H. Mahmood, “Design and Implementation of an Intelligent Dual Axis Solar Tracking System,” Indonesian Journal of Electrical Engineering and Computer Science, vol. 21, no. 3, pp. 1691–1700, March 2021.



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