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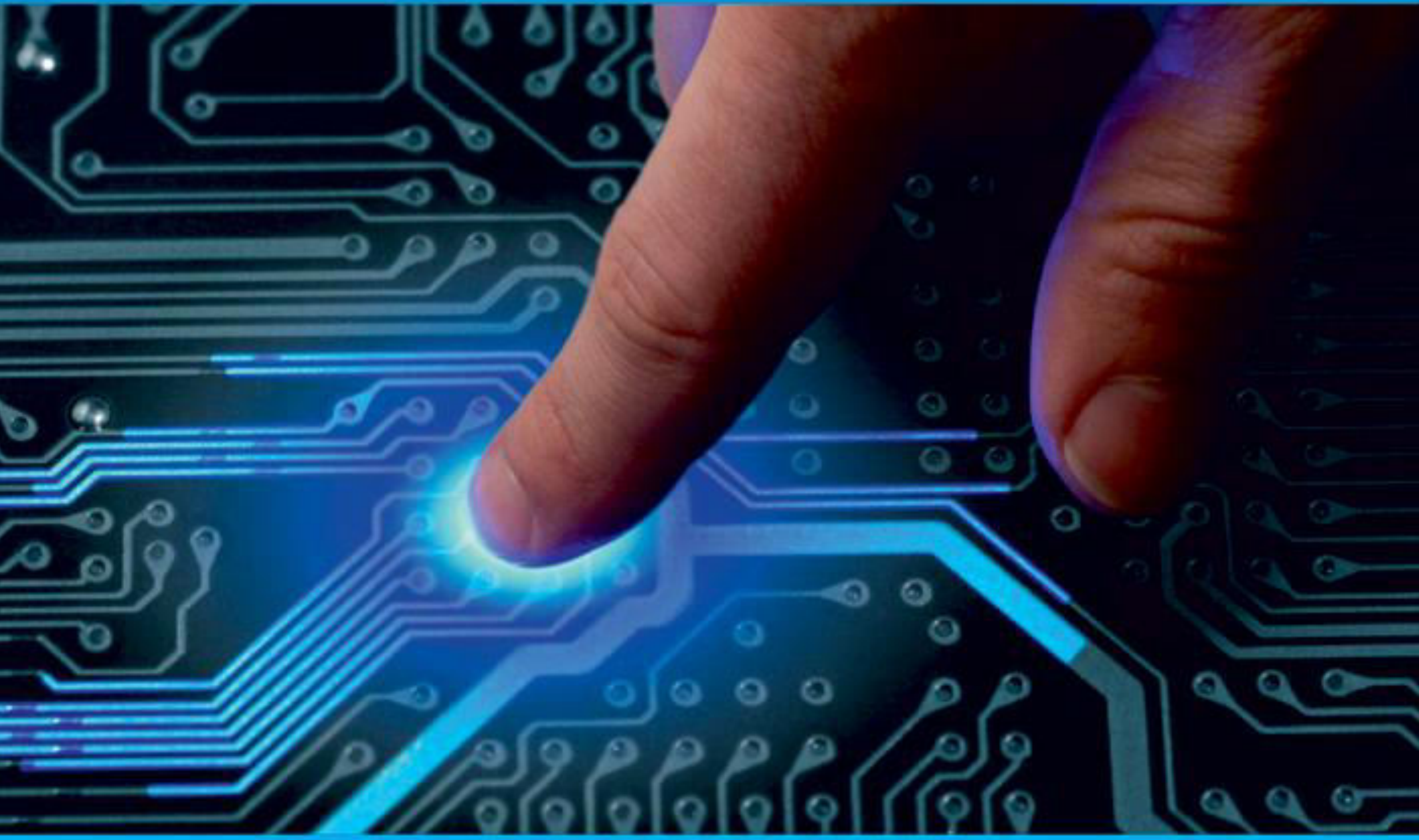

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Optimization of a Single-Axis Solar Tracker PID Control for Enhanced Energy Efficiency

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ABSTRACT: This research explores the design and performance of a single-axis solar panel tracking system integrated with a PID controller . The solar tracker is designed to ensure that the panels continuously follow the sun's movement, maintaining a perpendicular orientation to maximize energy capture. The system's core components include solar panels, light sensors (LDRs) for detecting sunlight intensity, motors for adjusting panel orientation, a microcontroller for processing sensor data and controlling motors, and a power supply with a solar inverter to convert energy into usable electricity.

KEYWORDS: Energy efficient algorithm; Manets; total transmission energy; maximum number of hops; network lifetime

I. INTRODUCTION

Today, a variety of resources are used to generate electricity, including thermal energy, fossil fuels, wind, and solar power. Fossil fuels are still the most popular option, but they are not renewable and present serious environmental risks. Solar energy, on the other hand, offers a sustainable substitute that may effectively provide electricity while reducing its negative effects on the environment. It is regarded as one of the most dependable and affordable ways to produce power [1]. Solar energy can be harnessed through thermal and photovoltaic (PV) methods, with proper solar panel alignment significantly enhancing power production.

Light-dependent resistors (LDRs), which sense the intensity of sunlight, are integral components of solar tracking systems. The resistance of these sensors, which are constructed of semiconductor materials like silicon or cadmium sulphide, decreases with increasing light exposure. Moreover, LDRs are employed in spectroscopy to assist in the detection of signals involving pulsed light [2]. PID (Proportional-Integral-Derivative) algorithms are control methods in solar tracking systems that allow real-time modifications to the panel's position depending on feedback, ensuring the system maintains optimal performance.

By lining up solar panels, reflectors, or lenses with the sun's movement throughout the day and over the seasons, a solar tracker improves energy capture. As a result, solar energy systems become much more efficient and can be used for higher temperature research and power generation. Solar trackers are necessary for optimizing energy output, despite the fact that they do increase system complexity and expense[3]

There are many different kinds of solar trackers, such as single- and dual-axis devices. Compared to dual-axis trackers, which can change in both vertical and horizontal directions[4], single-axis trackers are simpler and use less energy because they only adjust the panel's alignment along one axis. Because single-axis systems are affordable and simple to install—especially when there are financial or spatial constraints—they are a great option for a variety of solar projects because they strike a fair balance between functionality and affordability.

Based on theoretical analysis and previous research, this paper focuses on designing a single-axis solar tracking system and highlights its advantages over dual-axis and stationary solar panel setups.

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II. RELATED WORK

To enhance solar panel alignment with the sun, Bamigboye and Titus (2020) built and modeled a dual-axis solar tracking system that uses an Internal Model Control-based PID (IMC-PID) approach. Their solution seeks to overcome the limits of fixed-angle solar panels, which absorb only a portion of solar energy and cannot track the sun's course throughout the day. When compared to typical PID controllers employing the Dobrovolski approach, the incorporation of IMC-PID control improves disturbance rejection capabilities, resulting in higher tracking accuracy and stability. As a result, their dual-axis tracking system performed better and collected more solar energy. However, this option may not be affordable for all customers. As a result, single-axis tracking systems are frequently preferred in solar energy applications since they are less expensive and easier to implement[5]

(Marwan and Anshar's 2020) study centered on creating a proportional-integral-derivative (PID) controller for a dual-axis solar tracking system. Their research attempted to improve solar panel orientation in order to maximize solar radiation capture throughout the day. To guarantee adequate performance, the solar tracking system was mechanically tested using a variety of input parameters, and PID parameters were examined to determine the system's response to elevation and rotation changes. This experiment was carried out in the electrical power system laboratory of the State Polytechnic of Ujung Pandang in Makassar, Indonesia. Their studies showed that utilizing an improved PID controller for precise sun tracking can greatly increase solar energy collection efficiency (Marwan & Anshar, 2020)[6].

Safan et al. (2021) used a Multi-Degree of Freedom-Simplified Universal Intelligent PID (MDOF-SUI PID) controller to create a hybrid control approach for a solar tracking system. By successfully lowering the angle of incidence of solar radiation on the collecting surface, this technology seeks to maximize the output power of photovoltaic panels. The goal of the study is to minimize the energy needed to power the tracking mechanism while retaining maximum output power throughout the day. The MDOF-SUI PID controller's performance was assessed by the authors, who showed that it was useful in raising the overall efficiency of solar energy gathering and increasing the precision of sun tracking. By highlighting the significance of lowering dependency on fossil fuels and guaranteeing energy security, this effort advances solar technology.[7]

Sigit, M. F., Ridwan, and Sari, S. P. (2023) conducted a study to simulate a PID controller within a single-axis solar tracking system. Their research focuses on the issues of low solar cell efficiency, which can be attributable to temperature, tilt angle, and radiation levels. Using Matlab Simulink software, they created a model of the single-axis solar tracking system with a PID controller. The system is designed to modify elevation angles to maximize its ability to track the sun's movement between 7:00 and 17:00 WIB. The simulation results showed a considerable improvement in tracking accuracy for elevation angles ranging from 1.7 to 68.21 degrees. This study demonstrates the effectiveness of solar tracking systems in catching more solar radiation and increasing solar cell efficiency, hence aiding Indonesia's renewable energy projects.[8]

In their 2023 study, Sigit, M. F., Ridwan, and Sari, S. P. simulated a PID controller within a single-axis solar tracking system to address the issue of low solar cell efficiency, which is influenced by variables such as radiation levels, temperature, and tilt angle. They created a model with Matlab Simulink, focusing on elevation angles to improve the system's capacity to monitor the sun between 07:00 and 17:00 WIB. The results showed that the PID control framework greatly increased tracking accuracy at elevation angles ranging from 1.7 to 68.21 degrees. This study highlights the efficiency of solar tracking systems in boosting solar radiation collection, hence increasing solar cell output and promoting renewable energy advancements in Indonesia (Sigit et al., 2023)[1].

We were inspired by the work of Pallavi Deshpande et al. (2019) and (2021) when developing the structure, format, and progression of this paper for conference publishing. Although their studies provided useful guidance for our organizational strategy, we did not include any direct content or citations from their work to protect the originality of this research [12-13].

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III. METHODOLOGY

Objectives:
The objective is to combine a solar panel, Light Dependent Resistors (LDRs), and a single-axis tracker to construct a solar tracking system that functions effectively and generates electricity. Based on the direction of the sun, which is sensed by LDRs, a servo motor can adjust the solar panel's position. PID control is utilized to increase tracking precision and energy capture throughout the day. This project involves creating the necessary circuit, programming, and selecting the appropriate components in order to achieve optimal performance. The ultimate goal is to maintain the solar panel's alignment with the sun's movement in order to maximize solar energy output.

A. *PID:*
PID (Proportional-Integral-Derivative) control is a widely used feedback control system in engineering and automation. It continuously adjusts the control input to attain the set point by calculating an error value, which is the difference between the observed process variable and the intended set point. The algorithm consists of three components: the integral term, which removes steady-state bias by accounting for accumulated past errors; the proportional term, which provides an immediate response based on the current error; and the derivative term, which predicts future error trends by considering the rate of change. This combination enables PID controllers to operate accurately and consistently in a range of applications, including motion control, temperature regulation, and process control.

The PID (Proportional-Integral-Derivative) control method is essential to our solar tracking project since it allows us to align the solar panel with the sun accurately and effectively. PID is a well-liked automated control technique that continually modifies control inputs in response to real-time feedback, offering accurate and reliable performance. Light Dependent Resistors (LDRs) in this system measure the amount of sunshine and provide real-time data that the PID controller uses to determine how much to move the panel.[9]

Three parts make up the algorithm: the derivative term, which forecasts future error trends by taking the rate of change into account; the integral term, which addresses the sum of previous errors to remove long-term bias; and the proportional term, which reacts to the present error (the difference between the current and desired position). The PID controller makes sure that the solar panel is always oriented to maximize sunlight by adjusting the panel's orientation according to these variables. This method provides a cost-effective solution for solar energy applications by optimizing energy generation and improving the solar tracking system's overall efficiency.

B. *Components:*
- ARDUINO

In Controller is used to apply the PID algorithm which stands for Proportional Integral Differential Algorithm which will take the feedback from LDR and adjust the position of the servo motor which will further adjust the direction of the solar panel with respect to the sun's position.
- LDR

Light Dependent Resistor also known as LDR is a type of module which converts light intensity into its proportional resistance and gives analog and digital signals[2]. This is the only module in the circuit which will provide the information of angle of deviation between sun and solar panel which is feedbacked to the controller.[2]
- SOLAR PANEL

It is the type device which uses photovoltaic cells to convert sunlight into electricity. Each cell generates 0.6v and 10 of them are series and 2 sets are connected in parallel so the current capacity is increased due to this. The device is the main component of total hardware used which position is to be changed.
- SERVO MOTOR

It is the type motor which uses Pulse Width Modulation for rotational purpose. It is easy to implement and consumes less power. In this design the servo motor is connected to the axle which will change the position of the panel in accordance with solar radiation.

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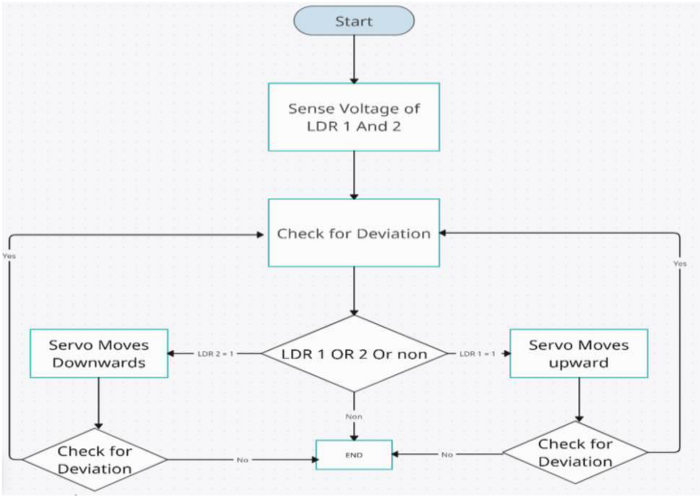

Fig. 1. Flowchart

C. *Explanation :*

The overall block consists of start which indicates the sunlight reaching the surface of solar panel. The process block which is indicated by rectangular block which represents the checking of signal of LDR 1 or LDR 2 or no signal using arduino uno. The arduino uno will sense the signals from LDR 1 or 2 or 3 and accordingly give 3 outputs as shown in above figure. If LDR 1 gives signal high Servo will rotate and wait for response from the block which will again check for deviation between both the LDR. This loop will continue unless and until the deviation is zero.

In second condition if LDR 2 will give high pulse then the servo motor will rotate in opposite direction so that to compensate the deviation and similarly the loop will continue until deviation becomes zero. When deviation becomes zero the servo will not rotate so we will get maximum efficiency.

D. *Schematic :*

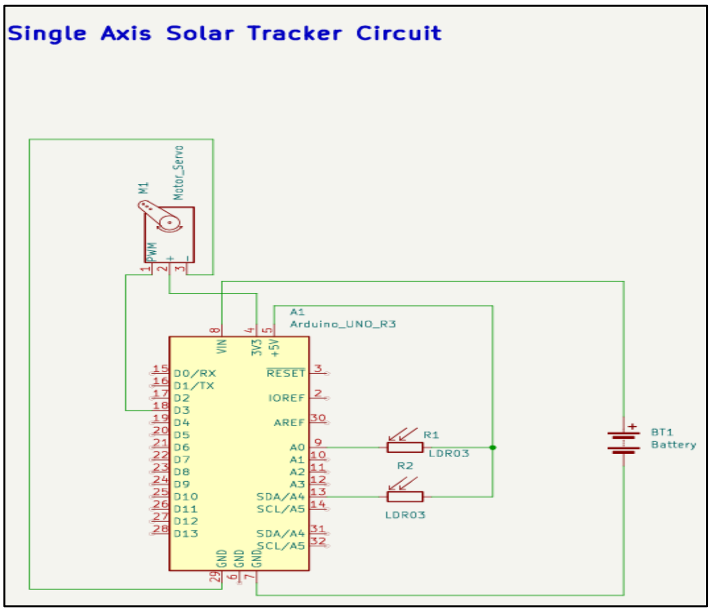

Fig.2. Schematic

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E. Explanation:

The objective is to combine a solar panel, Light Dependent Resistors (LDRs), and a single-axis tracker to construct a solar tracking system that functions effectively and generates electricity. Based on the direction of the sun, which is sensed by LDRs, a servo motor can adjust the solar panel's position. PID control is utilized to increase tracking precision and energy capture throughout the day. This project involves creating the necessary circuit, programming, and selecting the appropriate components in order to achieve optimal performance. The ultimate goal is to maintain the solar panel's alignment with the sun's movement in order to maximize solar energy output. Involves creating the necessary circuit, programming, and selecting the appropriate components in order to achieve optimal performance. The

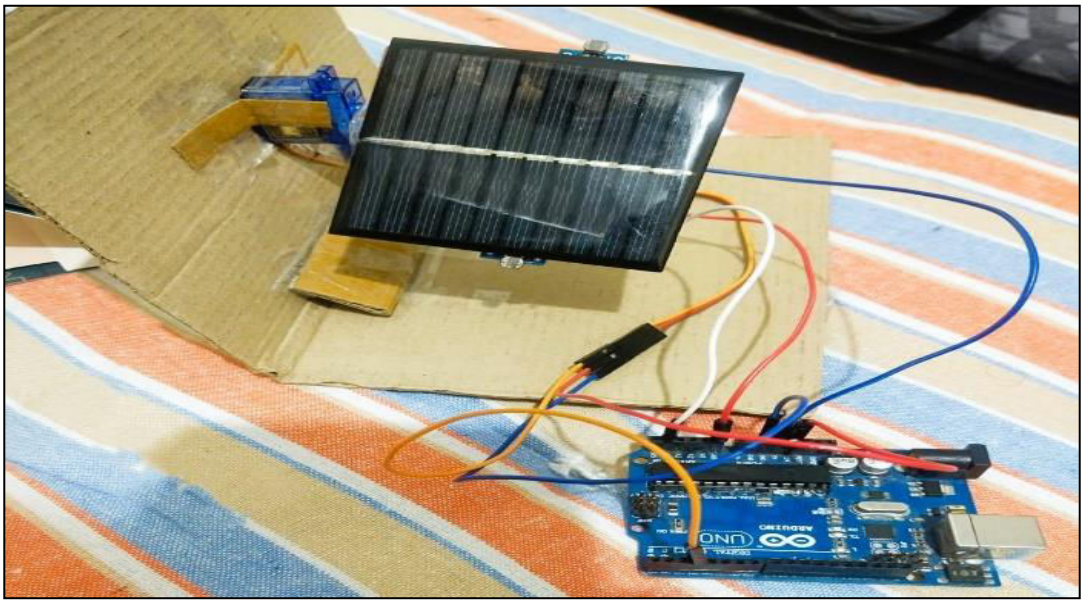

Fig.3. Hardware Setup

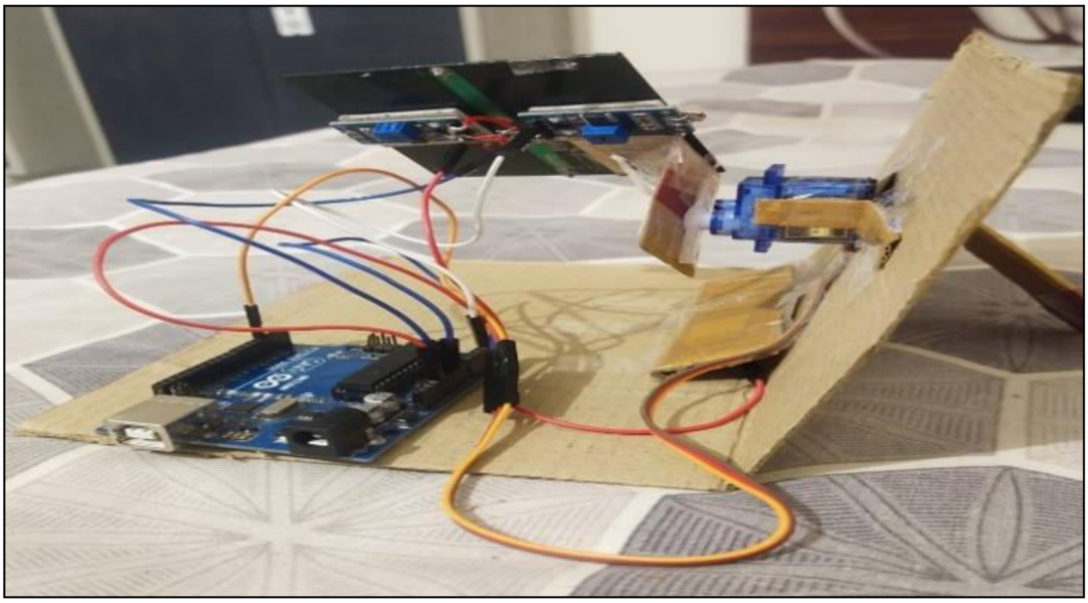

Fig.4. Hardware Setup

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IV. RESULTS AND DISCUSSIONS

Sr.no	Time	Voltage	Power
1	12:30	5.70V	509.01mW
2	13:00	5.68V	515.744mW
3	13:30	5.70 V	501.657mW
4	14:00	5.63V	481.083mW
5	14:30	5.58V	467.938mW
6	15:00	5.52V	458.16mW
7	15:30	5.10 V	361.59mW
8	16:00	5.05 V	326.886mW
9	16:30	4.80 V	241.92mW
10	17:00	4.50V	90mW

Table1. Results

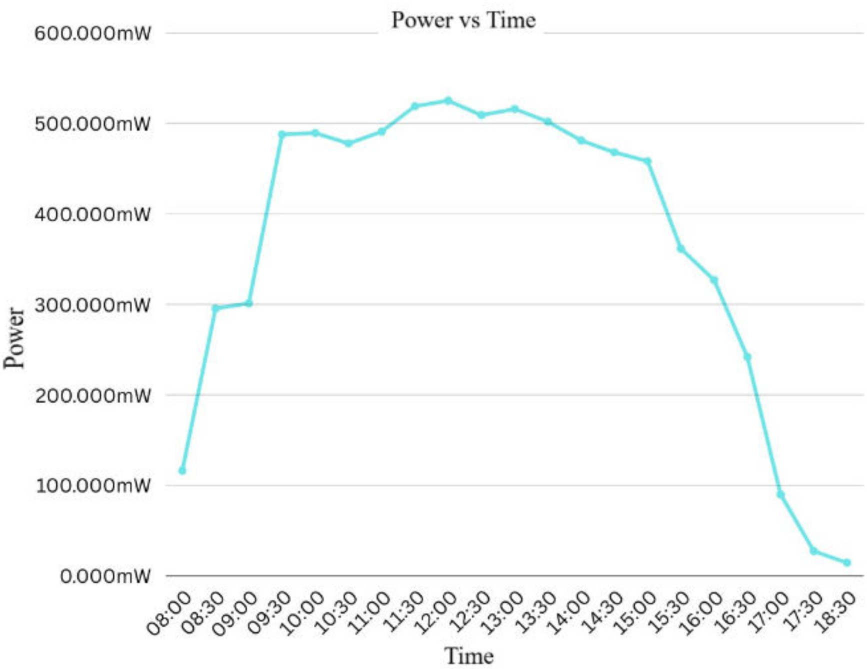

Fig.5. Power Vs Time graph

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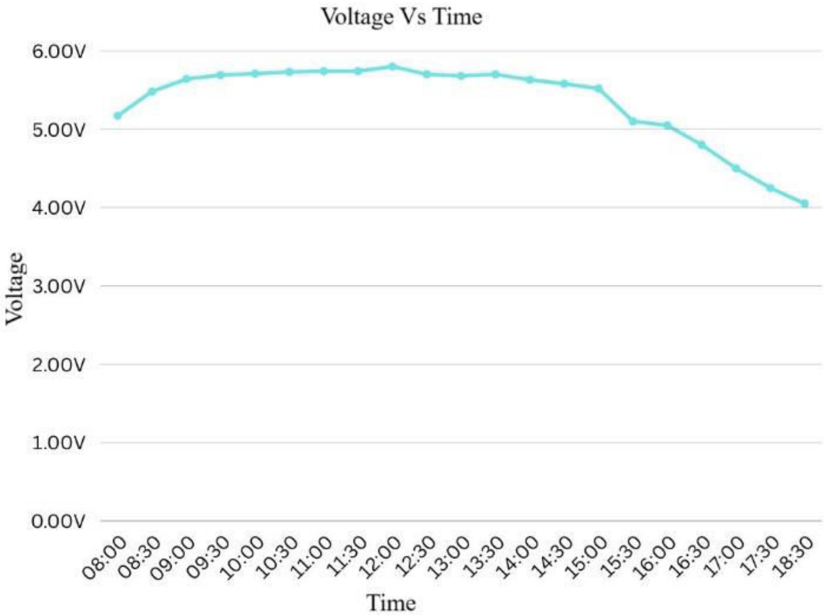

Fig.6. Voltage Vs Time graph

Fig.5 depicts the output voltage at the solar panel over a day. The voltage increases gradually in the morning with the increase in the intensity of sunlight, peaks in the late morning and afternoon, and then decreases linearly towards the evening with the approach of sunset. This graph does depict how the output by the solar panel depends inversely on the brightness of sunlight.

Fig.6 depicts the power produced by a solar panel at a particular time of a day. It can be observed that, power increases significantly during morning hours, which coincides with the increase in the intensity of solar light and reaches peak time in the middle of the day. The process starts to decline by evening because of the reduced light intensities of sunlight and almost touches zero level at evening. Thus, the variation is linear with relation between generation of solar power and sunlight intensities as output generated will also reach to the maximum peak time due to high light intensity in day.

In effect, we conclude that our single-axis solar tracker has better economy and efficiency in comparison to dual-axis solar tracking systems. While two-axis trackers update the solar tracker's azimuth and elevation angles to allow for just a few percent more energy capture, those gains are considered to be too small in most applications to offset the increased complexity and related costs of adding another axis. It is found that single-axis systems are at an optimal balance, offering significant energy savings over fixed-tilt systems with lower operational and maintenance demands, making it suitable for large-scale solar installations (Abdallah & Nijmeh, 2004).[10]

V. CONCLUSION

In this research paper we conclude that the single axis solar panel is more efficient and cost effective for small scale solar energy generation because of its simple construction and graphs as per above results. The single axis solar panel tracking device is more simple because only one servo Is used if dual axis solar panel tracking will be implemented the efficiency will be increased but the power consumption of servo will increase as we need motor controller to control two servo which is unnecessary power loss but on other hand to no motor controller is required to control one servo motor. Arduino can handle one servo motor's load easily. The method of single axis solar tracking is highly effective and highly efficient of small scale power generation.

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13. .International Journal of Computing and Digital Systems ISSN (2210-142X) Int. J. Com. Dig. Sys. 10, No.1 (Aug-2021) E-mail: archana.ratnaparakhi@viit.ac.in, pallavi.deshpande@viit.ac.in, gauri.ghule@viit.ac.in http://journals.uob.edu.bh A Framework for Segmentation and Classification of Arrhythmia Using Novel Bidirectional LSTM Network Archana Ratnaparkhi1 , Pallavi Deshpande1 and Gauri Ghule1.