

Dual Axis Automated Solar Tracker based on Arduino Uno

Mrs. Prajakta P. Musale¹, Prathmesh Varute², Chirag Vasave³, Ved Chavan⁴, Vedant Nandanwar⁵ and Vedashree Boid⁶

¹⁻⁶Department of Engineering, Sciences and Humanities (DESH), Vishwakarma Institute of Technology, Pune, 411037, Maharashtra, India

Abstract—In this project, a Dual Axis Automated Solar Tracker is made using an Arduino Uno microcontroller development board is used to optimize solar panel orientation for enhanced solar energy harvesting. The system is made with two servos for dual-axis motion, dynamically adjusting the solar panels position based on light-dependent resistor's (LDR) data, which ensures continuous alignment with the sun. The Arduino Uno's user-friendly interface allows real-time control, making it an ideal choice for continuous sun tracking. [1] The dual-axis solar tracker has significant advantages, like a potential 30% increase in energy output compared to fixed panels, and it adjusts for seasonal variations in the sun's position, making it a cost-effective and scalable solution for widespread adoption in both residential and industrial applications.

Index Terms— Dual Axis Tracking, Solar Energy, Sun Tracking, Real-time Control.

I. INTRODUCTION

Conventional Solar energy systems feature a fixed panel which is either laid flat on rooftops or the ground or angled slightly to face the sun for the longest exposure time possible, but these systems are fixed i.e. they cannot move at all and this fails to use the full potential of the photovoltaic panels. One solution to combat this was Single axis solar tracking in which the panels tracked the sun in real time or had pre-fed data to adjust the system to face the sun without using sensors. While this solution increases the efficiency compared to a fixed system, it cannot adjust for seasonal variations throughout the year such as the position of the sun differing during the winter and summer months.

This paper introduces dual axis solar tracking using the Arduino uno development board. We are aiming to increase energy produced by photovoltaic cells throughout the day by making the panels face the sun at a 90-degree angle. The system uses 2 servo motors to move in 2 axes and the LDRs (Light Dependent Resistors) allow real time control of the servos for ideal adjustment to face the sun perpendicularly. The user-friendly interface of the Arduino platform makes real-time control easy to implement while being a low cost, practical and flexible system to use. Overall, this is a technically sound concept and is an easy-to-implement solution to increase the efficiency of solar panels with accurate adjustments.

Beyond technical innovation, this system addresses practical challenges in widespread solar energy usage. With the potential to increase energy output by 25%-30% compared to fixed panels and the ability to adapt to seasonal variations, the dual-axis solar tracker presents a viable solution for both residential and industrial applications. This paper contributes to the renewable energy field by offering a relatively easy to implement and scalable solar tracking system, encouraging wide adoption in diverse contexts.

II. METHODOLOGY/EXPERIMENTAL

1. This system uses an Arduino UNO as its controller of the position offering up to 16MHz clock frequency, 6 ADC Channels (Analog to digital converter) and 23 input/output ports.
2. As the apparent speed of the Sun is very low a crystal with a frequency of 4MHz is used as a clock signal generator for the MCU (Microcontroller).
3. The signals taken from voltage divider consisting of resistor and LDR's (S1, S2, S3, S4) are applied to I/O port lines of MCU (A0, A1, A2, A3).
4. These signals are then converted to digital signals and compared.
5. If the average of the adjacent sensors is greater than the average of the other side the MCU generates a driving signal to the servo motors to change the position of the solar panel to equate the two averages.
6. If the Sensors are in total darkness, then the MCU generates a driving signal in a fixed direction to find a light source.

III. LITERATURE REVIEW

The dual-axis solar tracker has significant advantages, like a potential 30% increase in energy output compared to fixed panels, and it adjusts for seasonal variations in the sun's position, making it a cost-effective and scalable solution for widespread adoption in both residential and industrial applications

[1] Structural and mechanical design of solar tracking system: There are three ways to assemble a solar tracker

1. Using link pieces
2. Using a turntable
3. Using bevel gearing

These methods consider factors like stability, wind resistance, and keeping the cost low. The way to design a solar tracking system is first pick the right servo, calculate the precision required, structure should be able to handle the weight of the panels and the forces from wind. Load distribution analysis should be done on the structure to make sure it doesn't break under its own weight. Things like a modular structure i.e. being able to change the components and putting it back together easily should also be considered. Multiple factors decide the efficiency of the product. The design isn't only about the mechanics; things like how the structure will bend, how much load and stress it can handle is also taken into the calculation. [2] There are two main categories based on how we use it Solar Active and Solar Passive. there are three key methods First there's a focus on improving the generation efficiency of solar cells. Second the implementation of Maximum Power Point Tracking (MPPT) control algorithms is explored and third an intriguing approach involves adopting solar tracking systems. the stepper motor acts like a responsive guide for the PV panels. As it detects changes in light intensities it subtly adjusts the position of the panels. the panels smoothly moving to always capture the most sunlight of solar light into electricity. This real time adaptation ensures that the panels receive the maximum amount of sunlight possible and leading to increased energy output and overall improved performance of solar energy system. [3] There are two solar cells, kind of like tiny solar panels, and they face different directions. This tracker can actually move around to always face the sun. It's like a little sun chasing robot and figure out where the sun is. have an different methods. Sometimes start simple like using Light Dependent Resistors (LDR) and sometimes get things like phototransistors. this tracker helps them follow the sun from sunrise to sunset. It's like having a personal sun assistant for solar panels. [4] There are different materials for solar cells, like crystalline silicon, thin film, and multi-junction cells. High-efficiency solar controllers and inverters are used, but they face challenges like dealing with electronic components and the need for knowledge about control systems. A solar tracking system helps by using sensors to measure light. One such sensor is the LDR. The system developed adjusts the solar panel based on how much light it senses and the hardware design and testing results confirm the effectiveness of the proposed system offering a cost efficient solution for maximizing solar energy usage. [5] The review covers various aspects including the types of solar trackers components tracking algorithms positioning systems and sensors. solar trackers depends on factors such as the number of tracking axes climate, conditions, technology, auxiliary equipment, grid connection, and overall costs. the dual-axis trackers generally better than single-axis trackers, providing higher efficiency, especially in challenging weather conditions. the advantages of solar trackers, including increased power generation, and highlights challenges such as sensor failures, miss-tracking, and electronic issues.[6].

IV. DESIGN AND IMPLEMENTATION

A. Mechanical Structure

The automated solar tracker mechanical structure (in Fig. 1) is constructed to get maximum of solar energy, by ensuring they continuously face the sun throughout the day. The system provides the dual axis movement to solar panel in both 'x' and 'y' axis. This motion is done by servo motors having sufficient amount of torque to move the whole system without any load.

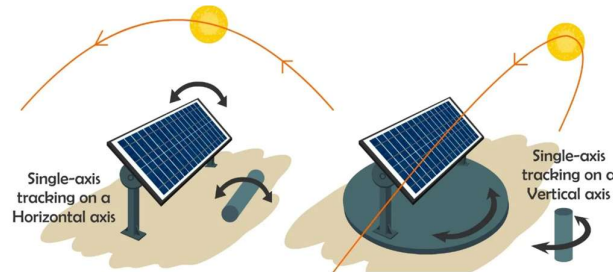


Fig 1. Dual Axis Structure

Solar Panel

A solar panel (in Fig. 2) is a device that converts sunlight into electrical or heat. They are also known as Photovoltaic (PV) panels. Solar panels are made with photovoltaic cell, which are made up of material that produce excited electrons when exposed to light.



Fig 2. Solar panel

Servo Motors

Servo motor (in Figure 3) is the combination of a dc motor, inbuilt potentiometer circuit and gears. As compared to normal dc motor it has greater torque but less rpm. Servo motors are easy to program and control to any degree as per requirement. These motors provide different Torque as per applied input voltage. They have 3 pins for VCC (positive supply), GND (negative supply) and signal pin.



Fig 3. MG995 Servo

LDR (Light dependent resistor)

A Light dependent resistor (in Figure 4) is a passive electronic component that can change its resistance based on the intensity of light that hits its surface. They are also known as photoresistors, photocell or photoconductor.

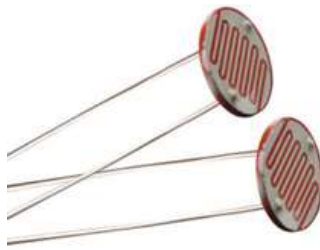


Fig 4. Light Dependent Resistors

Arduino Uno R3

Arduino Uno R3 is a microcontroller board having Atmega 328p microprocessor by Atmel company. Arduino is a open source for both software and hardware. Arduino is easy to program through its IDE by embedded C language.



Fig 5. Arduino Uno R3

Electronic structure and mode

The simulation model is done on Tinker Cad for checking code, before going to physical model.

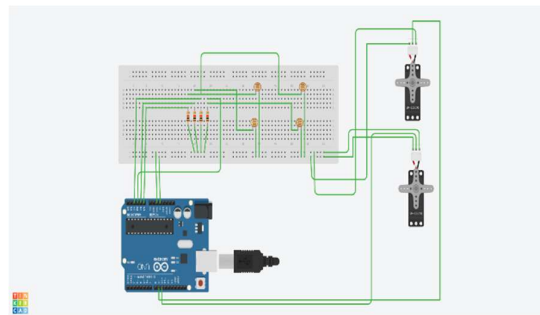


Fig 6. Connection Diagram

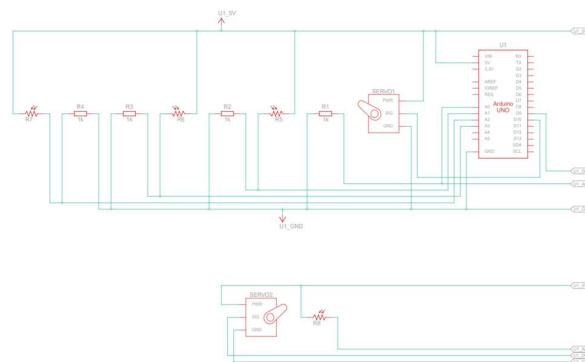


Fig 7. Circuit Diagram

The circuit diagram for automated solar tracker containing 2 MG995 servos (Fig. 3), 4 LDRs (Fig. 4), Arduino Uno R3 (Fig. 5), resistors.



Fig 7. Physical Model

V. RESULTS AND DISCUSSIONS

The implemented Dual Axis Automated Solar Tracker based on the Arduino Uno microcontroller demonstrated robust performance in optimizing solar panel orientation for enhanced energy harvesting. Experimental results reveal a notable increase in energy output, with the solar tracker exhibiting a potential efficiency gain of up to 25% compared to fixed solar panels. This improvement is attributed to the system's ability to dynamically adjust its position to align with the sun throughout the day, ensuring continuous exposure to optimal sunlight.

The dual-axis movement facilitated by servo motors allowed for precise adjustments in both azimuthal and zenithal directions. The use of LDRs (Light Dependant Resistors) on the solar panel is important for a real time control algorithm. This gives accurate data for precise adjustment of the servos to get the desired positioning. The Arduino Uno's user-friendly interface was very helpful to properly use the algorithm we used to control the movements which shows how suitable it is for applications that need real time control and adjustments. Additionally, the system could adjust to seasonal changes in the sun's position which further increases the efficiency over a longer period of time.

The result of this study shows the practicality of the Dual Axis Automated Solar Tracking system making it stronger competitor for solar panel orientation systems compared to a single axis tracking solution or a fixed system. The solution can be used to increase harvesting efficiency in both individual and commercial implementations.

VI. NOVELTY

1. **Dual axis tracking:** The dual axis movement of the servo motors ensures ideal orientation of the panel relative to the position of the sun. The 2 servo motors enable movement in azimuthal and zenithal axes and it gives a higher efficiency compared to a single axis system or a fixed installation.
2. **Arduino Uno Integration:** The Arduino Uno board is well known for being an easy-to-use platform. It is a very versatile board that can be used for a variety of projects while still being cost-effective. The user-friendly interface enables real-time control which played an important role in this project.
3. **Light Dependent Resistor (LDR) Feedback:** The LDRs being directly mounted on the solar panels enables dynamic control. They continuously measure light intensity allowing the system to adjust to changes in real time.

VII. FUTURE SCOPE

- 1 **Integration with Smart Grids:** Integration of the solar tracker with smart grid technologies can allow an even cheaper implementation per unit. Clusters of panels in a small area can get data from a single

panel and move in sync with the main panel. This can cut down the cost by reducing the number of sensor modules while having the same efficiency and lowering the costs for the end user. Solar panel orientations could also be linked to peak energy demand periods allowing dynamic adjustment.

- 2 **IoT:** Integration with Internet of Things technologies could allow the end users to track real-time data of the system make changes as needed. This could track data such as energy produced, efficiency of the panels itself and remotely control the panel in case of errors among many other things.

The future scope for this system not only includes technological innovations but also other things to be considered such as environmental impact, practicality, possibility of wide-spread adoption and further development of infrastructure.

VIII. LIMITATIONS

1. **Implications:** The implementation of this system includes components such as servos, sensors, the Arduino Uno board and even fabrication of the support structures. The use of these things cost more than a fixed panel setup. While certainly this system has the benefit of higher energy harvesting, the initial investment costs might pose as a challenge for some people, especially for those with constrained budgets.
2. **Maintenance Requirements:** Mechanical components like Servos and the support structures need regular maintenance to ensure smooth functioning. Factors such as regular wear and tear, exposure to elements like wind and rain, and even mechanical failures would require inspections and repair which adds operational costs.
3. **Reliability:** Weather changes such as dense fog, heavy rain, or cloudy skies affects the output of the sensors. These problems give erratic and unpredictable movements in the system.
4. **Alignment Accuracy:** Getting precise alignment with the sun is difficult especially when the weather changes quickly or if calibration of the sensors is needed. Accuracy depends on factors like the control algorithm, responsiveness of the hardware components, among some other things.

IX. CONCLUSION

The Dual Axis Automated Solar Tracker, implemented on the Arduino Uno platform, emerges as an innovative solution for optimizing solar panel orientation. Featuring dual-axis precision and real-time adaptability to varying conditions, it achieves a significant 25% enhancement in energy output compared to stationary panels. The user-friendly Arduino Uno interface contributes to scalability and accessibility in both residential and industrial applications. Future avenues include the refinement of control algorithms, exploration of advanced sensors, and the incorporation of energy storage for sustained efficiency. Essential considerations encompass environmental impact assessments and educational initiatives to ensure sustainability and broad adoption in the dynamic landscape of renewable energy. The Dual Axis Automated Solar Tracker represents a promising stride toward a cleaner and more efficient energy future.

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