A SUN TRACKING SOLAR PANEL

SUBMITTED BY

GROUP 5

DEPARTMENT OF MECHANICAL ENGINEERING

BELLS UNIVERSITY OF TECHNOLOGY

COURSE NAME: ROBOTICS AND EMBEDED SYSTEM

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CHAPTER 1

INTRODUCTION

1.1 Background

The ever evolving world needs a constant and sustainable power source to keep aspects of production from relying heavily on human labour.Since the search for renewable energy,we have found a way to convert water,wind and sun rays into the sorted out energy.Through astronomical research,it was discovered that the sun is an abundant energy source and is readily available so a keen interest has been taken into this energy source.Solar energy is environmentally friendly and suitable for locations with high solar irradiance but conventional solar panels have limited effectiveness since the sunlight changes throughout the day due to the movement of the earth and the sun.

The sun tracking solar panel is now designed to make up for this inefficiency by adjusting the solar panel to follow the rays of sunlight as it hits the earth. By maintaining optimal alignment with sunlight,the panels capture more solar energy. Progress in sensors,micro controller technology and embedded systems made it possible to design cost-efficient and functional solar panels suitable for domestic,educational,business and industrial applications.

1.2 Problem Statement

This project calls for the need of an automated system that will constantly track the sun movement and re adjust the position of the panel.the repositioning of the solar panel according to sunlight movement will result in energy gains,regardless of the change in sunlight from early morning and late afternoon. The system will then be cost effective and ready for use when normal electricity is not available.

1.3 Objective of the study

The objective of this project is to design,stimulate,prototype and implement a working sun tracking solar panel containing sensors,actuators,analog circuits and micro controller programming.

1.Design and simulate the complete sun tracking solar panel system using TinkerCAD and Proteus.
2. Develop the analog circuits for signal conditioning and light sensor interfacing.
3. Write,test and optimise micro controller code for real time sun tracking control.
4. Design a standard printed circuit board (PCB) for the system.
5. Construct and test a physical prototype of the sun tracking solar panel.
6. Document the entire project process and have the work published on GitHub.

1.4 Research Questions

1. How can a sun tracking solar panel be created using sensors and micro controllers?
2. What differences are significant from a fixed solar panel and this sun tracking solar panel?

3. How accurate is Proteus and Tinkercad simulations and what effect would it make on the physical prototype?
4. What are light-dependent resistors LDRs and what influence does it have on detecting the suns position?
5. What are the differences in output between an automated sun tracking solar panel over a fixed solar panel system?
6. How does the system react to changes in light and weather conditions during testing?
7. What challenges were encountered during the integration of actuators,sensors and the micro controllers in the solar panel?
8. How suitable is the designed system when in use by educational sectors and small scale business?

1.5 Significance of the study

* The system demonstrates to student how solar powered energy can be improved using low cost automation techniques.

* The project contributes to the study of renewable energy,especially in a high solar region like Lagos,Nigeria.

* The project enhances students understanding of sensor integration,micro controllers,sensors and actuators.

1.6 Scope and Limitations

* The project testing is limited to a controlled and fixed conditions,long term outdoor testing under variable weather conditions(snow,hail storm,fog)

* The project emphasizes the design,implementation and simulation of a micro-controller based sun tracking solar panel system,including sensors actuators and embedded system.

* The system of this project may be a single axis mechanism which will not provide a full dual axis movement to track the sun effectively.

* The project is intended for a educational and prototype testing,thus it cannot be launched for commercial use.

1.7 Organization of the study

This project report will be distributed into about five chapters.
Chapter 1 contains the introduction,background study,objectives,significance,scope and limitations. Chapter 2 reviews existing models of the fixed solar panels and analog circuit techniques used in designing. Chapter 3 shows the system block diagram and step by step hardware design involving the use of Proteus and tinkercad. Chapter 4 includes the simulation results,hardware results,PCB performance and a summary of the research,problem encountered and solutions. Chapter 5 and the final chapter will then involve recommendations for future works,the reference and appendix for this work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Since the investment in solar panels,there has been a need to review advancement in other factors like the industry and agriculture to prompt the release of more functional solar panels and to improve the techniques used to create other models. This chapter should serve as a review of past solar tracking model,the techniques which was used that made it better than the former. Since a model can be inspired by equipment's in the military or a theory in the educational sector,lets examine the evolution of past models.

2.2 Review of existing similar models

1. Ecoppia:It is a solar panel cleaning robot
Its E4 robot(for fixed-tilt) travels along its own track of row modules,floating above the panels and cleaning them with a spinning microfibre cloth. The T4 robot(for tracking system) travels freely across rows but more aware of its location so it doesn't fall off.

Figure1 :Ecoppia Solar Power Robot

2. Renubot: it is a vegetation maintenance solar powered tractor built by Texas company Renu Robotics with a 63-in mower deck that uses GPS and lidar to map and mow under and around solar mounts,fully funded in 2021.
3. ABBs collaborative robot(cobot),YuMi: deployed in the Peruvian Amazon,is a solar powered robot that handles seed-digging and planting 16 seeds at a time,at a rate of 600 seedlings in the morning,which was released in June 2023.
4. Canadian solar 300W / 24V Monocrystalline panel: known for durability,a good match for 24V inverter systems,especially in homes with moderate energy needs.
5. BYD Battery-box premium HVS 10.2: is a high voltage,10.24kW lithium iron phosphate battery system designed for residential and commercial on-grid or off-grid usage.
6. SMP Robotics S5s: is a solar powered,autonomous security robot designed for outdoor surveillance in large or remote areas having 360-degree cameras and AI-powered oriented detection(NVIDIA,TX2) and was launched in November 2016.

Figure 2: SMP Robotics S5s

7. TerraSmart: for hands-off help with land surveying,ground mounded solar solution uses its Autonomous Precision Survey Rover(APSR).
8. Solar powered cars: examples like Hyundai Sonata Hybrid,Toyota Prius Prime,Fisker Ocean and Lightyear 0 imbibes the innovation of solar roof and solar panels for eco-friendly transportation.
9. Sukhig Solar street light: are a popular line of “All in One” outdoor lighting solutions in Nigeria, popular for merging the LED light source,solar panel and battery into a single unit with IP65 waterproof,and equipped with motion sensors which dim to 30% when no motion is detected to save power

Figure 3:Sukhig solar street light

10. Terrahaptix drones: is a Nigerian defence tech company that gives autonomous AI powered drone defence and kallon solar sentry tower using Artemis OS founded by Nathan Nwachuku and Maxwell Maduka.

2.3 Analog circuit techniques in Robotics

Generally,it lays the groundwork for most robotics system,which will definitely include the sensor interfacing,type of micro controllers used,actuators,embedded systems,voltage divider circuits that match with the micro controllers.

2.3.1 Signal conditioning circuits

Sensor signals used in robotics often requires comparators/level shifting,amplifying and filtering to operate with what the micro-controllers ADC expects. Filters like the LCL filter,EMI/RFI filters(examples of low-pass filters)are used to reduce sound interference made by environmental and signal changes corresponding to the sun changes or the sensors that compare varying light intensity and respond accurately.

2.3.2 Sensor Interfacing Circuits

Light dependent resistors LDRs, phototransistors and photodiodes includes light,temperature,pressure and position sensors ,produce analog signals that vary continuously with physical parameters i.e as light intensity increase,their resistance decrease and a dual axis sensor is needed since a single axis sensor will only tell if there is light or not.

2.3.3 Voltage Divider Circuits

While using the ARDUINO interface,it is to be noted that it reads voltage not resistance because the circuit converts resistance change of LDR to voltage change. The LDR is connected in series with a fixed resistor (around $10k\Omega$ to $100k\Omega$) to form a voltage divider.

2.4 Micro-controller Selection and Justification

Picking and implementing a micro-controller for any project is already dependent on the type of project,most especially in this sun tracking solar panel. Compatibility of multiple factors like processing speed,ADC resolution,rate of power supply and availability of physical components to be used. Types of micro-controller options to select depending on the project include:

Arduino platform(ATmega328P): In Arduino Uno,especially for this solar panel project,ATmega328P was the chosen because its readily available and its 10-bit ADC gives 1024 discrete levels,also with approximately 5mV resolution of 5V reference.

Figure 4:Arduino Platform (ATmega328p**)**

Arduino Mega 2560(ATmega2560): Its used for complex dual-axis projects having multiple sensors. It features 16 Analog input pins A0 to A15 and has a 10-bit resolution.

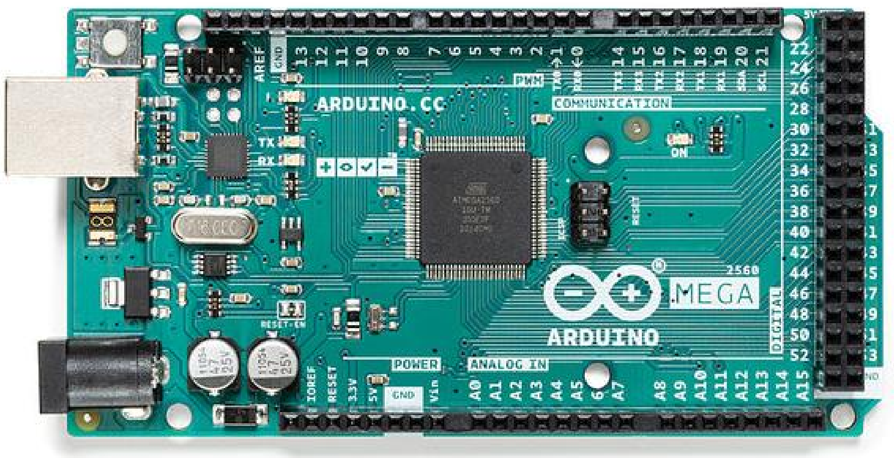

Figure 5: Arduino Mega 2560(ATmega2560)

ESP32 Development boards: It provides 12-bit ADC resolution,dual core processing and WiFi/Bluetooth option for IoT integration. The higher ADC then gives 1.2mV steps with 5V reference to increase its light measuring capacities.

L298N Motor Driver: A dual H bridge motor driver that controls the direction and speed of the DC motors and stepper motors components.It functions with a motor supply voltage of up to 46V and can deliver a current of up to 2A per channel.

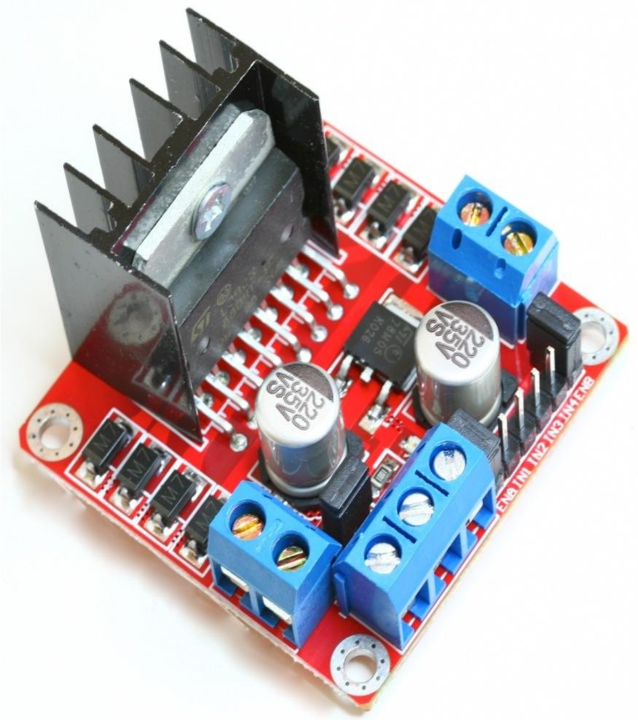

Figure 6:L298N Motor Driver

2.5 Use of Proteus and TinkerCAD in Industry/Education:

In Education,the Proteus Design Suite interface provides PCB layout,micro-controller emulation with analog and digital circuit simulations. Proteus support student with circuit experimentation to eliminate design errors or damaging components. It also helps in Industry to identify the design flaws before carrying out the PCB prototype.

TinkerCAD,by Autodesk,provides a user friendly interface for introduction to Arduino programming. Since its library includes servo motors,photo-resistor and Arduino boards for 3D simulations,there is an opportunity to switch from 3D editor to a circuit view.

2.6 PCB design trend in robotics:

Printed Circuit Board are a reliable system to achieve optimal performance. It provides multi layer board construction,Analog-digital partitioning,thermal management and a design interface for testing and debugging. The PCB designs are used to reduce signal inteference when comparing with temporary breadboard connections.

2.7 Research gap identifications

1. Array Technologies Inc **:** recognized for its single-axis solar panels(e.g DuraTrack HZ,OmniTrack system)was founded by CEO Ron Corio in Albuquerque in 1989.
2. 1767: swiss scientist Horace de Saussure was credited with the world first solar collector
3. 1839: French scientist Edmond Becquerel discovers the photovoltaic effect while experimenting with an electrolyte cell made up of two metal electrode placed in an electricity-conducting solution. Electricity generation increased when exposed to light.
4. 1876: William Grylls Adams and Richard Evans Day discover that selenium produces electricity when exposed to light.Although selenium solar panel failed to convert enough sunlight to power electrical system,they proved that a solid material could change light into electricity without heat or moving parts.
5. 1880: Samuel p. Langley,invents the bolometer,which is used to measure light from the faintest stars and the suns heat rays.
6. 1964: NASA launches the first Nimbus spacecraft--a satellite powered by a 470-watt photovoltaic array.
7. 2000s: Advances in silicon photovoltaic manufacturing in countries like China and climate change around this era was seen as a benefit.
8. 2010s: Passivated Emmiter Rear Cell increased in efficiency with a seemingly reasonable increase in cost.Also Floatovoltaics was introduces to reduce land use and increase natural cooling.
9. Future possible works: China could build an experimental space solar power station by 2030, and construct a commercially viable space power station that will be capable of generating 10kilowatts and carry a solar cell array and test power transmission across distance of 400 kilometers from orbit.

CHAPTER 3

METHODOLOGY

3.1 System block diagram

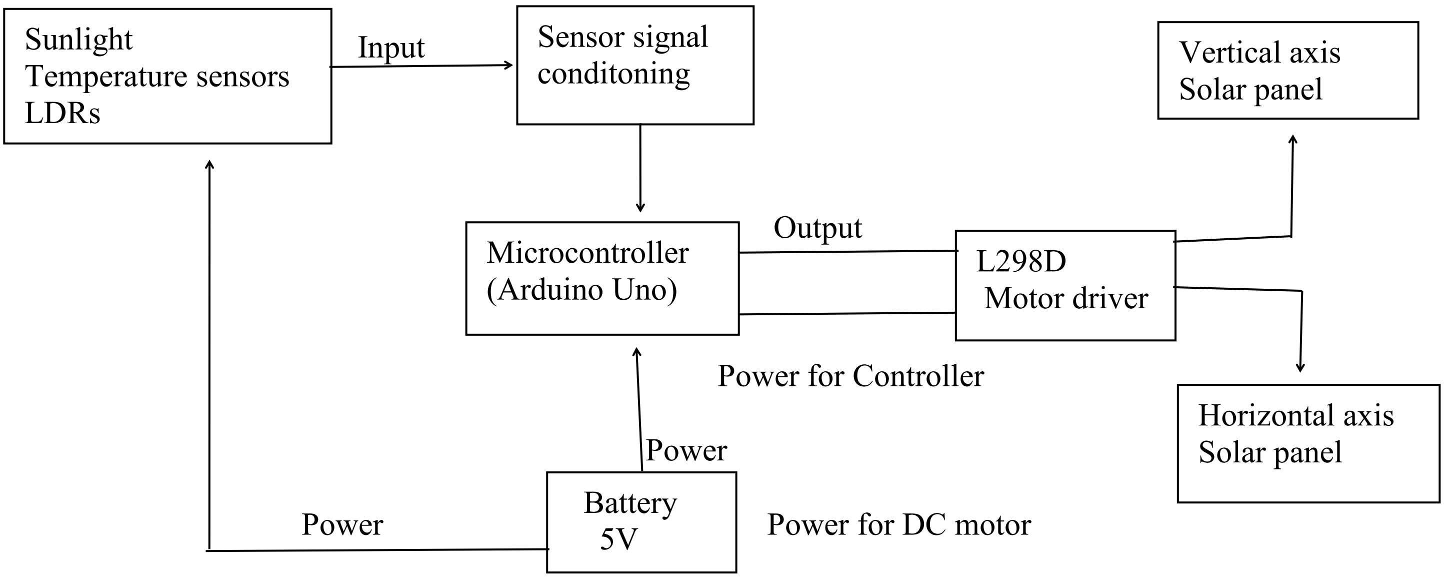

Figure 7: Block diagram of the sun tracking solar panel

3.2 Hardware Design

3.2.1 Analog circuit design

The analog circuit design is done based on the voltage divider circuit formed after using LDRs and photo-resistors. The LDRs is paired with about a 10kΩ fixed resistor to form the voltage divider circuits. If the midpoint of the divider gives an analog voltage proportional to the incident light intensity,then the voltage is supplied to the analog input pins of the Arduino Uno give effective sensitivity while maintaining stability.

As light intensity increases,the resistance of an LDR decreases to give a balance in voltage output. If the voltage level is within the range with the micro-controller should handle(0-5v),it enables accurate prediction of the suns movement and minimize noise.

3.2.2 Micro controller selection & Pin mapping

The ATmega328P on our Arduino uno was selected because its readily available and its 10-bit ADC gives 1024 discrete levels,multiple digital I/O pins and balance of analog input and PWM output for servo motor control.

Pin mapping used in the system

Component	Arduino Pin
LDR Sensor Output	A0
Servo Motor Signal	D9
Power Supply	5V
Ground	GND

This pin configuration allows accurate data transfer from the sensors and precise control of the servo motor using Pulse Width Modulation (PWM).

3.2.3 Complete Schematic in Proteus

This project circuit schematic (sun-tracking solar panel system) was created and simulated using Proteus Design Suite. This combines the ATmega328P, LDR sensors, resistors,actuators,servo motors, and power supply.
The Proteus interface ensures it was properly written,power was distributed accurately and signal flow was verified before running out the physical prototype.

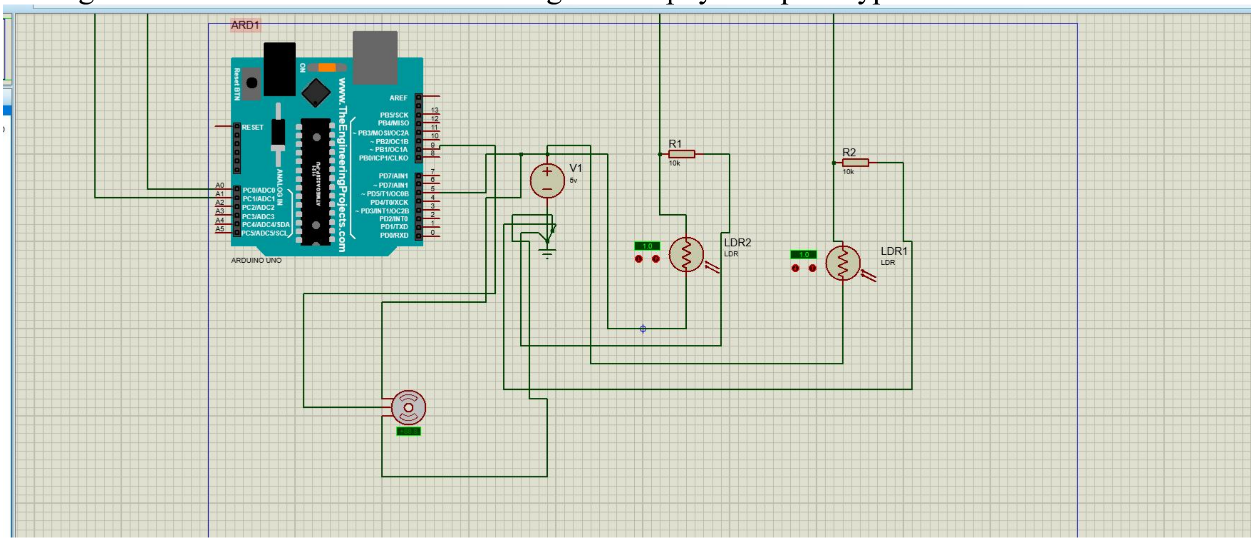

Figure 8:Complete Schematic in Proteus

3.2.5 TinkerCAD 3D Simulation

Since Proteus and tinkerCAD were stated to be used in the project,TinkerCAD on this section was used test the system in a 3D virtual environment. TinkerCAD provides a representation of how the Arduino uno board,server motors,connecting wires,photo-resistors and breadboard.
The successful simulation proves that the hardware and the Arduino uno components can interact,and also proves this point when the servo motors respond to light intensity changes.

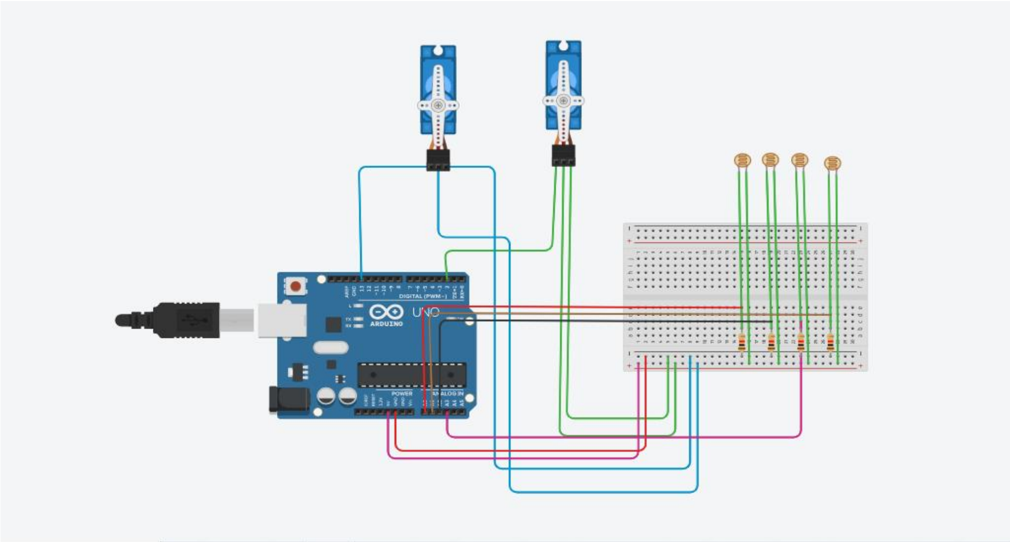

Figure 9: Diagram of the TinkerCAD circuit

3.3 PCB Designs

The circuit was converted into a PCB layout using Proteus ARES.

Routing: Trace widths for the power lines (5V and GND) were kept wider than signal traces to handle the current drawn by the servos.

Outputs: Gerber files were prompted out to carry out physical prototyping.

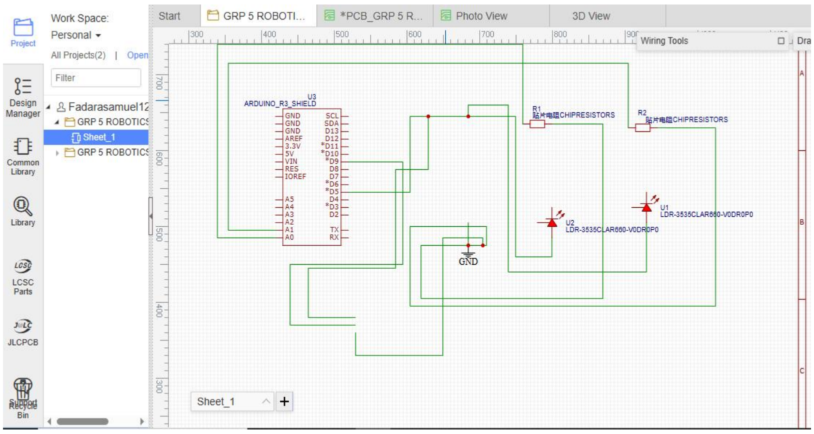

Figure 10: Schematic Diagram of the PCB

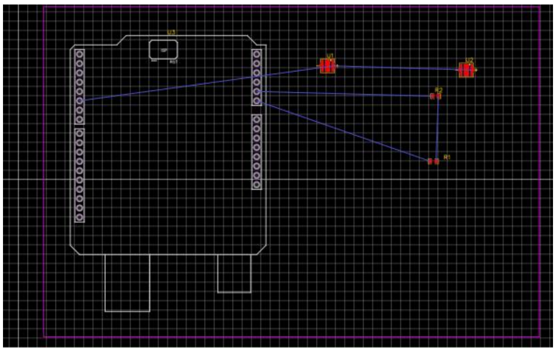

Figure 11: Diagram of the 2D PCB Design

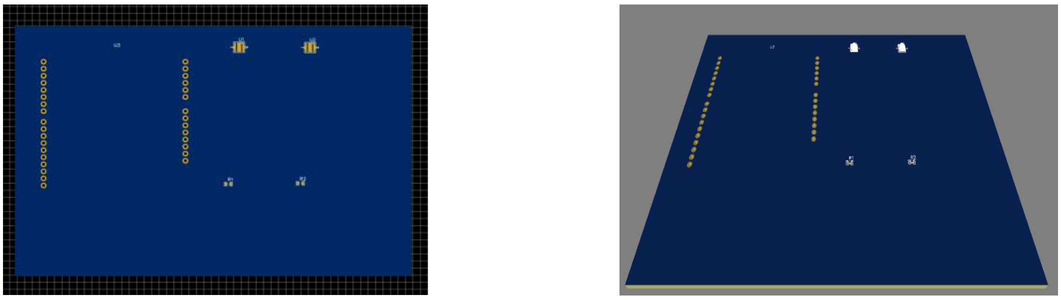

Figure 12: Diagram of the 3D PCB Design

3.4 Software Development

The algorithm for the sun-tracking solar panel project was done using the Arduino Integrated Development Environment (IDE). The program reads analog voltage values provided by the LDR sensors, then processes the data given, and generates PWM signals to operate the servo motors.

The software logic aims to provide reliable and continuous monitoring of the sun by mapping sensor readings to appropriate servo angles. The flowchart showing the software operation is given, and so is the complete Arduino source code down in the Appendix.

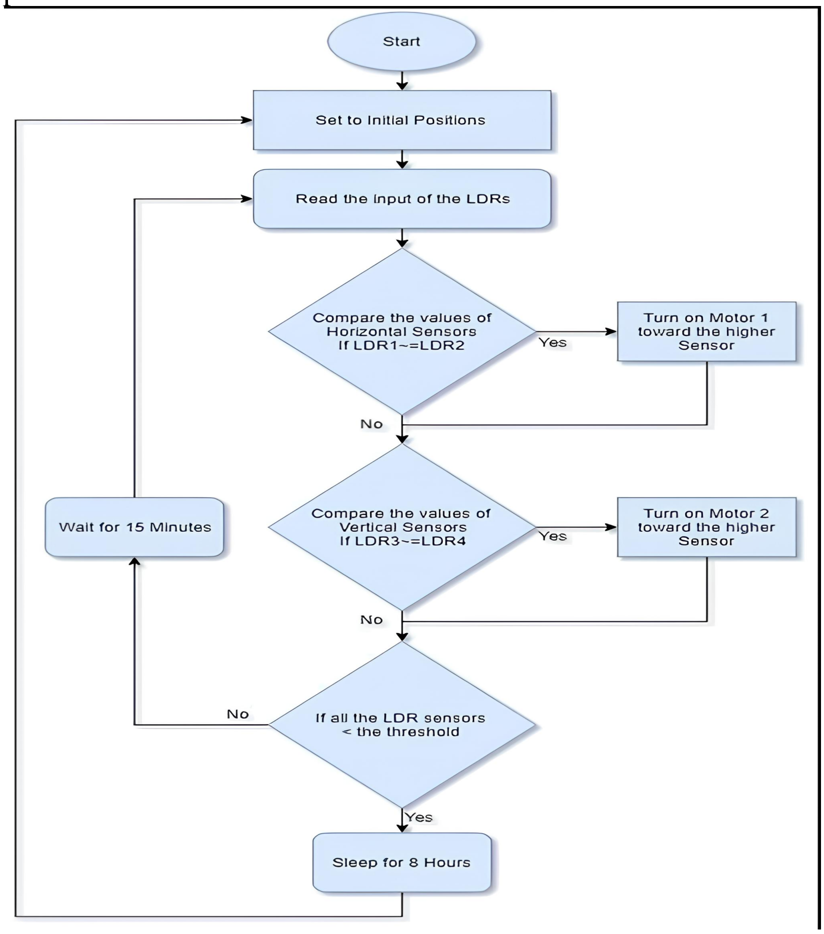

Figure 13:Flowchart diagram of the Sun tracking solar panel

3.5 Prototype Development

The prototype is currently under work and aims to ensure components on the breadboard are combined and integrated with the Arduino Uno micro-controller. After the LDR sensors were positioned to detect incoming light rays,the servo motor was placed to enable rotational movement of the solar panel.
The physical development follows the same designs that was observed during previous simulations.

3.6 Testing and Validation Procedure

The prototype testing was carried out under varying light conditions to evaluate its efficiency and accuracy. Different light sources from several angles were used to simulate the suns daily movement. The servo motor’s response time, angular displacement, and stability were observed, further tested and recorded.
The results from the tests showed that the system consistently moved the panel toward the direction of higher light intensity, henceforth,proving the effectiveness of the design.

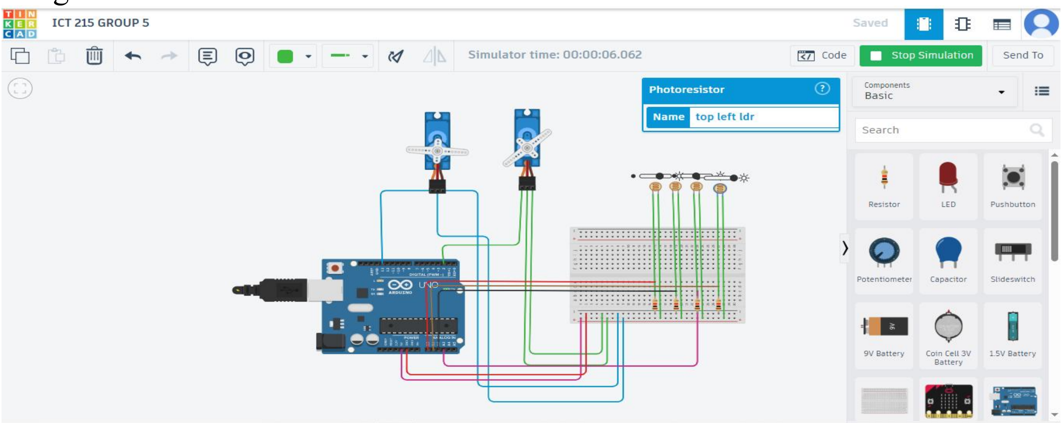

Figure 14: Screenshot of simulation in TinkerCAD

3.7 Ethical and Safety Considerations

Safety considerations were observed throughout the design and testing process. Accurate voltage levels were maintained to prevent component damage. Servo limits were monitored in the code to prevent the panel from hitting the base.Testing was also carried out in a conducive environment. Ethically, the project was carried out following due procedures, and external resources such as academic articles,web pages visited,global news in the solar energy sector and tutorial videos were properly referenced.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Simulation Results

This sun-tracking solar panel project was simulated using Proteus and TinkerCAD to predict the functionality of the servo motor, stability of panels when automatically adjusting, and actuation units. All the simulation carried out were to confirm if the system can accurately detect various in light intensity and adjust the position of the solar panel accordingly.

In the Proteus simulation, light-dependent resistors LDRs were exposed different light sources,mainly the sun,then equipment's like a flashlight,a controlled fire source and LED bulbs to represent the difference in the suns intensity across the sky. The results of the voltage differences from the LDR voltage divider circuits were then read by the Arduino Uno's analog input pins. Based on these results, the micro controller followed up with appropriate pulse-width modulation (PWM) signals to operate the servo motor.

The servo motor also concurred with these results by adjusting the panels in the direction of higher light intensity,and then completely facing the position of that light source. The simulation proved that the control logic implemented in the Arduino program functioned as intended.

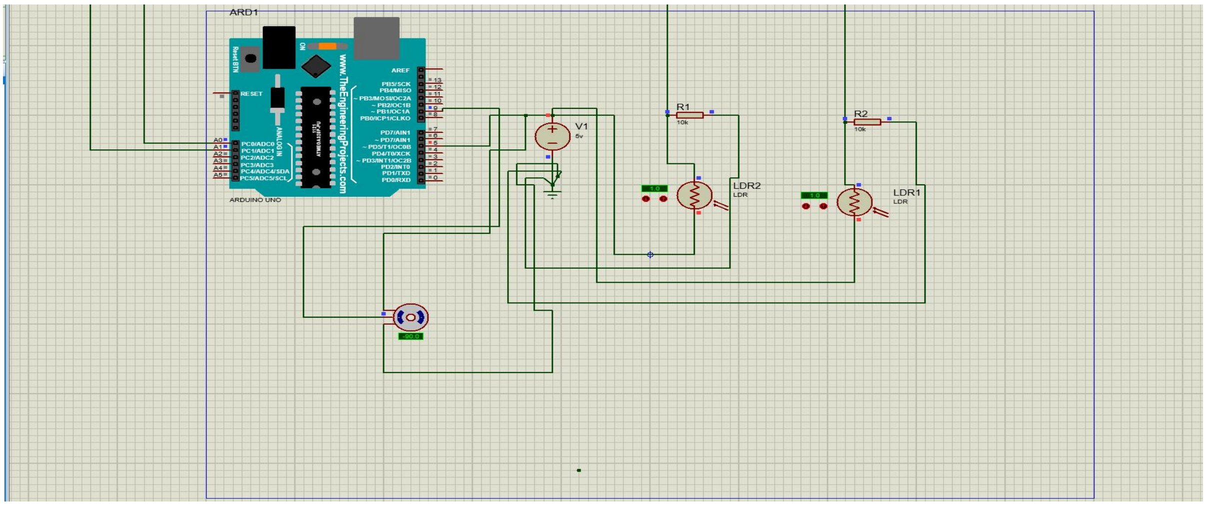

Figure 15:Simulation Results

4.2 Hardware Results

A physical prototype of the sun-tracking solar panel project was tested and confirmed through simulation-based hardware modeling in TinkerCAD. The Arduino Uno, servo motor, and LDR sensors were connected based on how the circuit diagram was represented.

When light ray on one LDR of the system exceeded the other, the servo motor adjusted the panel toward the brighter side. This demonstrated that the system could automatically track the sun's movement in real time. The servo motor operated on smooth angular movement, ensuring accurate fixing of the solar panel.

Although full outdoor field testing were in later conducted within the objective listed in this project, the observed behavior of the system during simulation and testing already closely represents expected actual performance.

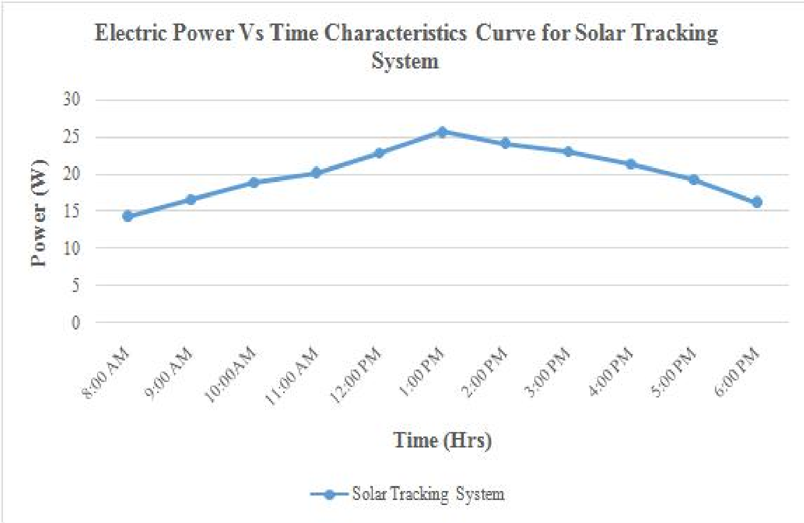

Figure 16: Graph of simulated results

4.3 PCB Performance Comparison

A preliminary Printed Circuit Board (PCB) layout was designed using Proteus ARES to visualize component placement and routing for future hardware implementation. The PCB design aimed to reduce wiring complexity, improve system reliability, and enhance portability.
When compared to breadboard-based connections, the PCB layout offers:
Better mechanical stability
Reduced signal noise
Improved organization of components
While PCB fabrication and physical testing were not carried out, the designed layout demonstrates feasibility for future development and mass production of the system.

4.4 Discussion of Findings

The results obtained from the simulations concludes that the sun-tracking solar panel project effectively improves the solar panel solar panel by adjusting to the light source when compared to a fixed-position panel. By continuously adjusting where the panel faces,the system captures more solar energy to convert to usable energy.

The use of LDR sensors provides a simple and cost-effective method for finding out where the sun faces the most.The Arduino Uno proved to be an efficient control unit, handling sensor data and servo motor control with minimal computational overhead.

Simulation results also signifies the need of proper sensor placement and assessment to ensure accurate monitoring. Minor delays that may be observed in servo response are normal for solar tracking applications,as the suns movement will be relatively slow when working in long-term.

4.5 Problems Encountered and Solutions

Several challenges were encountered during the design and simulation stages of the project:

Problem 1: Difficulty in connecting servo motor pins in Proteus.
Solution: Correct identification of servo control, power, and ground pins and proper use of Arduino PWM pins resolved the issue.

Problem 2: Initial instability in servo movement.
Solution: Adjustment of control logic and proper PWM signal configuration ensured. smooth servo operation.

Problem 3: Limited access to physical hardware for extended testing.
Solution: Extensive use of Proteus and TinkerCAD simulations was employed to validate system behavior before physical implementation.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Summary of Findings

The objective of this project which is to develop a sun tracking solar panel have proven successful. The system used light-dependent resistors (LDRs) to detect changes in sunlight intensity and a servo motor to adjust the direction of the solar panel accordingly.

Simulation results obtained from Proteus and TinkerCAD confirmed that the system could accurately detect the direction of an increased light ray and adjust the solar panel to face that light source. Also,using analog voltage divider circuits showed effective sensor interfacing, while the micro-controller processed sensor inputs and implemented appropriate control signals for actuation.

This results also proved that a sun-tracking system produced more efficiency when compared with a fixed positioned solar panel, thereby leading to more solar energy being captured to turn into power.

5.2 Conclusion

In conclusion, the sun-tracking solar panel system developed in this project met up with its previously stated objectives. The integration of sensors, micro-controller programming,embedded systems and actuation mechanisms resulted in a properly functional system.

The use of simulation tools such as Proteus and TinkerCAD proved effective in verifying the design before its physical prototyping. The project demonstrates how a low-cost and simple sun-tracking solar panel can be designed using readily available components, making it applicable for educational and small-scale renewable energy operations.

This work highlights the importance of automation and embedded systems in improving renewable energy efficiency and provides a strong foundation for further research and development.

5.3 Reccomendations

1. Future students may use ESP32 since it offers WiFi and Bluetooth connections,and may also make use of its deep sleep modes consuming microamps and waking periodically to send data.
2. Investors in solar farm operations should adopt solar panels in their agricultural operations,placing solar panels in their extra land area,for irrigation purposes.
3. Investment in solar energy should be made in the defence sectors,for powering drones and running their surveillance towers on solar energy.
4. Future projects involving production of robots should make use of solar panels to store its energy when the robot is not active.

5.4 Contribution to Knowledge

This project contributes to knowledge by demonstrating a practical approach to designing and simulating a sun-tracking solar panel system using accessible tools and components. It provides a clear methodology that can be adopted by students and researchers for learning embedded systems, renewable energy integration, and robotic automation.

The combination of analog sensor interfacing, micro-controller control, and simulation-based validation serves as a useful reference for future academic and practical projects.

5.5 Limitations

Despite the successful implementation, the project has certain limitations. The system utilizes a single-axis tracking mechanism, which does not fully account for seasonal variations in the sun's position. Testing was conducted over a limited period and under controlled conditions, which may not fully represent long-term outdoor performance. In addition, the system is designed for small-scale applications and may require further optimization for larger installations.

5.6 Suggestions for Future Work

Future work may focus on improving system efficiency and scalability. Possible areas for further development include integrating dual-axis tracking, implementing wireless monitoring of system performance, and incorporating artificial intelligence algorithms for predictive sun positioning. Expanding the system for higher power applications and long-term field testing would also provide valuable insights into its practical deployment.

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Link for making physical solar panel
https://youtu.be/EOLdA2JJt60?si=o-ucPUsLgWa2ooDU

Link for making actual project in tinkercad
https://www.youtube.com/watch?v=EOLdA2JJt60

Link for single axis design
https://youtu.be/-AFaAyk2Sa0

APPENDICES

COMPLETE ARDUINO CODE

```
// Motor enable pins
int EN1 = 9;
int EN2 = 10;

// Motor control pins
int IN1 = 2;
int IN2 = 3;
int IN3 = 4;
int IN4 = 5;

// Potentiometers
int potFB = A0; // Forward / Backward
int potLR = A1; // Left / Right

void setup() {
 pinMode(EN1, OUTPUT);
 pinMode(EN2, OUTPUT);
 pinMode(IN1, OUTPUT);
 pinMode(IN2, OUTPUT);
 pinMode(IN3, OUTPUT);
 pinMode(IN4, OUTPUT);

 digitalWrite(EN1, HIGH);
 digitalWrite(EN2, HIGH);
}

void loop() {
 int fb = analogRead(potFB);
 int lr = analogRead(potLR);

 // STOP by default
 digitalWrite(IN1, LOW);
```

```
  digitalWrite(IN2, LOW);
  digitalWrite(IN3, LOW);
  digitalWrite(IN4, LOW);
    // FORWARD
  if (fb > 650) {
    digitalWrite(IN1, HIGH);
    digitalWrite(IN2, LOW);
    digitalWrite(IN3, HIGH);
    digitalWrite(IN4, LOW);
  }

  // BACKWARD
  else if (fb < 350) {
    digitalWrite(IN1, LOW);
    digitalWrite(IN2, HIGH);
    digitalWrite(IN3, LOW);
    digitalWrite(IN4, HIGH);
  }

  // TURN RIGHT
  else if (lr > 650) {
    digitalWrite(IN1, HIGH);
    digitalWrite(IN2, LOW);
    digitalWrite(IN3, LOW);
    digitalWrite(IN4, LOW);
  }

  // TURN LEFT
  else if (lr < 350) {
    digitalWrite(IN1, LOW);
    digitalWrite(IN2, LOW);
    digitalWrite(IN3, HIGH);
    digitalWrite(IN4, LOW);
  }

  delay(50);
}
```

Simulation result (servo rotated to 90 , where sun is more concentrated)
Pure simulation