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Full Length Research Article

INTEGRATED DUAL AXIS SOLAR TRACKER USING A SINGLE TRACKING MOTOR

*Percy Okae, Osman Muntaka Raji, Jude Lade

Computer Engineering Department, School of Engineering Sciences, College of Basic & Applied Sciences (CBAS), University of Ghana, Legon

*Corresponding Author Email Address: pokae@ug.edu.gh

ABSTRACT
Solar energy is generally available in copious amounts globally and as a renewable energy resource, its importance now and in the future cannot be gainsaid. However, optimizing the rays of the sun by utilizing photovoltaic (PV) systems and aligning solar panels in a particular direction with regards to the sun's rays always present their own challenges. Solar heating, molten salt power plants, and artificial photosynthesis are all examples of ever-evolving technologies that harness the sun's radiant light and heat for electrical energy. Solar trackers aim solar panels or modules directly at the sun. In this paper, a solar tracking system using Arduino is built. This system captures free solar energy, stores it in a battery, and then transforms it to the appropriate alternating current. It allows the energy to be used as a standalone power source in ordinary households. This system is built to adapt to its surroundings as quickly as possible. The system ensures that any software and hardware issues are minimized or wholly removed. Our system is put through its paces in terms of real-time responsiveness, reliability, stability, and security. Weather, temperature, and mild mechanical stresses are all factors that our system is built to withstand. The solar tracking system is the most effective technology to improve the efficiency of solar panels by tracking and following the sun's movement. With the help of this system, solar panels can improve the way of sunlight detection so that more electricity can be collected as solar panels can maintain a sunny position. Thus, this paper discusses the development of two-axis solar-tracking development using Arduino Uno as the principal controller of the system.

Keywords: integrated solar tracker, solar energy, Arduino Uno, degrees of freedom, photovoltaic, electrical energy.

INTRODUCTION
Solar Tracking is the process of sensing and following the position of the sun to retrieve maximum energy from it to generate electrical energy. Electricity plays an integral role in our daily lives. The use of electricity is increasing everyday with increasing human usage of technology. The discovery of the photoelectric mechanism and the development of the solar cell - a semi-conductive substance that converts visible light into a direct current – made it possible to extract usable electricity from the sun. Solar arrays, which are made up of a sequence of solar cells that are electrically connected, provide a DC voltage that can be used to power a load. Solar arrays or panels are becoming more popular as efficiencies rise, and they're especially popular in distant places where installing electrical lines are not cost-effective. This alternative energy source is growing in importance, especially given the diminishing volumes of fossil fuels. However, reduced inverter losses, storage losses, and light gathering losses are all problematic much as the issues of solar energy are concerned. For instance, the angle of incidence of the light source delivering electricity (i.e. the sun) to the solar cell's surfaces determine how much light is collected, and the closer the angle is to 90 ^{o}, the more power is received. If a flat solar panel is installed on level ground, it is evident that the sunlight will have an angle of incidence close to 90° in the morning and evening. The cell's light gathering ability is effectively nil at this angle, resulting in no output. The angle of incidence approaches zero degrees as the day continues to midday, creating a constant increase in power until the light shining on the panel is perfectly perpendicular, at which time maximum power is obtained. As the day progresses toward dusk, the reverse occurs, and the increasing angle causes the power to drop back to zero.
Given this context, we can see why it is important to keep the panel's maximum power output by keeping the angle of incidence as near to zero degrees as possible. This can be accomplished by tilting the solar panel to face the sun continually using the technology of solar tracking.
This work proposes an empirical research approach to achieve maximum solar radiation on a continuous basis using a dual-axes solar tracker that runs on a single tracking motor precipitating a simple and efficient control scheme.
Thus, the objective here are to:

1. Build 3D models to hold models in place.
2. Position motors to rotate in both axes.
3. Finally, align light dependent resistor (LDR) sensors to detect all angles of the sun

Research into solar energy has gained a lot of traction in recent times owing to the fact that it is a renewable source of energy and humankind is in one way or the other running out of exhaustible sources of energy such as fossil fuels. The intensity of these research works have resulted in the publications identified below as part of the review of literature of this work.
In their work, (Natarajan et al., 2019) developed a two-axis tracking system for a solar parabolic dish and experimentally evaluated the performance of the tracking system. Here, the sensor used the illumination produced by the convex lens on the apex of a pyramid to align the dish in-line with the sun. The orientation of the lens and stepper motor ensured that the short-circuit current eventually was boosted by as much as 86 % from its original value.
Flores-Hernandez et al. (2017) also proposed a dual axis sun tracker that uses a mechatronic design and photovoltaic system driven by a robotic sensor. The design used mechatronics concepts methodology particularly, the VDI 2206 standard which integrates verification and validation. This technique provides an efficient energy collection system and it was evaluated that the performance was better compared to the fixed or single axis tracking system.
On their part, (Chen et al., 2015) also proposed an intelligent sun tracking system that uses NI9642 controller to integrate the dual

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axis with Maximum Power Point Tracking (MPPT). Many expert and intelligent functions are integrated into the design so that they can start automatically during the daytime and revert to its original position at night. With the help of MATLAB, the system is versatile enough to switch to dual axis sun tracking, single axis sun tracking and fixed solar panel according to the needs of the user.
When (Yilmaz et al., 2015), did a comparative study between the output of dual-axis solar tracking based PV panel and a fixed tilted PV panel on a 10 W prototype, the dual-axis produced 34.02 % more energy than the fixed one. It turned out that 55.91 Wh worth of energy was produced by the sun tracker system throughout the day whereas the fixed one managed to produce 41.71 Wh in a day. An open-loop control system that had a two-axis solar tracking system was also proposed by (Seme et al., 2017). In this design, the system yields good results in terms of tracking the trajectory of the sun. When components were meticulously selected and the electric circuit and photo sensors correctly configured, the tracking of the rays of the sun turned out to be of a high degree of accuracy. The dual axis solar PV tracking system generated 27 % more electrical energy than the fixed systems.

A dual axis active solar tracking system with linear Fresnel lens collector was used by (Perini et al., 2017). Here, a temperature range of 40 ºC to 90 ºC was used to generate the performance analysis curve of the collector. It was, however, detected that the global efficiency of the collector was less than 20 %. This was so because of factors such as reflection, refraction and deflection in the Fresnel lenses which precipitated optical loss of the lens system with 47% of the total energy going to waste. So to improve the global efficiency of this design, it was recommended to install an evaluated receiver and to insulate the recirculation system which could increase global efficiency by 55 %.
Active tracking systems use electrical energy as their source. There are several types of trackers, including electro-optical trackers, auxiliary bifacial solar cells, and chronological (time and date based) trackers. In some cases, a hybrid system will be created by combining these separate systems, and the resulting system will be referred to as a hybrid. Electro-optical-based trackers are the most popular of all active trackers (Singh et al., 2016). The use of differential lighting of connected electro-sensors to provide a differential signal to a controller, which subsequently transmits a signal to operate the solar system is described by (Abdallah and Nijmeh, 2004, Piao, et al., 2005, R., Nijmeh, S., & Abdallah, S.M., 2006, Mamlook, Mousazadeh et al., 2009, Hamadani et al., 2013,). The sensor can be installed on a pyramid for greater photosensitivity. It keeps diffused radiation from reaching the sensors, ensuring accurate measurement of the sun's position.
A tracker's overall function is determined, then broken down into its sub-functions and presented in a solution-independent manner. These functions are then converted into black and transparent boxes to determine the process's inputs and outputs in terms of energy, material, and signal flow. Finally, the relationship between a process's input and output is investigated in order to aid in the identification of functional modules.

MATERIALS AND METHODS

The system consists of two functional units; the hardware and software.
The hardware consists of the following:

a) **Arduino** is an open source, computer hardware and software company, project, and user community that designs and manufactures microcontroller kits for building digital devices and interactive objects that can sense and control objects in the physical world. It is a single board microcontroller. Arduino is also inexpensive considering the scale of this work (Kaur et al., 2016).
b) **Light Dependent Resistor** (LDR) or a photo resistor is a device whose resistivity is a function of the incident electromagnetic radiation. Hence, they are light sensitive devices. They are also called photo conductors, photo conductive cells or simply photocells.
c) S**ervo motor** is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors.
d) **Potentiometer** is a simple knob that provides a variable resistance, which we can read into the Arduino board as an analog value. By turning the shaft of the potentiometer, we change the amount of resistance on either side of the wiper which is connected to the center pin of the potentiometer.

System requirements and specifications

Certain requirements and specifications were used to achieve the dual axis solar tracker. They can be categorized into functional and non-functional requirements and are discussed in the sections that follow.

Functional Requirements

Functional requirements:

1. Allow the user to install Solar Panels anywhere.
2. Solar Panels able to rotate in all directions.

The web application shall aid the user in the absence of a mobile device.

Non-functional Requirements

The non-functional requirements:

1. Be user friendly.
2. Be easy to operate and understand.
3. Be secure and easily maintained.
4. Be reliable and always available.

Design and Development Process

The process taken to develop and design this project is as indicated below:

System Architecture

The system architecture defines the structure and behaviour of the system. The system architecture diagram as displayed in Fig 1 shows the relationship between the different components that make up the system and gives a description and representation to show the interaction between them.

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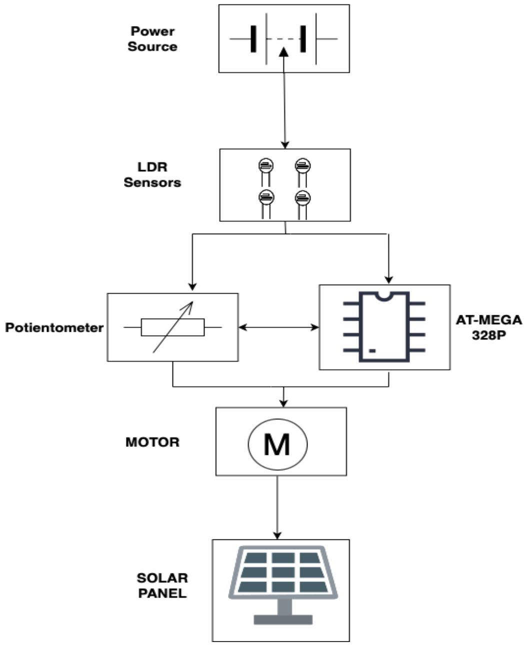

Fig. 1. System Architecture diagram
Block Diagram of Process

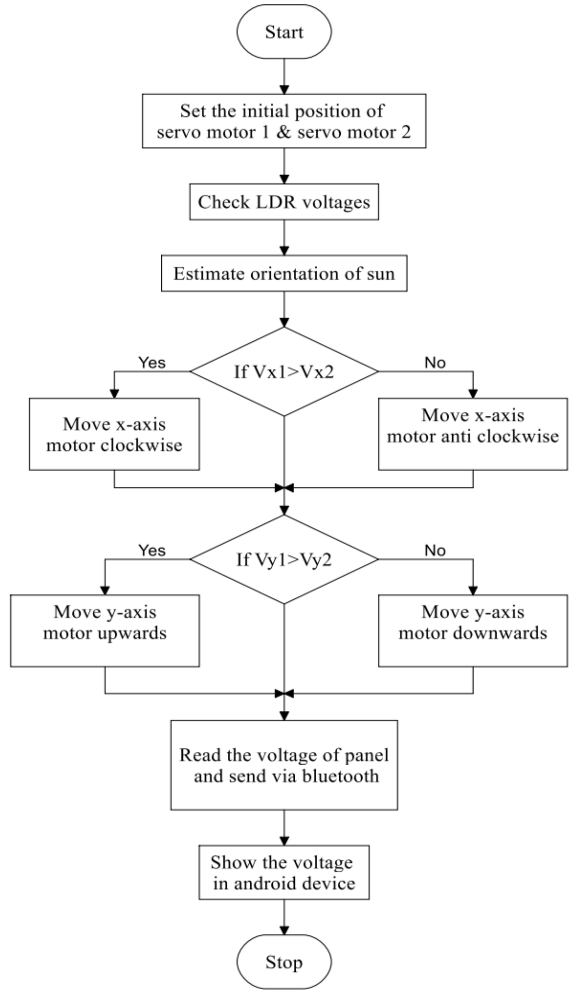

Fig. 2. Block Diagram of Process

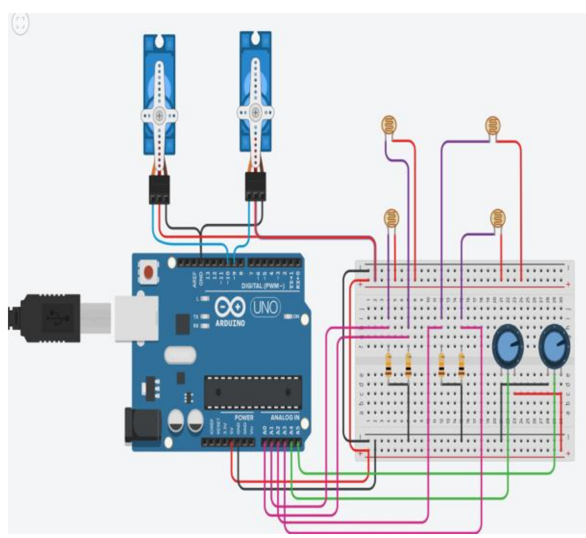

Fig. 3. Arduino connected to a power source and showing the simulation

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IMPLEMENTATION AND TESTING

System Implementation

The implementation process for the key parts or sections of the Integrated Solar tracker are indicated below.

Servo Motors in sweep motion

Fig. 4. Servo motor in sweep motion**.**

LDR placement

The LDR sensors are placed on a 3D model as shown in the figure below. This design was chosen because it makes use of a mechanism that allows you to block any incoming shadows falling on the sensors and particularly focus on the light rays hitting them
.

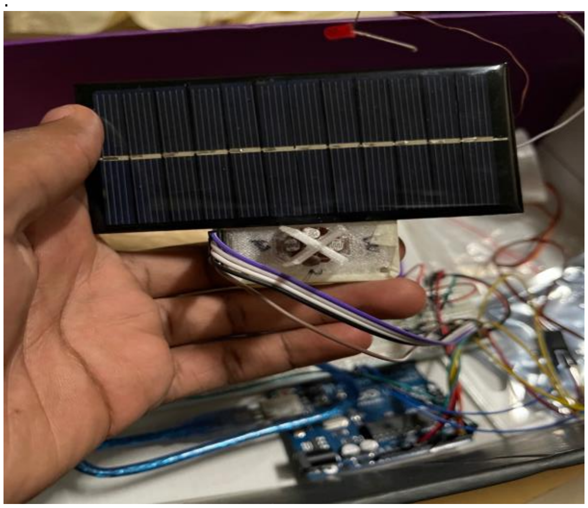

Fig. 5. LDR sensor position

Solar Panel

The PV panels is attached to the top of the LDR sensors. Solar Panels can be ignored for now to test the principle much better. Fig 5 above indicates the position of the solar panel.

Attaching the LDR model to the base

The LDR sensors are attached to the servo motors.

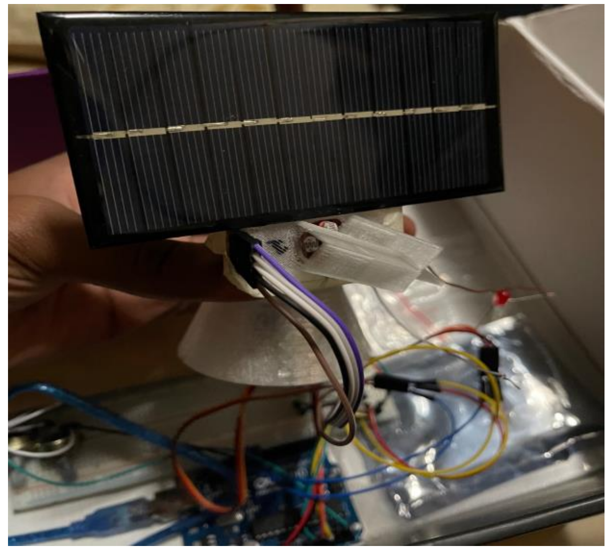

Fig. 6. Screenshot of LDR model attached to the base

Testing and results

This section describes the actual implementation of the tracking analysis as well as data obtained from the serial monitor.

Simulation

Fig. 7 shows the results obtained when the serial monitor was observed with low light intensity against a high light intensity in Fig 8.

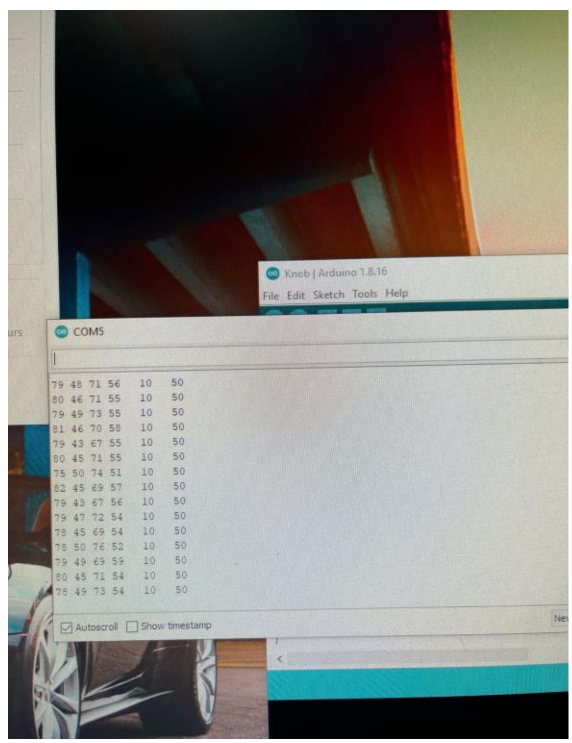

Fig. 7. Low light intensity position

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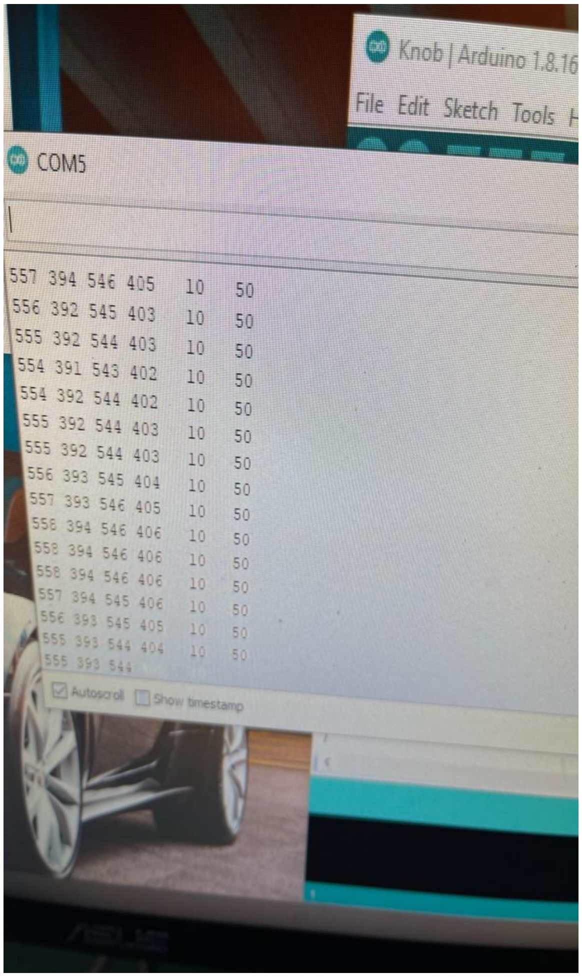

Fig. 8. High light intensity position

Experiment
Fig. 9 shows a flashlight being directed at one side of the tracker. In order to confirm the validity of the proposed theory, it was necessary to compare experimental data with the numerical predictions obtained from the computer model.

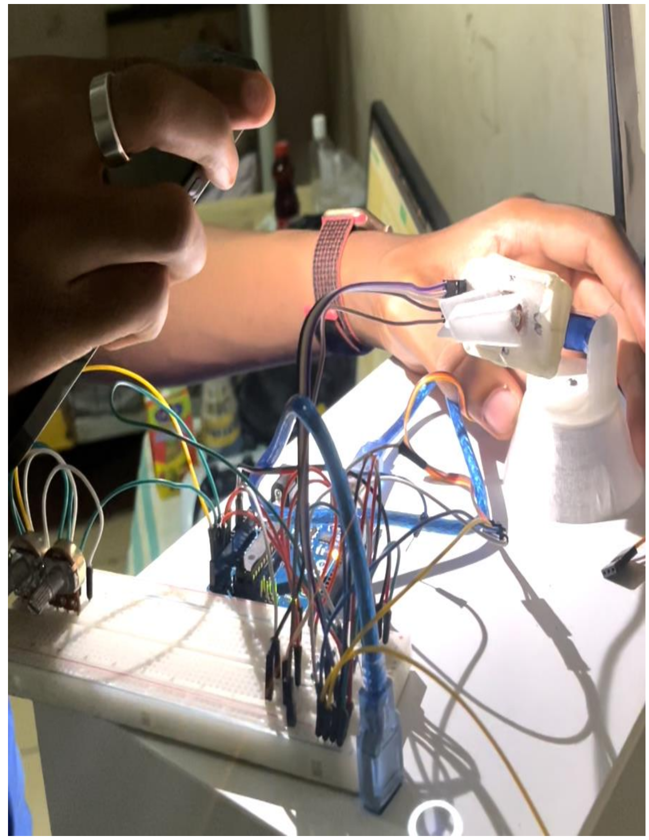

Fig. 9. Flash light on tracker

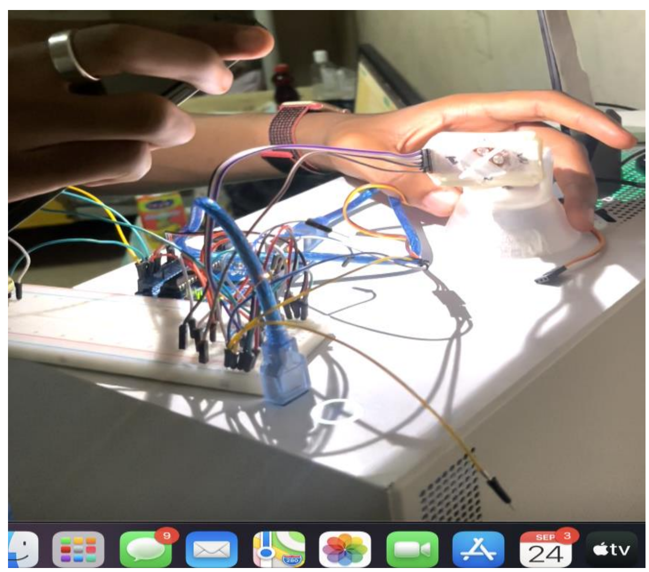

Fig. 10. Dual axis rotation achieved

From this experiment, the tracker was able to achieve a dual axis rotation towards a direction with higher light intensity.

DISCUSSION OF RESULTS AND ANALYSIS
From the results, the LDR sensors are able to detect directions of higher light intensity and the servo motors automatically gain

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motion towards these ends. The application was successfully able to rotate in both x and y axes as well as detect the places of higher luminosity as Fig. 11 depicts. Accuracy is dependent on the LDR sensors. Since LDR sensors are not manufactured of the same value, it is hard to set a certain accuracy for this work. The experiment indicates a little over 90 % in accuracy. In Fig. 12, one can observe that the generated waveforms are very distinct owing to the flashlight deployed on one end of the model. This indicates that the tracker was able to achieve a dual axis rotation towards a direction with higher light intensity.

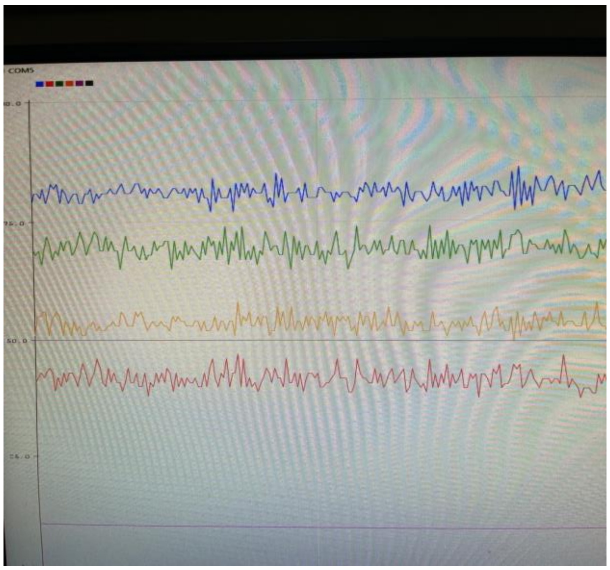

Fig. 11. Screenshot of simulation results indicating steady LDR values obtained in an enclosed area with little to no light**.**

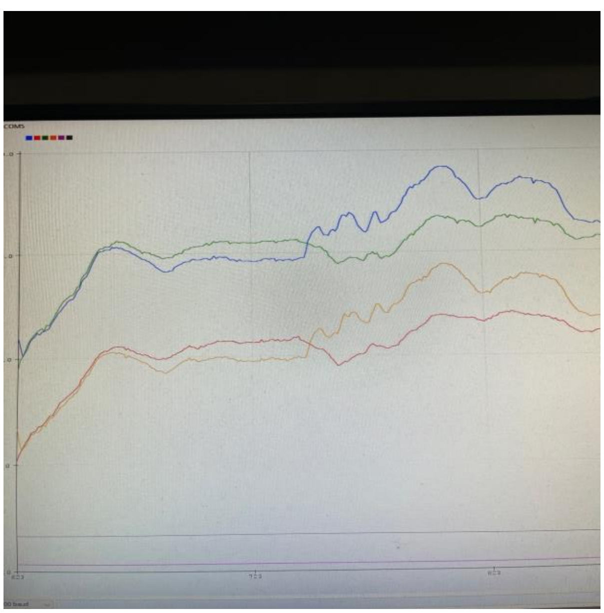

Fig. 12. Screenshot indicating simulation results of system with a flashlight on one end of our model.

Conclusions

The goal of this study was to create a dual-axis tracking system that could detect incident solar light on a panel and move it in the direction of the most intense solar light. Furthermore, the benefits and drawbacks were investigated. The drawbacks were obstacles that had to be overcome. The following are the key conclusions drawn from this research:

1. In comparison to current tracking systems in use for the same application, the proposed system is low cost and small.
2. It's very simple to program and alter because it is Arduino-based and does not require an external programmer.
3. The method is simple to operate and improves the panel's efficiency.
4. On the Serial Monitor, the created system retrieves real-time data.

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