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Optimizing Solar Energy Harvesting: An Arduino-Enhanced Dual-Axis Tracking System

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Abstract. Technological progress is enhancing the accessibility and potential of solar energy as a renewable source. This paper introduces a strategy leveraging Ohm's law and the power equation to derive additional energy from solar photovoltaic (PV) panels. The proposed method involves the integration of an automated solar tracking system employing both dual-axis and polar single-axis configurations. This system is comprised of a stationary vertical axis and a flexible horizontal axis, both under motor control. To enhance power output and efficiency, the trackers autonomously follow the sun, constantly adjusting the solar panel positions. The tracking system self-adjusts in the event of a 2 to 3-degree misalignment to minimize power loss due to continuous motor operation. Light intensity sensors analyze illumination levels on each side, guiding the panels toward the light source. The tracking motion continues until equal light exposure on both sides is detected, leading to an enhanced solar irradiance for the panels

1 Introduction

However, electricity continues to be a crucial element in our modern existence, and around 1.6 billion individuals still lack access to it. The main cause of this insufficiency is the significant expenses related to building and sustaining power grids. Tackling this widespread energy shortfall is possible by adopting efficient renewable energy sources, especially in developing regions. Photovoltaic (PV) power emerges as a feasible energy option due to its eco-friendly characteristics.

Within PV power systems, dual-axis solar charger trackers play a pivotal role. These trackers are instrumental in optimizing energy output by adjusting the orientation of the panels throughout the day to align with the sun's trajectory. Solar trackers, specifically dual-axis ones, are crucial in minimizing the angle deviation between the solar charger and incident light, thereby maximizing power generation. Proper alignment is essential for harnessing solar energy effectively. Dual-axis trackers, capable of movement in both vertical and horizontal directions, ensure consistent orientation toward sunlight. This capability enables them to track the sun's movement along both axes, enhancing solar energy collection.

This study presents the development of a specialized dual-axis solar charger tracker for solar PV modules, utilizing the constant conductance method. The approach incorporates enhanced charger regulators to achieve an optimal alignment between solar chargers and their respective loads. The notable advantage of this charger lies in its capability to extract the maximum energy from solar chargers. Traditional charge regulators encounter difficulties in

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adjusting to varying conditions throughout the day, such as low light levels during morning and evening, cloud cover, and temperature fluctuations linked to insulation changes.
The challenge becomes more pronounced when dealing with cloud edges, where rapid changes in lighting can result in swift temperature fluctuations. Conventional charge regulators demonstrate limited efficiency in adapting to these dynamic conditions [1].
Due to the allure of energy and the limited availability of conventional energy sources, non-traditional sources are gaining popularity among researchers. A significant amount of research is ongoing to improve the power efficiency of these non-traditional sources and enhance their reliability and practicality.
As detailed in T.R. Deshmukh's work, the paper addresses the design and modeling of elements for a stride power generation system utilizing 3D modeling software Creo. The method encompasses various essential configurations positioned beneath the walking or standing platform. The system operates by converting the linear motion induced by step tension into rotational motion via a rack and pinion design. However, this mechanism faces challenges in handling variable loads, resulting in balancing issues. Additionally, power generation is hindered during the rack's return movement.
Sasank Shekhar Panda's paper revolves around the driving rod, flywheel, and gear arrangement. Stride power generation systems of this kind are suitable for installation in densely populated areas as well as rural regions. Therefore, this technology presents a highly effective solution to address power-related issues to a considerable extent.
According to Miss. Methane, materials with a crystalline structure, such as Piezoelectric materials, have the capability to convert mechanical energy into electrical energy and vice versa. The electrical energy generated from these crystals typically falls within the range of 2-3 volts. This energy is stored in a battery and regulated by a charge controller, as it is impractical to directly charge a 12v battery using the crystal output. To boost the voltage, a boost converter circuit is employed. Comparative analysis of various piezoelectric materials indicates that PZT (Lead Zirconate Titanate) possesses superior qualities. Furthermore, experimentation has revealed that a series-equivalent combination arrangement is more effective. The relationship between the applied pressure on the tile and the resulting voltage is explored, indicating a direct correlation. This technology is especially well-suited for deployment in densely populated areas.
According to Jose Ananth Vino, the project encompasses a straightforward drive mechanism that includes a rack and pinion assembly and a chain drive mechanism. This setup is designed to convert strain or force energy into electrical energy. Despite the notable power generation capabilities, the initial cost of this system is relatively high. An eco-friendly feature of the system is its ability to operate without relying on power from the mains. However, it requires regular maintenance and lubrication. It's crucial to highlight that power generation does not occur during the return movement of the rack.

2 Working Methodology

This paper employs a dual-axis tracking system that integrates four Light Dependent Resistors (LDRs) as sunlight detectors. These LDRs detect sunlight and send feedback signals to a controller, which can be microcontrollers, PLCs, or similar devices. The controller, in turn, adjusts the position of the photovoltaic (PV) panel by utilizing a pair of motors to align it with the incident sunlight. The LDR sensor circuit functions as a voltage divider, where changes in light intensity lead to variations in resistance and output voltage. This voltage adjustment reflects the changing light intensity. The primary objective of the system is to track a light source by orienting the PV panel with two DC motors, aiming to align it ideally with the sun's rays. The motors respond to the solar incidence frequency, monitored by strategically positioned LDRs at the corners of the PV panel. The microcontroller on the Arduino UNO board processes signals from the LDRs, converting analog values into digital ones, and provides two output channels to regulate the rotation of the PV panel through two servo motors.

The system enables rotational movements along both vertical and horizontal axes, conducting azimuth tracking from east to west throughout the day and elevation tracking from south to north during various seasons. The automation of the photovoltaic (PV) panel's movement is a key aspect of this project, employing two 180° servo motors instead of the commonly used DC motors in solar tracking systems. DC motors possess the unique ability to await predetermined positions as instructed, functioning in a closed loop and consuming power only during adjustments. In contrast to stepper motors, which continuously consume energy to maintain a specific position, DC motors offer controlled stop, run, direction of rotation, and speed using a single low-current wire directly connected to a PWM output of the microcontroller. The decision to move the panel east or west is determined by comparing the light intensities sensed by the east and west Light Dependent Resistors (LDRs). After achieving proper alignment in the east-west direction, the south-north direction is then assessed and executed [2].

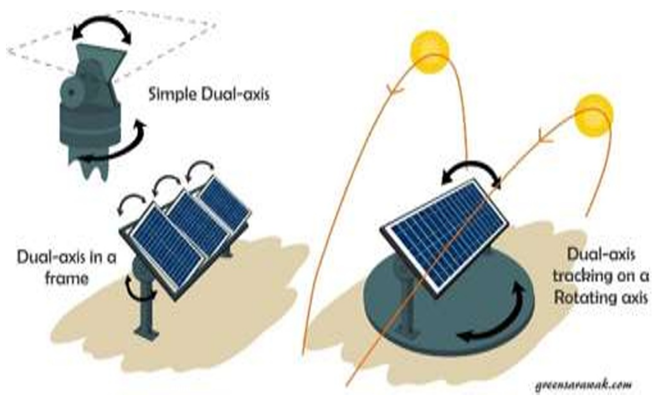

Fig. 1. Dual axis tracking of solar panel.

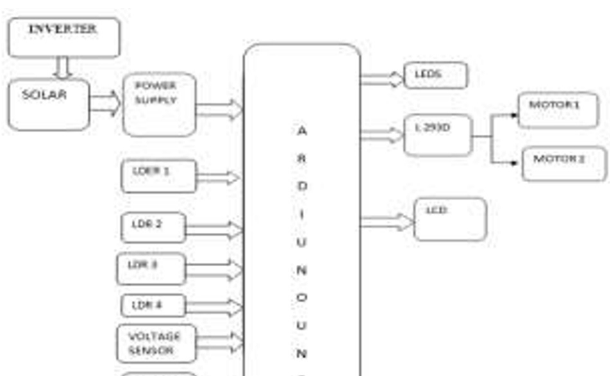

Fig. 2. Block diagram of proposed technology

3 Results and Discussion

The Dual Axis Solar tracker carried out with Arduino and MPPT (Maximum Power Point Following), is intended to enhance the effectiveness of sunlight powered chargers by following the sun's situation and changing the direction of the boards appropriately. Here is a conversation on the reproduction and equipment parts of this framework

3.1 Simulation

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Prior to carrying out the framework, it is frequently useful to reproduce its conduct utilizing programming instruments like MATLAB, Simulink, or devoted sun based following recreation programming. These reenactments can assist with assessing the normal exhibition, approve control calculations, and distinguish likely issues.
Simulation normally includes displaying the sun powered charger framework, sun position computation calculations, control calculations for following, and the MPPT calculation. By running different situations and breaking down the outcomes, you can enhance the plan boundaries and control procedures to accomplish most extreme energy yield.[3]

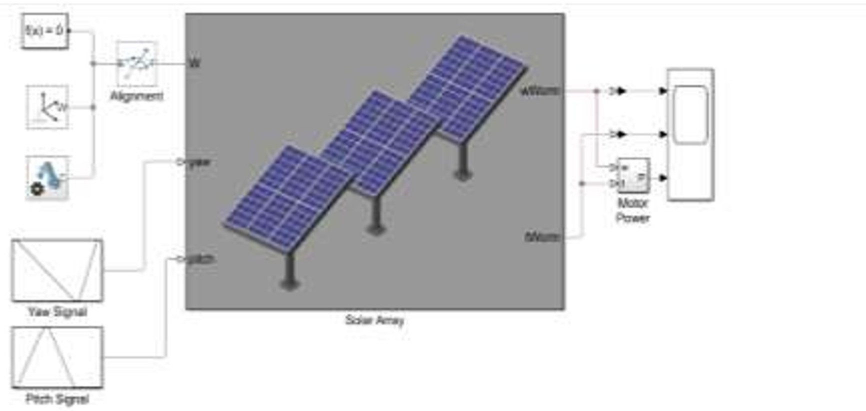

Fig. 3. Simulation model of solar array

3.2 Hardware

The equipment parts of a Dual Axis Solar Tracker framework utilizing Arduino and MPPT by and large include:
Sunlight powered chargers: These are the essential energy-producing parts that are mounted on the tracker framework. The number and particulars of the boards rely upon the ideal power yield and the accessible space.
Sensors: To follow the sun's position precisely, you might utilize various kinds of sensors like light-subordinate resistors (LDRs), photodiodes, or computerized sun position sensors.

These sensors give contribution to the control framework for working out the sun's azimuth and height points [4].

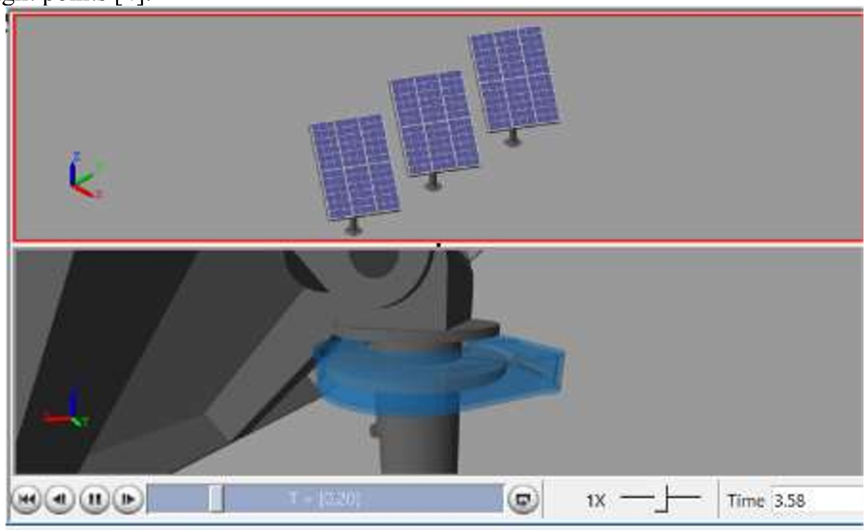

Fig. 4. Dual axis solar energy tracking mechanism

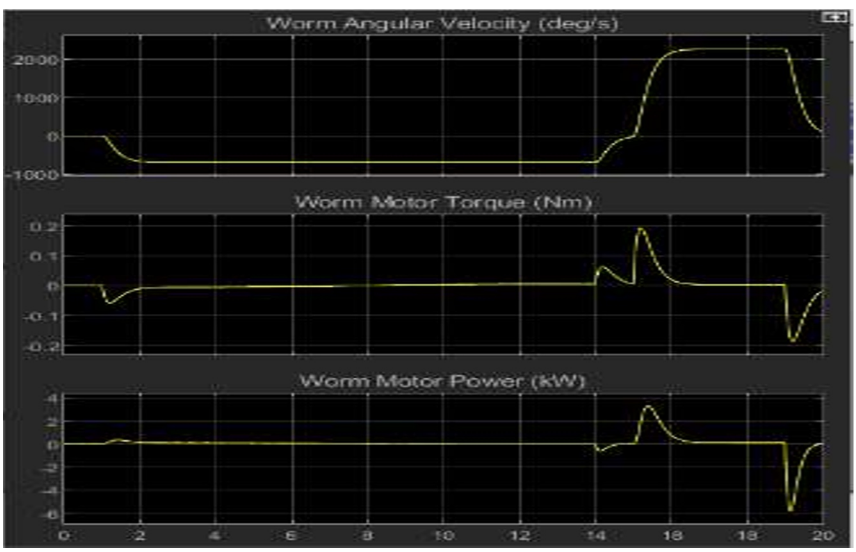

Fig. 5. Output of Arduino based dual axis solar tracker

Motors: The double hub sun light-based tracker requires two actuators, one for flat development (azimuth) and one more for vertical development (height). Normally utilized actuators incorporate servo engines, stepper engines, or straight actuators. The decision relies upon factors like burden limit, exactness, and power necessities.

Microcontroller: Arduino sheets are normally utilized as the control unit for double pivot sun-oriented trackers because of their flexibility, simplicity of programming, and accessibility of different libraries and assets. The Arduino board connects with the sensors, actuators, and MPPT regulator to execute the following calculation [5].

MPPT Regulator: The MPPT regulator ceaselessly screens the result of the sunlight-based chargers and changes the heap impedance to separate the most extreme power from them. MPPT calculations use criticism from the sunlight-based charger voltage and current to progressively follow the most extreme power point, hence streamlining energy age.

Reconciliation and Control: When the equipment parts are collected, you want to foster the control programming to connect with the sensors, actuators, and MPPT regulator. Arduino furnishes a strong improvement climate with libraries and code guides to work on this interaction [6].

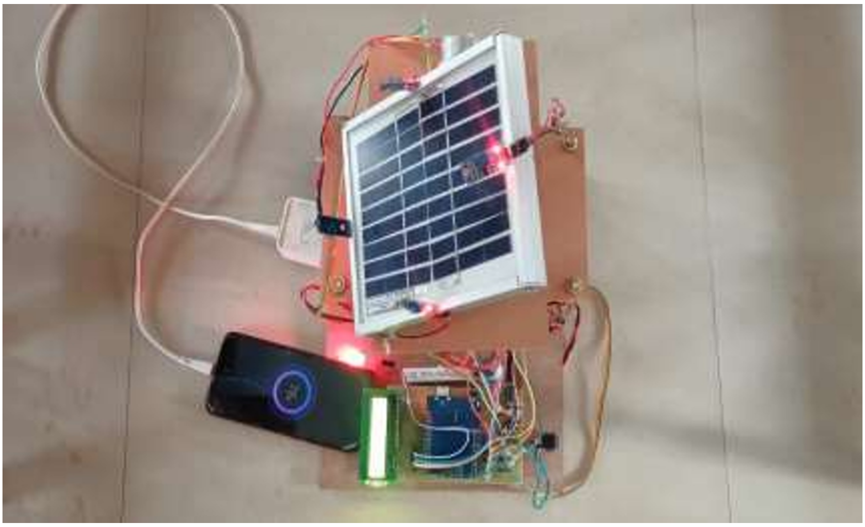

Fig.6. Prototype of dual axis solar tracker

The control programming peruses the sensor information to decide the sun's situation, ascertains the necessary following points, and sends suitable orders to the actuator engines for changing the board direction. Furthermore, the MPPT regulator constantly changes the heap impedance to keep up with the greatest power yield [7].

Standard testing and adjustment are fundamental to guarantee precise following and MPPT execution. It's essential to consider factors like power utilization, wellbeing measures, and ecological contemplations during the equipment execution [8]. By Combining of proficient MPPT calculations, and dependable equipment, the double hub sun-based tracker framework utilizing Arduino with MPPT can altogether further develop the energy result of sunlight-based chargers, upgrading their general productivity and lessening dependence on matrix power [9].

4 Conclusion

The paper introduces a sun tracking method incorporating a microcontroller and Light Dependent Resistor (LDR) sensors. It presents a practical software solution designed to optimize solar cell output by positioning a solar charger at the point of maximum light intensity. Notably, the tracker can establish its initial position without the reliance on additional photo resistors. The significance of this solar tracker lies in its straightforward system control mechanism. Given the widespread adoption of solar power production globally, even a modest 1% improvement in efficiency compared to a stationary plane can significantly boost overall power production. Hence, the efficiency enhancement provided by the tracker holds value. To summarize, this feature has potential applications in various systems requiring solar tracking, such as flat plate collectors, solar dishes, lenses, and other Photovoltaic (PV) systems, with the goal of maximizing solar radiation capture.

5 Future Scope

From an economic perspective, dual-axis solar tracking is not extensively embraced, even in countries heavily reliant on solar power, with single-axis tracking often considered sufficient. Nevertheless, the adoption of dual-axis tracking has the potential to significantly enhance power output. In our investigation, we applied this approach to a randomly selected photovoltaic (PV) panel, and the commercial viability and resilience of the proposed system can be assessed at a larger scale. Although our study employed a monocrystalline PV panel, the suggested model can also accommodate a poly-crystalline material-based PV panel. Despite the incorporation of LDRs in this design, their susceptibility to dust renders them less than ideal sensors. Consequently, future iterations might explore more efficient sensor alternatives. The construction of a reliable structure incurs expenses compared to solar panel costs; hence, choosing an additional panel over investing in a tracking design emerges as a more economically viable approach.

5.1 Advantages

- It boasts a 40% higher power delivery compared to stationary solar panels.
- Provides enhanced flexibility, enabling greater energy generation.
- Exhibits a heightened level of precision.
- Continuously tracks the Sun on both axes, ensuring a consistent power output throughout the day.
- These solar trackers offer a pragmatic solution in situations with limited grid power capacity.
- Requires less space and opens up possibilities for utilizing the remaining area for supplementary purposes like parking, farming, and more.
- The acknowledgements should be typed in 9-point Times, without title.

References

1. J. Bartlett, "Arise Energy Solutions," Arise Energy Solutions, LLC, [Online]. Available: http://ariseenergy.com/training-education/history-of-pv-solar-energy. [Accessed 28 September 2018].
2. A. Baker, 13 July 2013. [Online]. Available: https://www.solarpowerauthority.com/a-history-of-solar-cells/. [Accessed 28 September 2018].
3. S. Wahid, 25 February 2015. [Online]. Available: https://www.greentechlead.com/solar/tsec-dupont-to-showcase-v-series-solar-panelsat-tokyo-expo-21927. [Accessed 26 September 2018].
4. J Pradeep, "Development of Dual-Axis Solar Tracking using Arduino with Lab VIEW," International Journal of Engineering Trends and Technology (IJETT), vol. 17, p. 321, 2014.
5. Md. Tanvir Arafat Khan, "Design and Construction of an Automatic Solar Tracking System," International Conference on Electrical and Computer Engineering, ICECE, pp. 326-27, December 2010.
6. O. R. Otieno, "SOLAR TRACKER FOR SOLAR PANEL," University of Nairobi, 2009.
7. R. Bhandari, "Electrification using solar photovoltaic systems in Nepal," ELSEVIER, pp. 458-465, 2011. 45
8. C. Joshi, B. Pradhan and T. Pathak, "Application of Solar Drying Systems in Rural Nepal," in World Renewable Energy Congress VI, Brighton, UK, 2007, pp. 2237-2240.

[14] Suresh Baral, "Existing and Recommended Renewable Energy," SAP, vol. 4, pp. 16-28, 2014.

9. W. community, "Energy Sector Synopsis Report Nepal," Water and Energy Commission Secretariat (WECS), Nepal, 2010.