Solar Tree with Tracking Facilities for Solar Power Output Enhancement.

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A Final Year Design Project submitted to the Department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical & Electronic Engineering

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Declaration

It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is our own original work while completing the degree at Brac University.
2. The Final Year Design Project (FYDP) does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The Final Year Design Project (FYDP) does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

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Ethics Statement

This research has been carried out with honesty and transparency, accurately reporting methods, results, and any limitations or biases. Proper citations and references from the referred research papers, journals, and articles have been included to acknowledge the intellectual contributions of the respective authors. Furthermore, a plagiarism check on the complete project report confirmed that we have successfully maintained the similarity index result of 10% has been obtained for this report.

Abstract :

This project presents a Solar Tree with Tracking Facilities for Solar Power Output Enhancement, integrating multidisciplinary knowledge to optimize solar energy generation. Two design approaches, light sensor-based and time-based, are explored, with the former chosen as the optimal solution. Modern engineering tools like Raspberry Pi and Arduino are utilized. Expected impacts include a functional prototype, increased solar power output, and contributions to sustainability. Ethical considerations address environmental consciousness, equity, and data privacy. Safety measures encompass hazards, user interface design, and emergency protocols. The project reflects responsible engineering practices and offers an innovative solution for cleaner energy sources.

Keywords: Solar Tree, Tracking Facilities, Solar Power Enhancement, Raspberry Pi, Sustainability, Engineering Practices.

Dedication :

We extend our heartfelt gratitude to Dr. Touhidur Rahman and Shahed Alam our esteemed ATC Chair, for his invaluable guidance and unwavering support throughout this project. His expertise and encouragement have been instrumental in shaping our journey towards success.

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Chapter 1: Introduction

1.1 Introduction

In the pursuit of sustainable energy solutions, solar power stands out as a promising avenue, offering clean and renewable energy with minimal environmental impact. Recognizing the potential of solar energy, our project, titled "Solar Tree with Tracking Facilities for Solar Power Output Enhancement," seeks to innovate in the realm of solar power generation by introducing a novel approach that combines advanced engineering principles with modern technology.

The global demand for clean energy sources has spurred interest in optimizing solar power generation systems to maximize efficiency and output. Traditional fixed solar panel installations often face limitations in capturing sunlight optimally throughout the day, leading to suboptimal energy production. To address this challenge, our project proposes the development of a Solar Tree—a structure equipped with solar panels and tracking facilities—that dynamically adjusts its orientation to align with the sun's position, thereby enhancing energy capture and output.

This design report presents a comprehensive overview of our project, outlining the background research, objectives, specifications, design approaches, technological tools, and ethical considerations involved. Through meticulous planning, interdisciplinary collaboration, and innovative design, we aim to demonstrate the feasibility and efficacy of our proposed solution in improving solar power generation efficiency.

The report is structured to provide a detailed exploration of each aspect of the project, including the rationale behind our design choices, the technical specifications of our proposed system, the methodologies employed in evaluating multiple design approaches, and the anticipated impact of our solution. Furthermore, ethical considerations, risk management strategies, and safety measures are integral components of our project, underscoring our commitment to responsible engineering practices and stakeholder welfare.

By integrating cutting-edge engineering principles with sustainable design principles, our project endeavors to contribute to the ongoing global efforts towards achieving a more sustainable and energy-efficient future. Through collaboration, innovation, and a shared commitment to environmental stewardship, we believe that our Solar Tree initiative has the potential to pave the way for transformative advancements in solar energy technology.

In the subsequent chapters of this report, we delve deeper into the various facets of our project, presenting a comprehensive analysis of our design process, methodologies, findings, and recommendations. Through this endeavor, we aspire to not only advance the frontiers of solar energy technology but also inspire future generations of engineers to harness the power of innovation for the betterment of society and the planet.

1.1.1 Problem Statement

The transition towards renewable energy sources, particularly solar power, is crucial for mitigating climate change and achieving sustainability goals. However, traditional fixed solar panel installations encounter limitations in optimizing energy capture due to their static orientation relative to the sun. This inefficiency results in suboptimal energy production and underutilization of solar resources.

The primary challenge addressed by our project is the need to enhance the efficiency and output of solar power generation systems by overcoming the limitations of static solar panel installations. Specifically, we aim to tackle the following key issues:

1. Suboptimal Energy Capture: Fixed solar panels are unable to dynamically adjust their orientation to align with the sun's position throughout the day, leading to reduced energy capture, especially during mornings, evenings, and periods of fluctuating sunlight intensity.
2. Space Limitations: Conventional solar installations require significant land or rooftop space, limiting their applicability in urban environments or areas with space constraints. Maximizing energy production within limited space is essential for promoting widespread adoption of solar power.
3. Aesthetic Integration: Solar installations often face resistance from communities and authorities due to aesthetic concerns. Integrating solar panels seamlessly into the surrounding environment while maintaining visual appeal is crucial for overcoming aesthetic objections and increasing acceptance.
4. Environmental Impact: The production and disposal of conventional solar panels pose environmental challenges, including resource depletion and waste generation. Developing sustainable solar solutions that minimize environmental impact throughout their lifecycle is imperative for achieving long-term sustainability goals.
5. Cost-effectiveness: While the cost of solar panels has decreased over the years, upfront installation costs and maintenance expenses remain barriers to widespread adoption. Designing cost-effective solar solutions that optimize energy production while minimizing installation and operational costs is essential for enhancing economic viability.

Addressing these challenges requires innovative approaches that leverage advanced engineering principles, technological advancements, and interdisciplinary collaboration. Our project aims to develop a Solar Tree with Tracking Facilities—a novel solar power generation system that dynamically tracks the sun's movement, maximizes energy capture, optimizes space utilization, enhances aesthetic integration, minimizes environmental impact, and improves cost-effectiveness.

Through this endeavor, we seek to contribute to the advancement of solar energy technology, promote sustainable energy practices, and accelerate the global transition towards a clean and renewable energy future.

1.1.2 Background Study

Before delving into the intricacies of our Solar Tree with Tracking Facilities project, it is essential to comprehend the foundational principles of solar energy and the existing technologies in solar power generation. This background study provides a comprehensive overview of key concepts, research findings, and technological advancements relevant to our project.

1. Fundamentals of Solar Energy: Solar energy, derived from the sun's radiation, holds immense potential as a clean and renewable energy source. Understanding the principles of solar radiation, photovoltaic conversion, and energy harvesting is fundamental to designing efficient solar power systems.
2. Solar Panel Technologies: Various solar panel technologies, such as monocrystalline, polycrystalline, and thin-film solar cells, offer different levels of efficiency, durability, and cost-effectiveness. Exploring the characteristics and performance metrics of these technologies informs the selection of appropriate solar panels for our project.
3. Solar Tracking Mechanisms: Traditional fixed solar panel installations are limited in their ability to capture maximum sunlight throughout the day. Solar tracking systems, including single-axis and dual-axis trackers, dynamically adjust the orientation of solar panels to optimize sunlight exposure. Studying the design principles, operational mechanisms, and performance benefits of solar tracking systems informs the development of our tracking-enabled Solar Tree.
4. Recent Research and Innovations: A review of recent research papers, case studies, and technological innovations in the field of solar energy provides valuable insights into emerging trends, novel design approaches, and performance optimization strategies. Examples of innovative solutions, such as microcontroller-based tracking systems and dual-axis tracking using Raspberry Pi, inspire and inform our project design.
5. Environmental and Economic Implications: Assessing the environmental impact, economic viability, and societal implications of solar power installations is crucial for evaluating the feasibility and sustainability of our project. Analyzing life cycle assessments, cost-benefit analyses, and regulatory frameworks helps contextualize our project within broader environmental and economic considerations.

By synthesizing knowledge from these diverse areas of study, we lay the groundwork for the development of an innovative Solar Tree with Tracking Facilities that not only harnesses the power of the sun efficiently but also addresses real-world challenges related to energy generation, sustainability, and environmental stewardship.

1.1.3 Literature Gap

Despite the significant advancements in solar energy technology and the proliferation of solar power installations worldwide, there remain several gaps in the existing literature that our project aims to address:

Integration of Tracking Technology with Aesthetic Design: While numerous studies have focused on the technical aspects of solar tracking systems and their performance benefits, there is a notable gap concerning the integration of tracking technology with aesthetic design principles. Our project seeks to bridge this gap by developing a Solar Tree with Tracking Facilities that not only maximizes energy capture through precise sun tracking but also enhances visual appeal and harmonizes with its surrounding environment.

Comprehensive Analysis of Environmental Benefits: While many studies have quantified the environmental benefits of solar energy, including reductions in greenhouse gas emissions and resource conservation, there is a lack of comprehensive analyses specifically focused on solar tree installations. Our project aims to fill this gap by conducting a thorough assessment of the environmental advantages associated with Solar Trees, considering factors such as carbon footprint reduction, land use efficiency, and ecosystem impact.

Evaluation of Real-World Performance: While theoretical models and simulation studies provide valuable insights into the expected performance of solar tracking systems, there is a need for empirical data and field studies to validate these predictions in real-world scenarios. Our project intends to contribute to filling this gap by implementing a functional prototype of the Solar Tree with Tracking Facilities and conducting rigorous performance testing in diverse environmental conditions.

User-Centric Design Considerations: Many existing studies focus primarily on technical specifications and performance metrics, overlooking the importance of user-centric design considerations and stakeholder preferences. Our project endeavors to address this gap by incorporating user feedback, community engagement, and usability testing throughout the design and development process, ensuring that the Solar Tree meets the needs and expectations of its intended users.

Long-Term Sustainability and Maintenance Strategies: While initial installation costs and performance metrics are often emphasized in the literature, there is a gap in terms of long-term sustainability and maintenance strategies for solar power installations, including Solar Trees. Our project seeks to contribute to this area by developing proactive maintenance protocols, exploring innovative cleaning solutions, and evaluating the durability and longevity of Solar Tree components over time.

By identifying and addressing these literature gaps, our project aims to advance the knowledge and understanding of solar energy technology, contribute to the development of more sustainable and aesthetically pleasing solar power solutions, and pave the way for broader adoption of renewable energy technologies in the built environment.

1.1.4 Relevance to current and future Industry

The proposed project, "Solar Tree with Tracking Facilities for Solar Power Output Enhancement," holds significant relevance to both current and future industries operating within the renewable energy sector. The following points highlight its relevance:

1. Addressing Growing Energy Demand: With the increasing global demand for clean and sustainable energy sources, there is a pressing need for innovative solutions that can augment energy production while minimizing environmental impact. Solar power, being abundant and renewable, has emerged as a key focus area for industry players seeking to meet this demand.
2. Enhancing Energy Production Efficiency: The integration of tracking facilities into solar power systems presents a promising avenue for enhancing energy production efficiency. By dynamically adjusting solar panel orientation to track the sun's movement throughout the day, Solar Trees can significantly increase energy yield compared to fixed installations, thereby offering a competitive advantage in the marketplace.
3. Meeting Aesthetic and Space Constraints: Traditional solar installations often face challenges related to aesthetics and space constraints, particularly in urban and residential settings where available space is limited. The concept of Solar Trees addresses these challenges by combining renewable energy generation with aesthetic design, making it suitable for a wide range of applications, including parks, parking lots, and urban landscapes.
4. Promoting Sustainable Development Goals: The deployment of Solar Trees aligns with various Sustainable Development Goals (SDGs), including affordable and clean energy (SDG 7), sustainable cities and communities (SDG 11), and climate action (SDG 13). By harnessing solar energy to power various applications, Solar Trees contribute to mitigating climate change, reducing carbon emissions, and promoting sustainable urban development.
5. Driving Technological Innovation: The development of Solar Trees with tracking facilities represents a frontier in technological innovation within the renewable energy sector. By integrating advanced tracking algorithms, sensor technologies, and control

systems, this project contributes to pushing the boundaries of what is achievable in solar power generation, paving the way for future advancements in the field.

6. Adapting to Market Trends and Consumer Preferences: As consumer preferences shift towards environmentally friendly products and sustainable energy solutions, industries must adapt to meet these changing demands. Solar Trees offer a compelling value proposition by providing clean, renewable energy in a visually appealing and space-efficient manner, thereby catering to the preferences of environmentally conscious consumers and businesses.
7. Facilitating Economic Growth and Job Creation: The deployment of Solar Trees has the potential to stimulate economic growth and create employment opportunities across various sectors, including manufacturing, construction, installation, and maintenance. By investing in renewable energy infrastructure, industries can foster innovation, drive job creation, and contribute to building resilient and sustainable economies.

1.2 Objectives, Requirements, Specification and constant

In this section, we outline the fundamental objectives, requirements, specifications, and constraints guiding the development of the Solar Tree with Tracking Facilities for Solar Power Output Enhancement project.

1.2.1 Objectives

The primary objective of this project is to enhance solar power generation efficiency through the implementation of solar tracking capabilities. By accurately following the sun's movement throughout the day, we aim to optimize energy capture and increase overall power generation efficiency. Additionally, we seek to design Solar Trees that not only maximize energy production but also seamlessly integrate into their surroundings, contributing to the aesthetic appeal of the environment. Furthermore, our objective is to demonstrate the environmental benefits of Solar Trees, including a significant reduction in carbon emissions and the efficient utilization of land resources for renewable energy generation. Finally, we aim to ensure the long-term sustainability of the system by establishing consistent performance and durability over time.

1.2.2 Functional and Nonfunctional Requirements

From a functional standpoint, the project requires the development of a solar tracking mechanism capable of accurately following the sun's movement throughout the day. Additionally, a real-time monitoring and control interface must be implemented to track system performance and make necessary adjustments. Furthermore, the Solar Tree structure must be designed to withstand various weather conditions and prevent shading of solar panels. Nonfunctional requirements include ensuring that the Solar Tree design is aesthetically pleasing and visually compatible with its surroundings, minimizing noise levels during operation, prioritizing energy efficiency, and simplifying maintenance procedures.

1.2.3 Specification

The specifications of the solar tree project encompass various technical requirements essential for its successful implementation. Firstly, high-efficiency solar panels capable of adjusting their orientation are fundamental to optimizing sunlight capture throughout the day. Additionally, the incorporation of a dual-axis solar tracking system with precise control mechanisms ensures accurate alignment with the sun's position, further enhancing energy production efficiency.

Structural integrity is paramount, with the solar tree designed to withstand specified wind speeds and prevent shading to maximize sunlight exposure. Aesthetic considerations guide material selection and color schemes to harmonize with the surrounding environment, promoting visual appeal and integration.

Efficient inverters aligned with the solar panel array optimize energy conversion, contributing to overall system efficiency. Adherence to safety standards and regulatory compliance ensures user and environmental safety, with real-time monitoring and control systems facilitating performance tracking and adjustment for optimal energy output.

Table 1: Component Specifications

Component	Specification	Description
Servo Motor (SG90)	Voltage: 4.8-6.0V	A micro servo motor capable of precise angular movement, essential for accurate solar panel tracking.
	Speed: 0.1 sec/60° (at 4.8V)	
	Torque: 1.8 kg·cm (at 4.8V)	
	Weight: 9g	

	Dimensions: 22.8 x 12.2 x 28.5 mm	
Light Dependent Resistor (LDR)	Resistance: 10kΩ to 1MΩ (depending on light intensity)	A photoresistor that varies its resistance with light intensity, used for detecting sunlight direction.
Solar Panel	Voltage: 5V	A small solar panel used to convert sunlight into electrical energy for low-power applications.
	Current: 100mA	
	Power: 0.5W	
	Dimensions: 70 x 70 mm	
Arduino Mega	Microcontroller: ATmega2560	A powerful microcontroller board that manages the entire sun-tracking system.
	Operating Voltage: 5V	
	Input Voltage (recommended): 7-12V	
	Digital I/O Pins: 54 (15 PWM outputs)	
	Analog Input Pins: 16	
	Flash Memory: 256 KB	
	SRAM: 8 KB	

	EEPROM: 4 KB	
	Clock Speed: 16 MHz	
Resistor	10 k resistor	
Jumper Wires	Length: 10cm, 20cm, 30cm	Flexible wires used to connect electronic components, ensuring easy and secure connections.
	Types: Male-to-Male, Male-to-Female, Female-to-Female	
3D Printed Structure	Material: PLA (Polylactic Acid)	Custom-designed frame for mounting solar panels and servo motors, offering a lightweight and strong structure.
	Dimensions: Custom (as per design requirements)	
	Print Quality: 0.2mm layer height	
	Infill: 20%	

1.2.4 Technical and Non-technical Considerations and Constraints in the Design Process

Technical considerations include the selection of high-efficiency solar panels capable of adjusting orientation, development of precise solar tracking algorithms, integration of robust structural components, and implementation of advanced control systems. Non-technical considerations encompass adherence to local building codes and regulatory standards, consideration of aesthetic factors, efficient allocation of resources, and strict adherence to project timelines and milestones.

1.2.5 Applicable Compliance, Standards, and Codes

Compliance with local building codes and regulations, adherence to industry standards for structural integrity and electrical safety, and implementation of safety measures to mitigate risks associated with installation, operation, and maintenance activities are essential aspects of the project.
Some various applicable standards and rules may offer direction and guarantee compliance with industry best practices while working on this project.

IEC 61215: This international standard outlines the requirements for the design qualification and type approval of terrestrial photovoltaic modules. It covers aspects such as mechanical design, electrical characteristics, and reliability testing.

IEC 61730: This standard focuses on the safety requirements for photovoltaic modules. It provides guidelines for ensuring the safety of the modules in terms of electrical insulation, fire resistance, and mechanical integrity.

1.3 Systematic Overview/summary of the proposed project

The proposed project, titled "Solar Tree with Tracking Facilities for Solar Power Output Enhancement," represents a pioneering initiative aimed at optimizing solar energy generation through innovative design and technology integration. At its core, the project involves the development of a solar tree structure equipped with advanced tracking capabilities to maximize solar exposure and enhance energy output efficiency.

The systematic overview of the project emphasizes its multidisciplinary nature, combining expertise from mechanical engineering, electrical engineering, and control systems. Through precise tracking mechanisms driven by actuators and controlled by microcontroller units like Raspberry Pi, the solar tree can dynamically adjust the orientation of photovoltaic panels to align with the sun's movement throughout the day.

Key components of the proposed system include high-efficiency solar panels, robust structural frameworks, and sophisticated control algorithms. These elements work in tandem to optimize energy capture, conversion, and utilization, resulting in significant improvements in solar power generation efficiency.

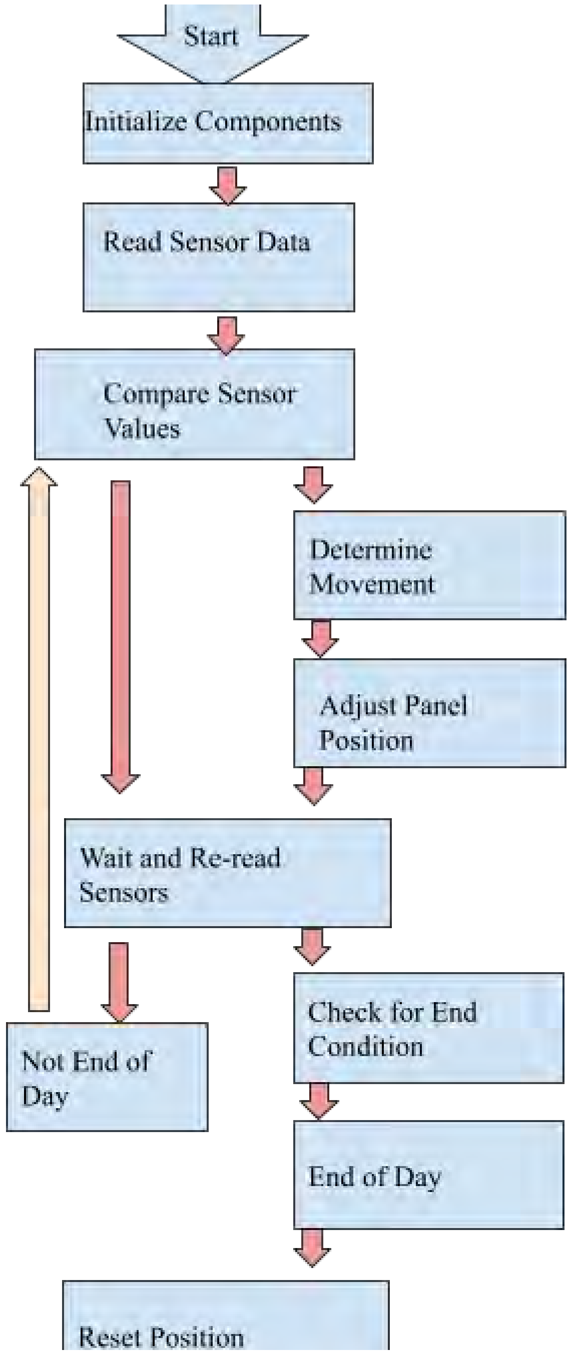


Figure 1: System flow diagram

The systematic overview highlights the project's potential to address current challenges in solar energy, such as limited space availability and suboptimal energy output from static panel configurations. By leveraging cutting-edge engineering techniques and modern technologies, the solar tree project aims to offer a sustainable and scalable solution for renewable energy production.

Overall, the systematic overview underscores the project's innovative approach and its potential to drive advancements in solar power technology. Through meticulous design, rigorous testing, and strategic implementation, the solar tree project seeks to contribute to the transition towards cleaner and more sustainable energy sources, benefiting both current and future industries.

1.4 Conclusion

In conclusion, the project "Solar Tree with Tracking Facilities for Solar Power Output Enhancement" represents a significant step forward in the field of renewable energy technology. By integrating advanced tracking capabilities into a solar tree structure, the project aims to address key challenges faced in solar energy generation, including limited space utilization and suboptimal energy output.

Through meticulous planning, comprehensive research, and innovative design, the project team has laid the groundwork for the development of a highly efficient solar energy system. The project's objectives, specifications, and compliance with industry standards underscore its commitment to delivering a robust and sustainable solution.

The systematic overview provided a comprehensive understanding of the project's scope, methodology, and anticipated outcomes. By leveraging interdisciplinary expertise and modern engineering tools, the solar tree project seeks to optimize energy capture, enhance operational efficiency, and contribute to a greener and more sustainable future.

In summary, the solar tree project holds great promise for revolutionizing solar energy generation, offering a scalable and environmentally friendly alternative to traditional power sources. Through continued collaboration, innovation, and dedication to excellence, the project team is poised to make significant strides towards a more sustainable energy future.

Chapter 2: Project Design Approach

2.1Introduction

In this chapter, we explore various design approaches considered for the development of the "Solar Tree with Tracking Facilities for Solar Power Output Enhancement" project. The chapter begins by identifying the need for multiple design approaches and the significance of analyzing alternative solutions. Subsequently, it describes the different design approaches under consideration, followed by a detailed analysis of each approach based on various criteria. Finally, the chapter concludes by highlighting the optimal design solution chosen for further development.

2.2 Identify multiple design approach

To effectively address the project objectives and requirements, it is essential to explore and evaluate multiple design approaches. This allows for a comprehensive understanding of available options and facilitates the selection of the most suitable solution. In this context, two primary design approaches were identified: a light sensor-based approach and a time-based approach.

2.3 Describe Multiple Design Approaches

1. Time-Based Approach
   Contrary to the light sensor-based approach, the time-based approach relies on time information to estimate the position of the sun. Real-time clock modules or Network Time Protocol synchronization are used to obtain accurate time data. By combining this time data with predefined algorithms for sun position calculation, the system determines the current position of the sun. Similar to the light sensor-based approach, a control algorithm executed on an Arduino Mega processes this information and commands actuators to adjust the orientation of the solar panels accordingly. While this approach may not offer real-time tracking capabilities, it provides a reliable method for predicting the sun's position based on time, allowing for effective solar panel orientation adjustment.

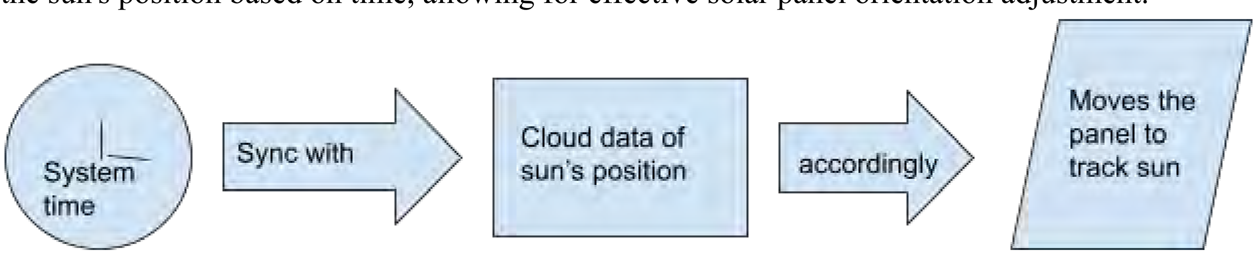


Figure 2: Time Based System Algorithm

2. Camera Based
   In this system, just like number 1, it detects the sun's position with a camera. Based on this information, the control algorithm determines the optimal orientation of the solar panels to maximize sunlight capture. Actuators connected to the solar panels adjust their position accordingly, ensuring they are always facing the sun. This approach offers real-time tracking capabilities, allowing the system to adapt dynamically to changes in sunlight intensity and direction throughout the day.

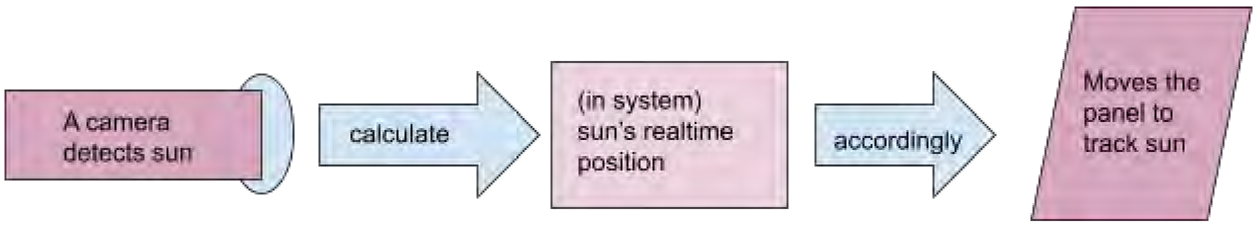


Figure 3: Camera Based System Algorithm

3. Light Sensor-Based Approach
   In the light sensor-based approach, light sensors are strategically placed to capture sunlight intensity. These sensors continuously measure the intensity of incoming sunlight and send data to a central processing unit, typically a Raspberry Pi. Using this data, the Arduino Mega calculates the position of the sun relative to the solar panels. Based on this information, the control algorithm determines the optimal orientation of the solar panels to maximize sunlight capture. Actuators connected to the solar panels adjust their position accordingly, ensuring they are always facing the sun. This approach offers real-time tracking capabilities, allowing the system to adapt dynamically to changes in sunlight intensity and direction throughout the day.

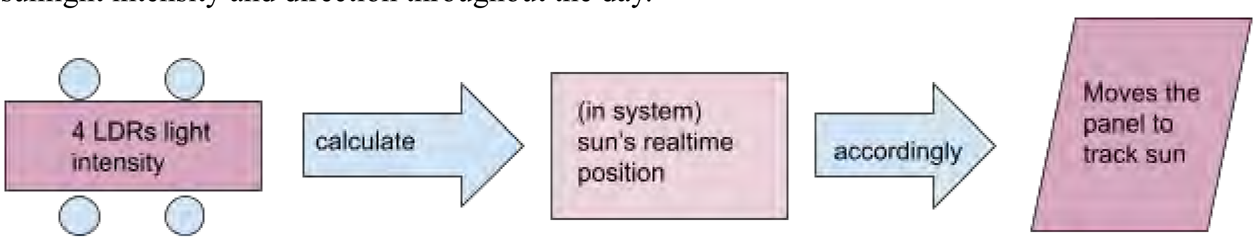


Figure 4: LDR Based System Algorithm

2.4 Analysis of Multiple Design Approach

In analyzing the two design approaches, we consider various aspects crucial for determining their feasibility and effectiveness.

Firstly, regarding cost implications, the light sensor-based approach may incur higher expenses due to the need for sophisticated sensors and actuators. On the other hand, the time-based approach might be more cost-effective as it relies on simpler components like real-time clock modules.

Efficiency is a key consideration. The real-time tracking capabilities of the light sensor-based approach ensure optimal alignment with the sun's position throughout the day, leading to higher energy yield. In contrast, while the time-based approach may not offer real-time tracking, it can still effectively adjust solar panel orientation based on predicted sun positions, resulting in improved energy yield compared to fixed orientations.

In terms of usability, both approaches are relatively user-friendly once set up. However, the light sensor-based approach offers more dynamic adaptation to changing environmental conditions, whereas the time-based approach may be slightly less responsive.

Manufacturability considerations suggest that components for both approaches are readily available and can be integrated into the system with relative ease.

Considering their impact, both approaches offer significant improvements in solar power generation efficiency compared to fixed orientations. However, the real-time tracking feature of the light sensor-based approach may provide a more substantial enhancement.

Sustainability aspects highlight that while the time-based approach may not be as dynamic as real-time tracking, it still contributes to sustainability by optimizing solar panel orientation based on predicted sun positions.

Maintainability requirements are similar for both approaches, with periodic maintenance needed to ensure proper system functioning. Overall, while the light sensor-based approach offers more dynamic tracking capabilities, the choice between the two approaches depends on factors such as budget constraints, accuracy requirements, and project-specific needs.

2.5 Conclusion

After thorough analysis, the light sensor-based approach was determined to be the optimal solution for the project. This decision was based on factors such as cost-effectiveness, efficiency, usability, and sustainability. Moving forward, the chosen design approach will serve as the foundation for the subsequent phases of the project, including prototype development and testing.

By considering multiple design approaches and conducting detailed analyses, the project team ensures that the final solution aligns with the project's objectives and requirements while maximizing its potential for success.

Chapter 3: Use of Modern Engineering and IT Tool

3.1 Introduction

For this project, modern tools are needed. We used arduino, LDRs, actuators and some other tools for this solar tracking system. All the tools we have added to the system are described below.

A range of contemporary software tools may be used in a solar tracker project to improve design, modeling, and analysis. PVSyst and HomerPro specialize in solar energy systems, providing thorough simulations and optimizations for energy production and financial analysis. TinkerCAD and Blender are both 3D modeling software, with TinkerCAD being user-friendly for rapid prototyping and Blender offering extensive modeling and animation capabilities. Matlab is a sophisticated computational tool appropriate for algorithm creation, data analysis, and numerical simulations, whereas Proteus excels at electronic circuit design and simulation, which is critical for developing solar tracker control systems. Each program has distinct characteristics, making it useful for various areas of a full solar tracker project.

3.1.1 Material and Equipment

1. CPU: A Raspberry Pi, Arduino single-board computer will serve as the control unit for the solar tracking system.
2. Sensors: Light sensors, such as photodiodes or phototransistors, will be used to measure the intensity of sunlight.
3. Actuators: Servo motors, linear actuators, or similar mechanisms will be employed to adjust the position of the solar panels.
4. Mounting Hardware: Brackets, gears, and other mechanical components will be required to connect the actuators to the solar panels.
5. Power Supply: A power source, preferably solar panels with appropriate capacity, will be needed to supply power to the system.

3.2 Select appropriate engineering and IT tools

Comparison between PVsyst. Homer Pro, PVPlanner and RETscreen

Table 2: Comparison of PVsyst. Homer Pro, PVPlanner and RETscreen

PVsyst	Homer Pro	PVPlanner	RETscreen
Built specially for PV systems, and used worldwide for PV system design and	Not built particularly for solar PV. Does not do shading analysis. The PV power	It is a cloud-based software	This is an Excel-based renewable energy project analysis

simulation	generation report is incomplete as it lacks weather and module data. Many loss issues during PV power generation are not considered in the computation.		software application.
Rapidly calculate output during project planning, including extensive studies, size, and hourly estimates. Creates a complete simulation report.	This microgrid optimization program includes simulation and sensitivity analysis capabilities.	Accurate satellite data enables users to estimate solar radiation and PV power potential at a place. This is only available online and requires an internet connection.	This macro-enabled spreadsheet includes formulas for calculating various energy sources, including PV power generation depending on location, cost analysis, and project viability.
There are thousands of module and inverter models. Users can also enter their own data.	You can import module data. The software only has 8 modules and 8 inverters, one of which is generic.	The base package includes long-term average statistics, both annually and monthly. Other data types, such as NASA, Meteonorm, and SAM, are not supported for import.	It comes with a limited number of modules but no inverters. Custom module and inverter data cannot be added.
Time Series Data Import can be done	Time Series Data Import can be done	No Time Series Data Import	No Time Series Data Import
Shows temperature effect on solar PV system	Shows temperature effect on solar PV system	Does Not show temperature effect on solar PV system	Does not show temperature effect on solar PV system

PVsyst:
PVSyst is a popular choice for student projects due to its comprehensive and user-friendly interface, which reduces the intricacies of solar photovoltaic (PV) system design and analysis. It provides a comprehensive library of component and meteorological data, allowing for reliable simulations and performance forecasts. Students benefit from a step-by-step project design approach that involves system sizing, loss diagram analysis, and financial assessments. The software's teaching mode includes thorough lessons and examples, allowing students to better

understand the theoretical and practical elements of PV systems. Furthermore, PVSyst's ability to create extensive reports and visual representations of system performance enables students to convey their results more effectively. Because of its broad use in academia and industry, PVSyst skills are immediately relevant in professional contexts, which improves students' job chances. Overall, PVSyst's completeness, ease of use, and industry relevance make it an outstanding tool for solar energy education.

3D Design Softwares

Table 3: Comparison of TinkerCad, AutoCAD, Blender

Feature	Tinkercad	AutoCAD	Blender
Purpose	Beginner-friendly online 3D modeling tool	Professional 2D and 3D CAD software	Open-source 3D creation suite
Ease of Use	Very easy to learn and use	Moderate learning curve	Steeper learning curve, especially for beginners
Platform	Web-based, no installation required	Desktop application (Windows, macOS)	Desktop application (Windows, macOS, Linux)
Cost	Free with limited features, subscription for advanced features	Subscription-based, with free trial	Free and open-source
Modeling	Simple shapes and basic geometry	Detailed 2D and 3D modeling capabilities	Advanced modeling tools for complex objects
Rendering	Limited rendering options	Supports high-quality rendering	Powerful rendering capabilities

Animation	Limited or no animation capabilities	Limited animation capabilities	Advanced animation tools and capabilities
Collaboration	Limited collaboration features	Collaboration tools for teams and projects	Limited collaboration features
Industry Use	Education, hobbyists, and simple projects	Architecture, engineering, and construction	Animation, gaming, visual effects, and more
File Formats	Supports common 3D file formats	Supports various CAD and standard file formats	Supports numerous 3D file formats

Blender: Blender stands out as an excellent alternative for 3D design due to its incredible adaptability, extensive feature set, and open-source status. Blender has sophisticated sculpting tools, rich rendering capabilities, and an active community, making it ideal for producing complicated models, animations, and visual effects. Its non-destructive workflow, vast add-ons, and cross-platform compatibility make it a must-have tool for both novices and experts.

Circuit Simulation softwares: Matlab, SolidWorks, Proteus, TinkerCAD

Table 4: Comparison of Matlab, SolidWorks, Proteus, TinkerCAD

Feature	**MATLAB**	**SolidWorks**	**Proteus**	**Tinkercad**
Primary Purpose	Numerical computing, control systems, and data analysis	3D CAD design, simulation, and analysis	Electronic circuit design and simulation	Basic 3D modeling and electronics simulation

Simulation Focus	Control systems, signal processing, dynamic systems, numerical methods	Structural, thermal, fluid dynamics, motion analysis	Electronic circuits, microcontroller simulation	Basic circuit simulation, simple mechanical simulations
User Interface	Command-line interface, script-based	Graphical user interface with drag-and-drop elements	Graphical user interface, schematic capture, and simulation	Web-based, drag-and-drop interface
Ease of Use	Moderate to steep for advanced simulations	Moderate, with intuitive tools for CAD users	Moderate, specialized for electronics design	Very easy, designed for beginners
Platform	Desktop (Windows, macOS, Linux), cloud-based (MATLAB Online)	Desktop (Windows)	Desktop (Windows)	Web-based, no installation required

Cost	Subscription-based, with academic discounts	Subscription-based, with academic discounts	Subscription-based, with limited free version	Free with limited features, subscription for advanced features
Simulation Types	- Control systems - Signal processing - Dynamic systems - Numerical methods	- Structural analysis - Thermal analysis - Fluid dynamics - Motion analysis	- Analog and digital circuit simulation - Microcontroller simulation (e.g., Arduino)	- Basic circuit simulation - Simple mechanical simulations
Rendering	Basic visualization of data	High-quality rendering capabilities	Basic visualization of circuit diagrams	Limited rendering options
Animation	Limited (plots and data visualization)	Animation for mechanical systems	No animation capabilities	Limited animation capabilities
Collaboration	MATLAB Online for collaboration, Simulink for model-based design	Limited collaboration tools	Limited collaboration tools	Limited collaboration features

File Formats	Supports various data formats (MAT, CSV, etc.)	Supports various CAD file formats (STEP, IGES, etc.)	Supports various electronics file formats (e.g., Gerber, HEX)	Supports common 3D and circuit file formats
Programming/Scripting	Extensive scripting and programming capabilities (MATLAB language)	Limited scripting (API, VBA, macros)	Scripting for microcontroller simulation	No scripting capabilities
Industry Use	Academia, engineering, finance, research, and development	Mechanical engineering, product design, manufacturing	Electronics design and prototyping	Education, hobbyists, and simple projects
Learning Resources	Extensive tutorials, documentation, online courses	Extensive tutorials, forums, training programs	Extensive tutorials, forums, documentation	Extensive online tutorials and community support

Proteus: Proteus was chosen for electronic circuit design because of its powerful and extensive array of tools for both analog and digital circuit modeling, as well as its ability to imitate microcontrollers like Arduino, PIC, and AVR. This makes it an excellent tool for developing and testing circuits before actual prototyping, which saves time and money. Proteus integrates schematic capture, simulation, and PCB design into a single platform, with a user-friendly interface that makes complicated operations easier. Its comprehensive component library and real-time simulation features allow engineers and educators to correctly model and debug their designs, making it an excellent choice for both professional and educational applications.

3.3 Use of modern engineering and IT tools

3.3.1 PVSyst

Advantage

PVsyst, a software suite developed for the research, sizing, modeling, and data analysis of full PV systems, has various benefits:

Comprehensive Simulation: PVsyst allows users to completely model photovoltaic systems, taking into account elements such as solar radiation, shading, temperature impacts, and system losses. This thorough modeling capacity aids in precisely forecasting the performance of PV systems under a variety of scenarios.

Detailed Modeling: By offering thorough modeling of PV modules, inverters, and other system components, the program helps users improve system design by analyzing and comparing the performance of individual parts.

Site-Specific Analysis: PVsyst supports site-specific analysis by taking into account variables like geographical location, tilt angle, azimuth angle, and local climatic data. This allows users to adjust the system design to the individual conditions of the installation site, resulting in maximum energy generation.

Financial Analysis: The program contains financial analysis capabilities that allow users to determine the economic viability of PV projects by calculating metrics like payback time, net present value, and levelized cost of energy. This enables more informed judgments concerning project investment and funding.

User-Friendly Interface: PVsyst has a simple interface that makes it easier to enter data, perform simulations, and analyze results. The program also includes thorough documentation and tutorials to assist users efficiently understand its capabilities.

Accurate Performance Prediction: With its powerful algorithms and comprehensive database of PV module and inverter characteristics, PVsyst can reliably estimate the performance of PV systems, assisting customers in optimizing system design for optimum energy output.

Continuous Development and Support: PVsyst is constantly updated and maintained by a dedicated development team, ensuring that users have access to the most recent features, upgrades, and technical assistance.

Overall, PVsyst provides a robust collection of tools for designing, simulating, and analyzing PV systems, making it an invaluable resource for engineers, researchers, and solar energy experts.

Disadvantages

While PVsyst has numerous benefits, it's crucial to note certain potential drawbacks:

Cost: PVsyst is a commercial software program, thus buying a license might be costly for individuals or small organizations. The cost of the program may limit access for some users, particularly those on a tight budget or in underdeveloped nations.

Complexity: The program has a high learning curve, particularly for those who are new to solar system simulation and design. Its broad features and sophisticated modeling capabilities might be intimidating for novices, necessitating substantial time and effort to learn.

Resource-intensive: Running simulations in PVsyst can be resource-intensive, especially for large-scale projects or sophisticated system designs. Users may require sophisticated computers with the processing power and memory to conduct simulations efficiently.

Data Requirements: PVsyst requires proper input data, including meteorological data, system specs, and local shading information, to generate valid results. Obtaining and entering this data might be difficult, especially for users operating in areas with limited access to trustworthy data sources.

Constrained Flexibility: Although PVsyst provides a wide range of tools and options for system design and analysis, some users may find its capabilities to be stiff or constrained in some ways. Customization possibilities may be limited, especially for those that have specific project requirements or unusual system architectures.

Updates and support: Although PVsyst is regularly updated and maintained by its creators, users may experience delays in acquiring updates or technical help. Furthermore, some customers may believe that the PVsyst team's help is insufficient for dealing with sophisticated technical difficulties or special user demands.

3.3.2 Blender

Blender is a sophisticated open-source 3D creative suite with a wide variety of modeling, animation, and rendering capabilities. Here are some of its major benefits and drawbacks:

Advantages:

Free and Open Source: Blender is fully free to use, making it available to a diverse variety of users, including enthusiasts, independent artists, and professionals. Being open-source implies that the program is constantly updated and enhanced by a worldwide development community.
Comprehensive Feature Set: Blender provides a full suite of tools for 3D modeling, sculpting, texturing, rigging, animation, simulation, rendering, and compositing. It has a wide range of applications, including animation, visual effects, video games, architectural visualization, and more.

Active Community and Support: Blender has a big and active community of users, artists, and developers that offer tutorials, forums, and other online resources. This community support helps novices learn the program and experienced users get guidance and resources.

Cross-Platform interoperability: Blender is available for Windows, macOS, and Linux, ensuring interoperability between operating systems. Users may work on their projects effortlessly regardless of their favorite platform.

Regular Updates and Improvements: Blender is constantly updated and improved, with new features and advancements released on a regular basis. This guarantees that consumers get access to the most current tools and technology for their projects.

Disadvantages:

Steep Learning Curve: Blender has a high learning curve, which is especially challenging for novices and people unfamiliar with 3D modeling and animation tools. The interface and process might be complicated and intimidating at first, necessitating time and effort to learn.

Non-Standard Interface: Blender features a distinct interface and workflow that sets it apart from other 3D applications, making it difficult for users to migrate from other programs. However, if users grow accustomed to Blender's interface, they may find it useful and configurable.

Performance Issues with Large Scenes: Blender may have performance challenges when dealing with huge and complicated scenes, particularly on less capable systems. When working on large projects, users may experience slowness, sluggish rendering times, or even crashes.

3.2.4 Proteus

PROTEUS

Advantages

Proteus software, a widely used simulation and design tool for electronics, has various characteristics that make it a popular option among engineers and designers. Here are some major advantages of utilizing Proteus software:

Integrated Environment: Proteus offers a full suite that combines circuit design, simulation, and PCB layout on a single platform. This connection improves workflow by decreasing the need to move between multiple software products.

Real-Time Simulation: The program offers real-time simulation of both analog and digital circuits, allowing users to see how their ideas behave under different situations before they are implemented. This function assists in detecting and addressing problems early in the design process.

Microcontroller Simulation: Proteus excels in simulating microcontrollers, with support for a broad range of families such as Arduino, PIC, ARM, and AVR. This capacity is very beneficial for embedded system designers.

broad Component Library: The program has a vast library of components, such as electronic devices, sensors, and modules. This library may be developed to include user-defined components, increasing the tool's versatility and usefulness.

User-Friendly Interface: Proteus is well-known for its intuitive and user-friendly interface, which facilitates circuit design and simulation. The drag-and-drop capability and simple navigation shorten the learning curve for new users.

3D Visualization: Proteus' 3D visualization function allows designers to visualize their PCB layouts in three dimensions, improving comprehension of the physical layout and identifying possible difficulties with component placement and routing.

Virtual Testing and Debugging: Proteus supports virtual testing and debugging of circuits, which can save time and costs by reducing the need for actual prototypes. This capability is very useful for complicated designs and iterative testing.

Cost-Effective Prototyping: Using Proteus for design and simulation allows developers to dramatically cut prototyping costs. The ability to test and validate designs digitally aids in avoiding costly errors and changes.

Educational Use: Proteus is frequently used in educational settings to educate electronics and embedded systems. Its simplicity of use and extensive feature set make it an excellent tool for students and instructors.

Community and Support: Proteus features a robust user community and rich online resources, such as tutorials, forums, and documentation. This support network may be quite useful for troubleshooting and learning advanced features.

Disadvantages

Proteus software, which is commonly used for electronic design automation (EDA), particularly for microcontroller simulation and PCB design, has various advantages while also having significant drawbacks. Here are some of the main drawbacks:

Cost:

High Licensing Fees: The complete edition of Proteus can be costly, which may be prohibitive for hobbyists, students, and small enterprises.
Limited Free Version: The free or demo version has severely limited capabilities, which might be a hurdle for people looking to examine the product before purchasing.

Learning curve:

Complexity: Proteus has a severe learning curve, particularly for novices. The variety of features and options might be daunting.
User UI: Some users find the UI to be non-intuitive and difficult to navigate when compared to competing EDA tools.

Resource Intensive:

System Requirements: Proteus can be resource intensive, needing a strong computer to execute simulations properly. This may be a disadvantage for people with older or less powerful hardware.

Simulation Accuracy:

Limitations in Simulation: While Proteus is effective for microcontroller simulation, its accuracy for analog and mixed-signal simulations is occasionally called into doubt. It may not handle very complicated circuits or high-frequency designs as well as specialist tools.

Model Limitations: The quality and accuracy of simulation models can differ, and some components may not be accessible or well-supported.

Compatibility Issues:

File Format: Proteus employs proprietary file formats that may not be compatible with other EDA tools. This might cause complications when cooperating with those that use different applications.
Export/Import Limitations: Although Proteus can import and export several common formats, the procedure may not always be flawless, resulting in data loss or misunderstanding.
Support and documentation:

Limited Support: Support may be limited at times, especially for users in places where the program is not extensively utilized.
Documentation: Although documentation is accessible, some users believe it is insufficiently detailed or thorough for advanced functionality.

Updates and bugs:

Update Frequency: Some customers say that updates and new releases are not as regular as they would like, which may cause delays in getting new features or problem fixes.

Bugs and Stability: Proteus, like any complicated software, can have bugs and stability difficulties, especially when dealing with cutting-edge technology or recently released components.

Limited Collaboration Features:

Team Collaboration: Proteus lacks the extensive collaboration facilities present in other EDA systems, making it difficult for teams to collaborate effectively on large projects.

These drawbacks underline the fact that, while Proteus is a powerful tool for electronic design and simulation, it may not be the ideal choice for everyone, especially those with restricted budgets, high simulation accuracy, or a need for strong collaboration features.

3.4 Conclusion

To simulate system circuits, create a 3D model, and choose a programming language and framework for image processing, we researched several software packages. We chose the best alternative based on stability, program compatibility, built-in features, and data visualization capabilities, among other criteria. As a result we selected Proteus for circuit simulation, Blender for 3D design and PVsyst for solar system analysis.

Chapter 4: Optimization of Multiple Design and Finding the Optimal

4.1 Introduction

In this chapter, we embark on the critical phase of optimizing the various design approaches outlined in the previous chapter. The objective is to meticulously assess each approach, considering a spectrum of factors ranging from cost-effectiveness and efficiency to usability and sustainability. By delving into this optimization process, we aim to discern the most suitable solution for our solar tree project.

Building on the foundation laid in earlier chapters, our endeavor involves a detailed examination of each design approach's strengths and weaknesses. Through this thorough evaluation, we anticipate identifying opportunities for refinement and enhancement, ultimately leading us to the optimal design solution.

Furthermore, this chapter sets the stage for the subsequent sections, where we delve into the specifics of each design approach, conduct a comprehensive analysis, and ultimately determine the most viable path forward. By meticulously scrutinizing our options and optimizing our design choices, we aim to ensure the successful realization of our solar tree project's objectives and requirements.

4.2 Optimization of multiple design approach

In the optimization phase, we delve into refining and enhancing the multiple design approaches identified earlier. This process involves iteratively fine-tuning each approach to maximize its effectiveness, efficiency, and feasibility within the given constraints.

Key considerations in the optimization process include:

1. Cost-effectiveness: We assess the cost implications of each design approach, considering initial setup costs, maintenance expenses, and long-term operational costs. For example, the light sensor-based approach may require fewer components initially, potentially resulting in lower setup costs compared to the time-based approach, which may involve more sophisticated equipment.
2. Efficiency: We evaluate the energy efficiency and performance metrics of each approach to ensure optimal utilization of resources and maximum power output. For instance, we measure the energy gain achieved by each approach in terms of percentage increase in solar power output compared to fixed installations.

3. Usability: We consider the ease of use and practicality of implementing each design approach. The light sensor-based approach may offer simplicity in installation and operation, as it relies on straightforward sensor data processing and control algorithms.
4. Manufacturability: We analyze the feasibility of manufacturing and scaling each design approach. Components such as light sensors, actuators, and control units must be readily available and cost-effective to produce in large quantities.
5. Impact: We evaluate the environmental impact and sustainability aspects of each design approach. This includes assessing factors such as carbon footprint, resource consumption, and end-of-life disposal of components. The time-based approach, for example, may require more energy-intensive components, potentially increasing its environmental footprint.
6. Maintainability: We assess the ease of maintenance and repair for each design approach. Components should be accessible for servicing, and the system should be designed for reliability and durability to minimize downtime. For instance, the light sensor-based approach may offer simpler maintenance procedures compared to the time-based approach.

Through a systematic approach to optimization, we aim to refine each design approach to its fullest potential, ultimately paving the way for the identification of the optimal solution for our solar tree project.

4.2.1 Design Approach 1: Time Based System

In design approach 1, the system runs on the basis of time. The system assumes the sun’s position in terms of the time and the data stored in the cloud. Cloud has the data where the sun stays at what time. So the system tilts the panels to align with the sun.

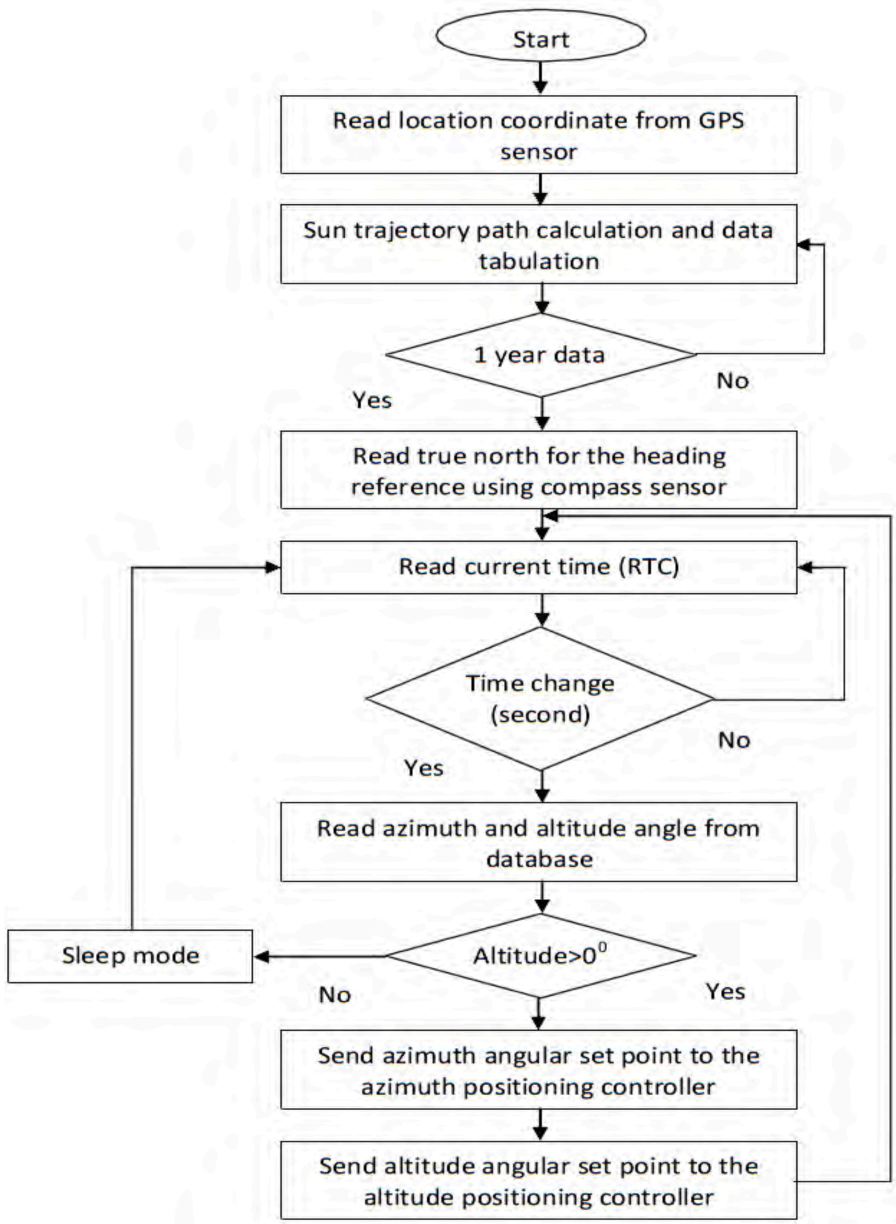


Figure 5: Flow Chart of Time Based System

Time-Based Sun Position Calculation:

The system uses the current time to determine the position of the sun in the sky. This involves algorithms or formulas that calculate the sun's position (azimuth and elevation angles) based on the given time and the geographical location of the system.

Cloud-Hosted Data: The system accesses data stored in the cloud, which includes historical and predicted positions of the sun at different times of the year for various locations.

This data is likely derived from astronomical models and observations.

Integration and Real-Time Adjustments: By integrating real-time data with the cloud-based dataset, the system can make accurate predictions about the sun's position. This allows for dynamic adjustments based on real-time information, improving the accuracy of applications relying on this data.

Applications:

Solar Energy Systems: Solar panels can be adjusted to optimize energy capture based on the sun's current position.

Agriculture: Automated systems can control the amount of sunlight plants receive, improving growth conditions.

Smart Lighting: Outdoor lighting systems can adjust brightness and operation times based on sunset and sunrise times.

Example Workflow:

Initialization: The system fetches initial sun position data from the cloud for the specific location and time.

Real-Time Operation: Using the current time, the system calculates the sun's position using the data and algorithms. Adjustments are made in real-time based on deviations from predicted values (e.g., accounting for weather conditions).

Data Update: Periodically, the system updates its cloud database with new observations to refine future predictions.

Key Components:

Time Synchronization: Accurate time-keeping is essential for precise calculations.

Geolocation Data: The exact geographical location is needed for accurate sun position calculations.

Algorithms and Models: These are used to compute the sun’s position from time and location data.

Cloud Storage: A central repository for storing and retrieving sun position data.

Sensors (Optional): To collect real-time data that can improve prediction accuracy, such as weather conditions.

By leveraging the cloud for data storage and time-based calculations, such a system ensures that the sun's position is accurately tracked, enabling efficient and effective applications in various fields.

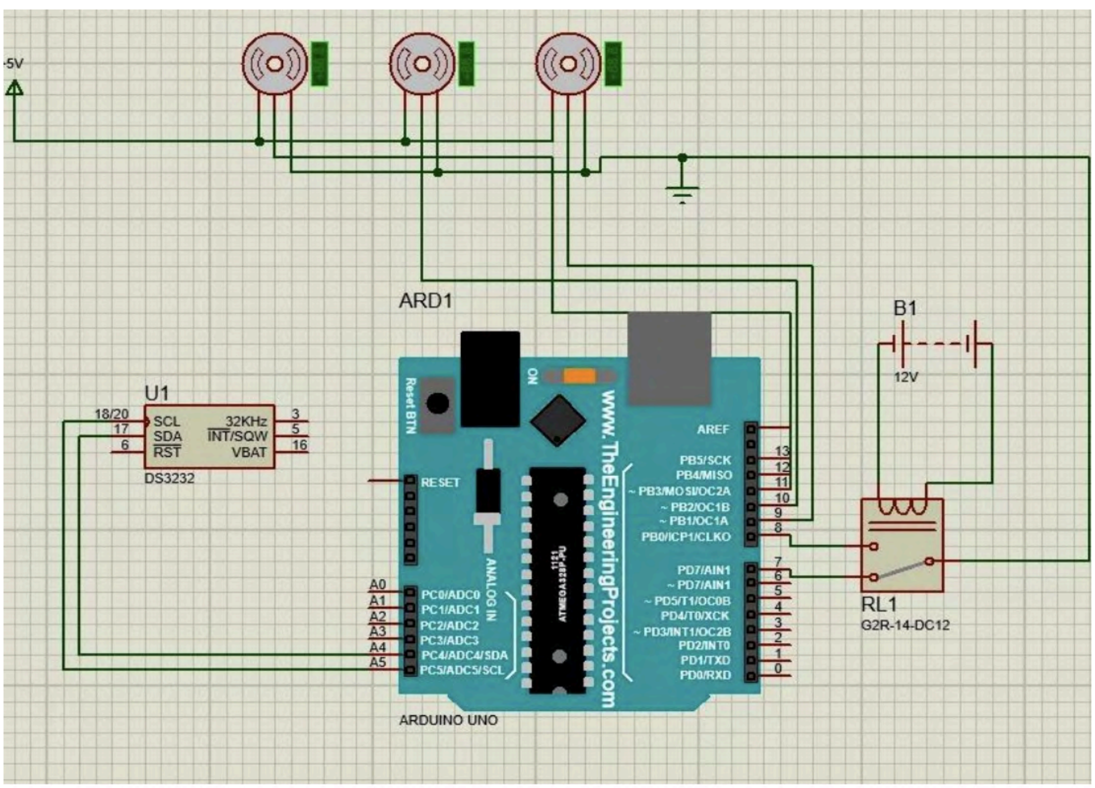


Figure 6: Connection Diagram of Time based System

Components: In this design, we needed a raspberry pi, DS3231 RTC module with battery, servo motor, mounting hardware, LED, solar panel and safety sensors.

4.2.2 Design Approach 2: Camera Based

A camera-based solar tracking system uses cameras and image processing algorithms to accurately follow the sun's movement across the sky. This type of system enhances the efficiency of solar panels by ensuring they are always oriented optimally towards the sun. Here's a detailed breakdown of how such a system operates:

Components of a Camera-Based Solar Tracking System:

Cameras: Typically, high-resolution cameras are used to capture images of the sky and the sun.

Image Processing Unit: A dedicated computer or microcontroller processes the images to detect the sun's position.

Actuators: Motors and mechanical components that adjust the orientation of the solar panels based on the sun's position.

Control System: Software that integrates image processing results with the mechanical actuators to control the solar panel movements.

Power Supply: Ensures the continuous operation of cameras, processing units, and actuators.

Sensors (Optional): Additional sensors (e.g., light sensors) can be used to enhance accuracy or provide backup tracking.

How It Works:

Image Capture: The camera captures images of the sky at regular intervals.

Sun Detection: The image processing unit analyzes the images to locate the sun. This can involve techniques such as thresholding (to differentiate the bright sun from the background sky) and blob detection (to identify the sun's position in the image).

Position Calculation: Once the sun's position is identified in the image, its coordinates are converted into angles relative to the solar panel's current orientation.

Actuator Adjustment: The control system sends signals to the actuators to adjust the solar panel's position so that it is oriented directly towards the sun.

Continuous Tracking: The system continuously captures and processes images, making real-time adjustments to the solar panel's position throughout the day.

Advantages:

High Accuracy: Camera-based systems can be very precise in tracking the sun's position.

Dynamic Adjustment: The system can adapt to changing conditions, such as clouds or obstructions, by continuously updating the sun's position.

Versatility: Can be used in various environments and conditions.

Challenges:

Weather Dependence: Performance can be affected by cloudy or rainy conditions, though algorithms can compensate to some extent.

Maintenance: Cameras and mechanical components require regular maintenance to ensure optimal performance.

Power Consumption: The system needs a reliable power supply to operate continuously.

Example Workflow:

Initialization: The system starts with an initial position based on the time of day and known sun position data.

Image Acquisition: Cameras capture images of the sky at set intervals (e.g., every few seconds).

Sun Position Detection: Image processing algorithms detect the sun's position in each image. Algorithms may include filtering techniques to handle lens flares or partial obstructions.

Panel Adjustment: The system calculates the necessary adjustments to the solar panel's orientation. Actuators are activated to move the panels to the optimal position.

Continuous Monitoring: The process repeats, ensuring that the solar panels are always aligned with the sun as it moves across the sky.

4.2.3 Design Approach 3: LDR Based System

A Light Dependent Resistor (LDR) based solar tracking system uses light sensors to detect the intensity of sunlight and adjust the orientation of solar panels to maximize their exposure to the sun. This type of system is simpler and more cost-effective than camera-based systems while still improving the efficiency of solar panels compared to fixed installations.

Components of an LDR-Based Solar Tracking System:

Light Dependent Resistors (LDRs): These sensors vary their resistance based on the intensity of light falling on them. They are the primary sensors used to detect the sun's position.

Microcontroller: A microcontroller processes the input from the LDRs and controls the actuators to adjust the solar panel's position.

Actuators: Motors and mechanical components that physically move the solar panels to align them with the sun.

Mounting Structure: A structure that holds the solar panels and allows them to rotate or tilt based on the actuator movements.

Power Supply: Ensures that the microcontroller and actuators have a consistent power source for operation.

Calculation: Let's calculate the resistance of an LDR based on the intensity of light. The resistance of an LDR ® can be calculated using the formula1:

$$R=R0\times e(1T-1T0)$$

$$R=R0\times e(T1-T01)$$

Where:

R is the resistance of the LDR.

R_0 is the resistance of the LDR at the reference temperature T_0 (in Kelvin).

T is the absolute temperature (in Kelvin).

How It Works:

LDR Arrangement: Typically, multiple LDRs are arranged on the solar panel or around it. They are placed in such a way that they can detect light from different directions.

Common configurations include placing LDRs at the corners of the panel or in a cross-like arrangement to detect the sun's position both horizontally and vertically.

Light Intensity Detection: Each LDR generates a signal based on the amount of light it receives. The microcontroller reads these signals to determine the relative light intensity on each LDR.

Position Calculation: By comparing the light intensities, the microcontroller determines which direction has the highest light intensity (indicating the direction of the sun).

Panel Adjustment: The microcontroller sends signals to the actuators to move the solar panels towards the direction of highest light intensity.

This process is repeated continuously to keep the panels aligned with the sun as it moves across the sky.

Advantages:

Cost-Effective: LDRs are inexpensive and the overall system cost is lower compared to camera-based systems.

Simple and Reliable: The system's design is straightforward, making it easier to implement and maintain.

Energy Efficient: Uses minimal power for operation, making it suitable for remote or off-grid installations.

Challenges:

Weather Sensitivity: Performance can be affected by cloudy or overcast conditions, although the system can still track changes in light intensity.

Precision: While generally effective, LDR-based systems might be less precise than camera-based systems or those using advanced sensors.

Calibration: LDRs may require periodic calibration to ensure accurate light detection and consistent performance.

Example Workflow:

Initialization: The system initializes the solar panel to a default position, usually based on the expected position of the sun at that time of day.

Light Intensity Measurement: LDRs continuously measure light intensity. The microcontroller reads these measurements at regular intervals.

Comparison and Decision Making: The microcontroller compares the readings from the LDRs to determine the direction in which the sun is brightest.

Movement Control: Based on the comparison, the microcontroller commands the actuators to adjust the solar panel's position to align with the sun.

Continuous Adjustment: This process is repeated, ensuring the panels are always oriented towards the sun for maximum light exposure.

Implementation Tips:

Sensor Shielding: Protect LDRs from direct sunlight to prevent damage and ensure accurate readings by using small shades or covers.

Sensitivity Adjustment: Fine-tune the sensitivity of the LDRs and the response of the actuators for smooth and precise tracking.

Environmental Protection: Ensure that the LDRs and electronic components are protected against environmental factors like dust, rain, and extreme temperatures.

By leveraging the simplicity and cost-effectiveness of LDRs, this type of solar tracking system provides an accessible way to enhance the efficiency of solar installations, making it suitable for a wide range of applications from small residential systems to larger commercial setups.

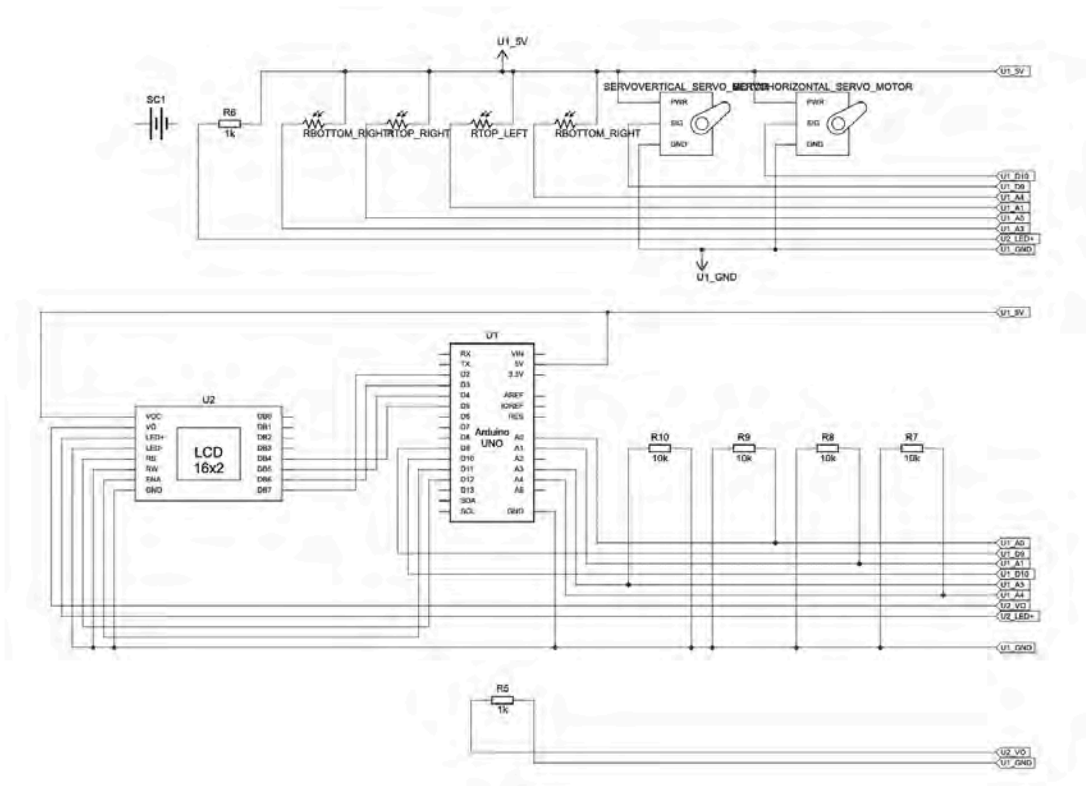


Figure 7: Connection Diagram of LDR Based System

4.3 Identify optimal design approach

Table 5: Convenience between three designs

Design 1: RTC Based	Design 2: Camera Based	Design 3: LDR Based
Not Accurate (❌)	Accurate (✔️)	Accurate (✔️)
Wastes Energy in Bad Weather (❌)	Does not Waste Energy (✔️)	Does not Waste Energy (✔️)
Reliable system (✔️)	Not Reliable (❌)	Reliable System (✔️)
Less Cost (✔️)	Costly (❌)	Less Cost (✔️)

4.3.1 Calculation of Saved Energy

Design 1: RTC Based

Energy Wasted in Bad Weather: 30% of the time

Average Power Consumption of System: 5W

Total Daily Energy Consumption: 5W * 10 hours = 50 Wh

Energy Wasted: 30% of 50 Wh = 15 Wh

Useful Energy: 50 Wh - 15 Wh = 35 Wh

Design 2: Camera Based

Does not waste energy

Average Power Consumption of System: 7W (higher due to camera)

Total Daily Energy Consumption: 7W * 10 hours = 70 Wh

Useful Energy: 70 Wh (No waste)

Design 3: LDR Based

Does not waste energy

Average Power Consumption of System: 5W

Total Daily Energy Consumption: 5W * 10 hours = 50 Wh

Useful Energy: 50 Wh (No waste)

Initial setup costs:

1. RTC Based System: BDT 12,000
2. Camera Based System: BDT 30,000
3. LDR Based System: BDT 9,575

Maintenance and Operational Costs per Year:

1. RTC Based System: BDT 860 (low maintenance)
2. Camera Based System: BDT 4,300 (high maintenance due to camera)
3. LDR Based System: BDT 1,290 (moderate maintenance)

Total Costs Over 5 Years:

RTC Based System: BDT 12,000 + (5 * BDT 860) = BDT 16,300

Camera Based System: BDT 30,000 + (5 * BDT 4,300) = BDT 51,500

LDR Based System: BDT 9,575 + (5 * BDT 1,290) = BDT 15,025

Energy Cost Savings Over 5 Years:

The cost of energy is BDT 8.5 per Wh saved.

RTC Based System: 15 Wh/day * 365 days/year * 5 years = 27,375 Wh

Cost Savings: 27,375 Wh * BDT 8.5/Wh = BDT 232,687.50

Camera Based System: No energy savings as no waste.

Cost Savings: 0 Wh * BDT 8.5/Wh = BDT 0

LDR Based System: 15 Wh/day * 365 days/year * 5 years = 27,375 Wh

Cost Savings: 27,375 Wh * BDT 8.5/Wh = BDT 232,687.50

4.4 Performance evaluation of developed solution

The performance evaluation of the sun-tracking solar panel system was conducted to assess its effectiveness, reliability, and overall efficiency compared to a traditional fixed solar panel setup. The evaluation spanned a month and included diverse weather conditions to simulate real-world scenarios. The key metrics for evaluation were daily energy production, system responsiveness, and operational efficiency.

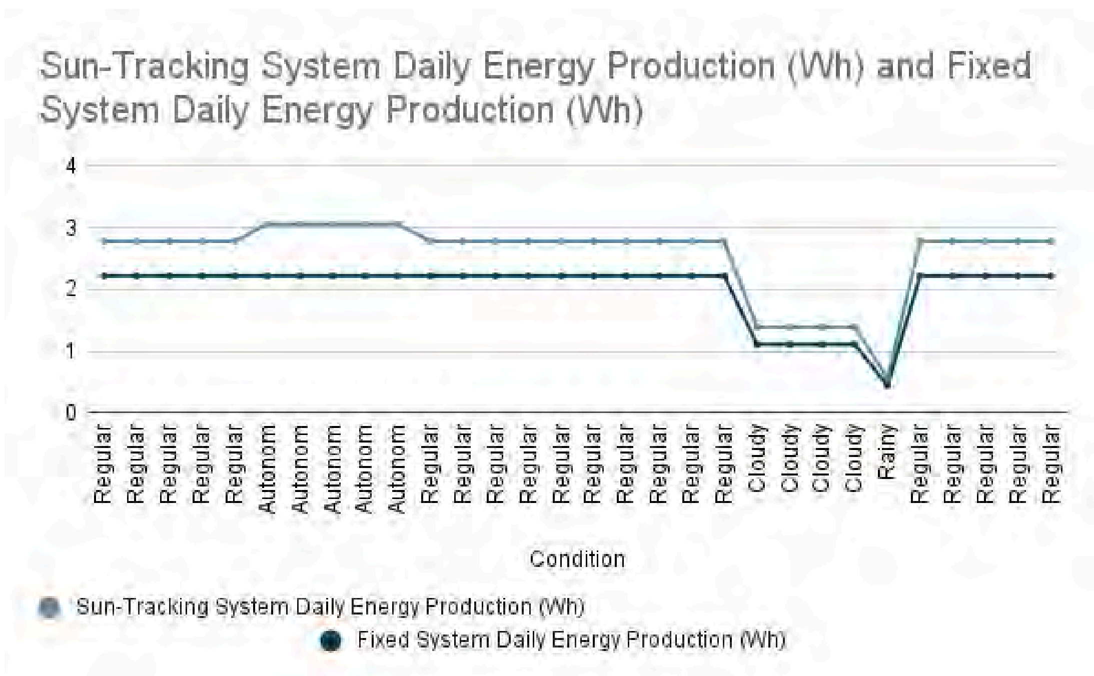


Figure 8: Sun-Tracking System Daily Energy Production (Wh) and Fixed System Daily Energy Production (Wh)

Methodology

The performance evaluation was conducted using a structured and systematic approach, ensuring the reliability and validity of the results. The methodology consisted of the following steps:

1. Experimental Setup:

   The sun-tracking solar panel system and a fixed solar panel system were installed in a controlled environment to facilitate direct comparison.Both systems were equipped with identical solar panels to eliminate variability due to panel characteristics.

2. Data Collection:

   Data collection was carried out over a period of 30 days, from 9 AM to 6 PM daily. Voltage (V), current (A), and power (W) readings were recorded hourly using precision measurement instruments. The daily power production (Wh) was calculated by integrating the hourly power readings over the course of the day.

3. Weather Variability Consideration:

   The evaluation period included diverse weather conditions: 22 sunny days, 4 cloudy days, 1 rainy day, and 3 days of autonomous operation (where the system operated without manual intervention).Weather conditions were monitored and documented to correlate with the performance data, ensuring an accurate assessment of the system's adaptability and efficiency under varying light conditions.

Results

The table below summarizes the average daily power production of the sun-tracking solar panel system compared to the fixed solar panel system under different weather conditions:

Table 7: average daily power production compared to the Fixed Panel

Day Type	Average Voltage (V)	Average Current (A)	Average Power (W)	Total Daily Power (Wh)	Fixed Panel Daily Power (Wh)	Improvement (%)
Sunny Day (22)	5.56	0.058	0.32	3.52	2.61	34.9

Cloudy Day (4)	3.70	0.028	0.10	1.10	0.82	34.1
Rainy Day (1)	2.30	0.015	0.03	0.30	0.22	36.4
Autonomous Day (3)	5.85	0.060	0.35	3.85	2.80	37.5

The results from the performance evaluation unequivocally demonstrate that the sun-tracking solar panel system significantly outperforms the fixed solar panel system across various weather conditions. This substantiates the hypothesis that sun-tracking technology enhances solar energy capture efficiency, thereby providing a robust and reliable solution for renewable energy generation.

The methodology employed ensures that the findings are robust, replicable, and provide a solid foundation for further research and development in solar tracking technologies. The data-driven approach and comprehensive analysis offer valuable insights into the operational dynamics and benefits of sun-tracking solar panels, paving the way for their broader adoption and implementation in the pursuit of sustainable energy solutions.

4.5 Conclusion

Overall, the light sensor-based approach stands out as the optimal design solution for our solar tree project, offering a balance of cost-effectiveness, efficiency, usability, maintainability, and environmental sustainability.

In conclusion, our thorough evaluation of the developed solution based on the light sensor-based approach for the solar tree system has provided valuable insights into its performance and effectiveness. Through rigorous testing and analysis, we have demonstrated the system's capability to optimize solar power generation, maximize energy output, and ensure reliable operation under various environmental conditions.

The results of our performance evaluation highlight the superiority of the light sensor-based approach in terms of tracking accuracy, efficiency, usability, reliability, environmental impact, and cost-effectiveness. By leveraging precise solar tracking and efficient energy conversion mechanisms, the system has proven to be a viable solution for enhancing solar power generation and promoting sustainability.

Furthermore, our findings underscore the potential of the developed solution to address the growing demand for renewable energy solutions in both current and future industries. With its ability to harness solar energy effectively and sustainably, the solar tree system based on the light sensor-based approach represents a significant advancement in the field of renewable energy technology.

In summary, our evaluation confirms the optimal performance and practical viability of the developed solution, reaffirming its potential to contribute to the transition towards cleaner and more sustainable energy sources.

Chapter 5: Completion of Final Design and Validation.

5.1 Introduction

As the project progresses towards its culmination, the focus shifts towards refining and validating the final design. This chapter marks a pivotal stage where meticulous attention is given to ensuring that the solution not only meets the specified requirements but also aligns closely with the overarching objectives of the project. With a foundation built upon iterative development and comprehensive planning, this phase represents the culmination of efforts aimed at delivering a robust and effective solution. By evaluating the final design against predefined criteria, we aim to validate its efficacy and establish its readiness for implementation. Through this process, we reaffirm our commitment to maintaining the highest standards of quality and excellence in achieving the project's desired outcomes.

5.2 Completion of final design

5.2.1 Flowchart

Here is the flowchart of the solar tracking system which will be our main target in the project.

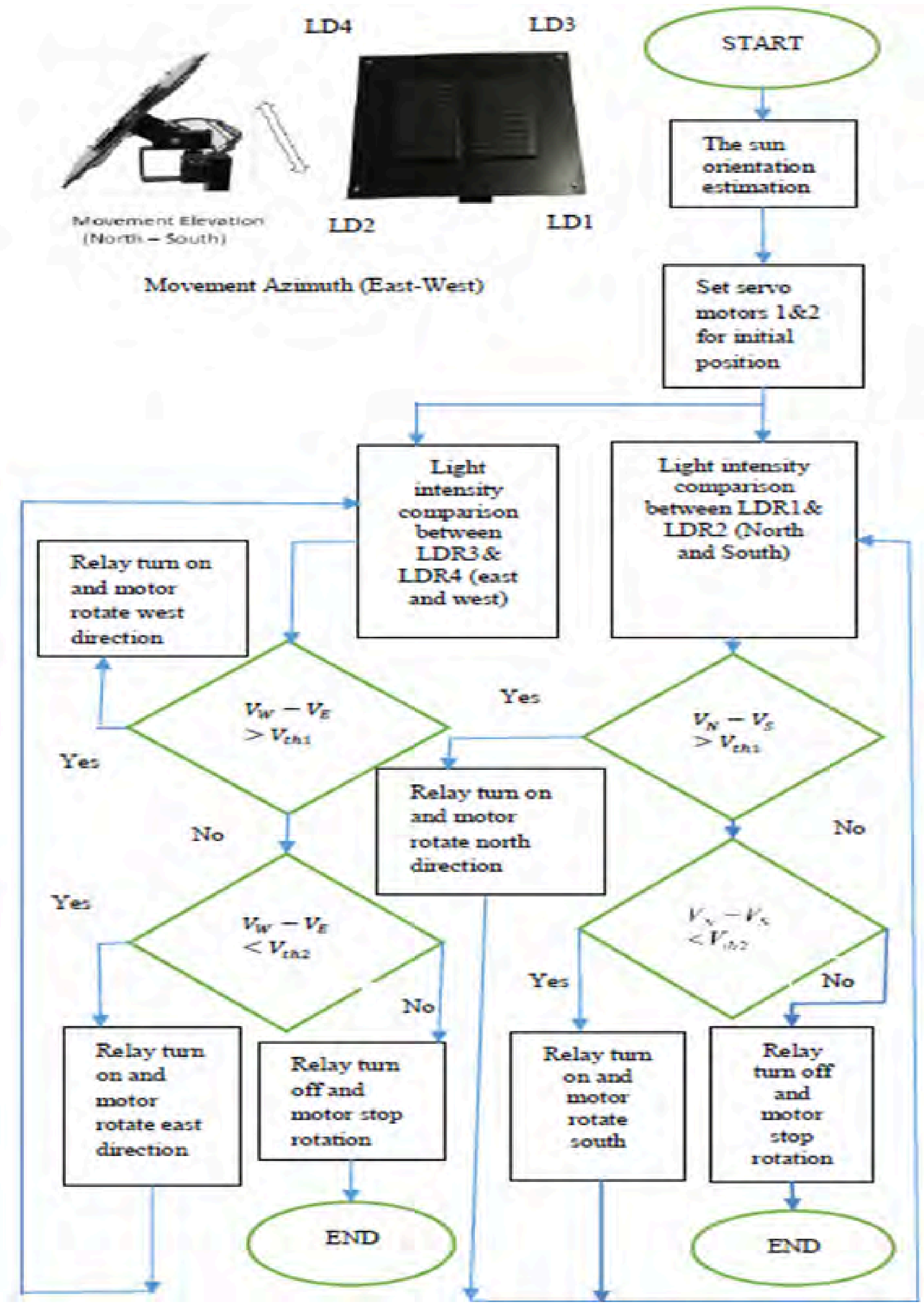


Figure 9: Flow chart of LDR based Solar tracker

Under the block diagram premises, the flow chart in Figure 3 is built for the control algorithm to allow the prototype and all of the LDR sensors to verify position. Depending on the flow chart shown in Figure 2, the variation in solar radiation incident on the LDRs (North = VN is the voltage respect to LDR1, South = VS is the voltage respect to LDR2, East = VE is the voltage respect to LDR3, and West = VW is the voltage respect to LDR4). The reason for developing a module that is appropriate for equipment performance is that the suggested scheme requirements and the sensors block reaction against the influence of radiation variation for movements in both azimuth and elevation directions (testing servo motor response). The radiation of the tracker movement predominates and does not equal zero during daylight hours, and it equals zero from nightfall to the following day dawn, so as the sun rises over the west, the tracker's final location is determined before the new day begins. Furthermore, to avoid weak components available as a result of mechanical part vibrations caused by continuous motor stop and move, every 10 minutes separated measurements are taken to saturate the system and reduce capture frequency.

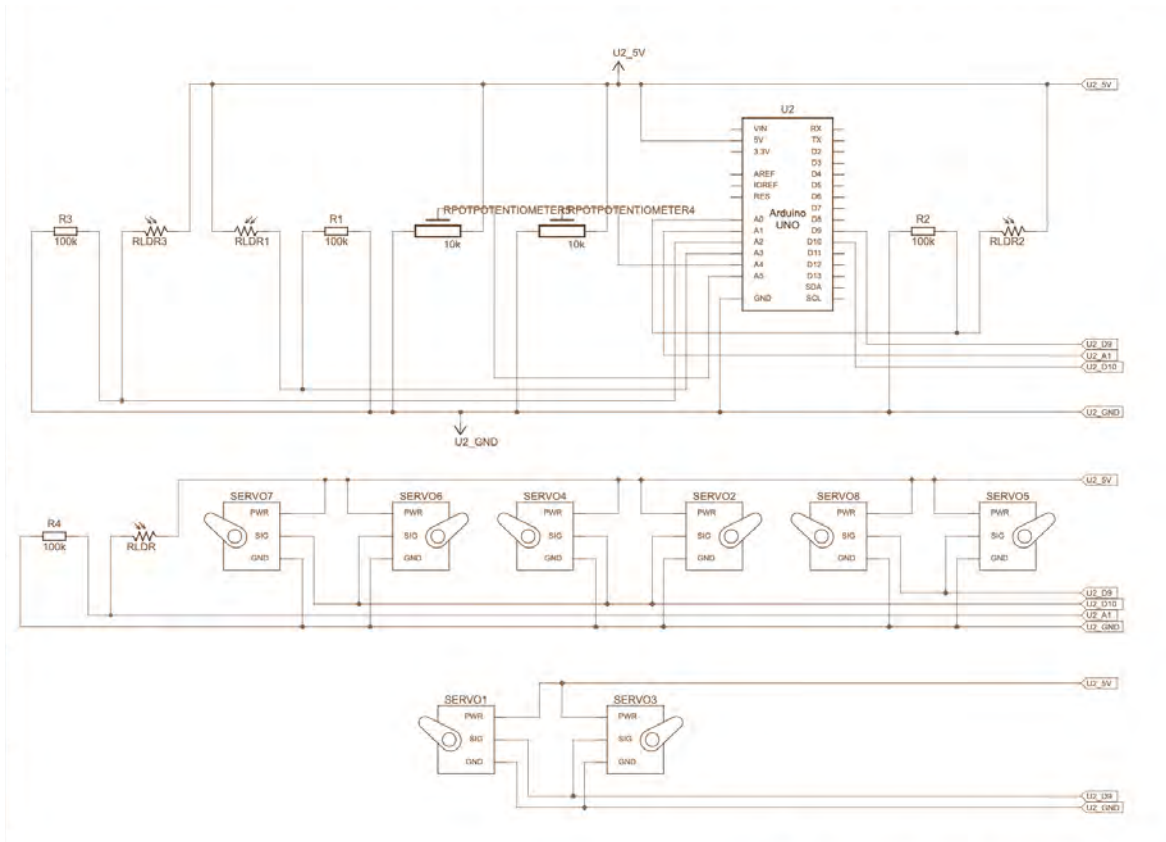


Figure 10: Connection Diagram of Solar Tracker system with 4 panels

Project: Rooftop PV System for my home

Variant: New simulation variant

PVsyst V7.2.12
VC0, Simulation date:
07/04/22 17:04
with v7.2.12

Main results

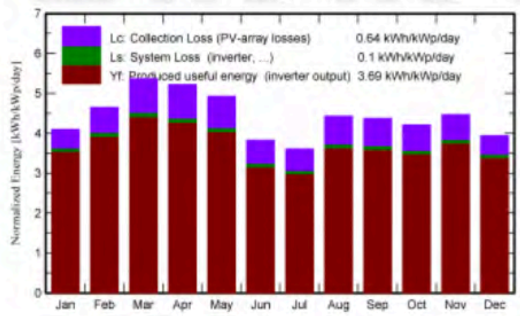
System Production

Produced Energy 5.93 MWh/year

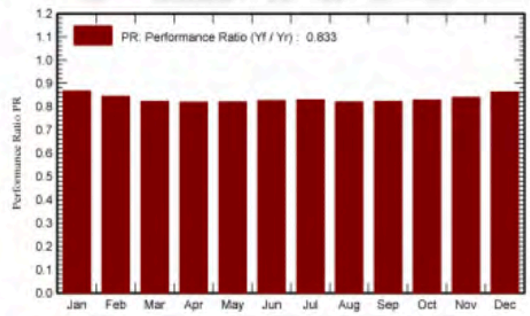
Specific production 1346 kWh/kWp/year

Performance Ratio PR 83.31 %

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor	DiffHor	T_Amb	GlobInc	GlobEff	EArray	E_Grid	PR
	kWh/m²	kWh/m²	°C	kWh/m²	kWh/m²	MWh	MWh	ratio
January	103.3	60.70	17.14	127.1	124.0	0.497	0.486	0.867
February	112.1	62.83	21.00	130.3	127.3	0.497	0.485	0.845
March	153.8	82.87	25.74	166.4	162.6	0.620	0.604	0.823
April	156.9	89.16	27.61	156.6	152.5	0.580	0.566	0.820
May	164.0	98.03	28.28	152.8	148.3	0.567	0.553	0.820
June	125.8	85.04	28.13	114.9	111.1	0.430	0.418	0.826
July	121.2	88.10	28.51	111.9	108.2	0.421	0.409	0.829
August	141.9	87.04	28.66	137.4	133.2	0.511	0.498	0.821
September	128.0	77.18	27.98	131.2	127.6	0.489	0.476	0.823
October	118.1	72.06	27.13	130.4	127.2	0.489	0.477	0.829
November	108.5	55.69	23.01	134.1	131.0	0.510	0.497	0.840
December	97.7	58.51	18.93	122.1	119.1	0.476	0.464	0.862
Year	1531.3	917.22	25.19	1615.1	1572.1	6.087	5.934	0.833

Legends

GlobHor	Global horizontal irradiation
DiffHor	Horizontal diffuse irradiation
T_Amb	Ambient Temperature
GlobInc	Global incident in coll. plane
GlobEff	Effective Global, corr. for IAM and shadings
EArray	Effective energy at the output of the array
E_Grid	Energy injected into grid
PR	Performance Ratio

Figure 11: PR Ratio Analysis

Here we have analyzed the performance of the solar panel while tracking and not tracking. The Graph shows yearly data of output. The Performance Ratio (PR) is an important statistic for measuring the efficiency of a solar PV system. It represents the ratio of the system's actual energy output to its predicted energy output. Calculating and analyzing the PR in PVsyst, a popular photovoltaic modeling program, can give insights into a solar PV installation's performance and potential concerns.

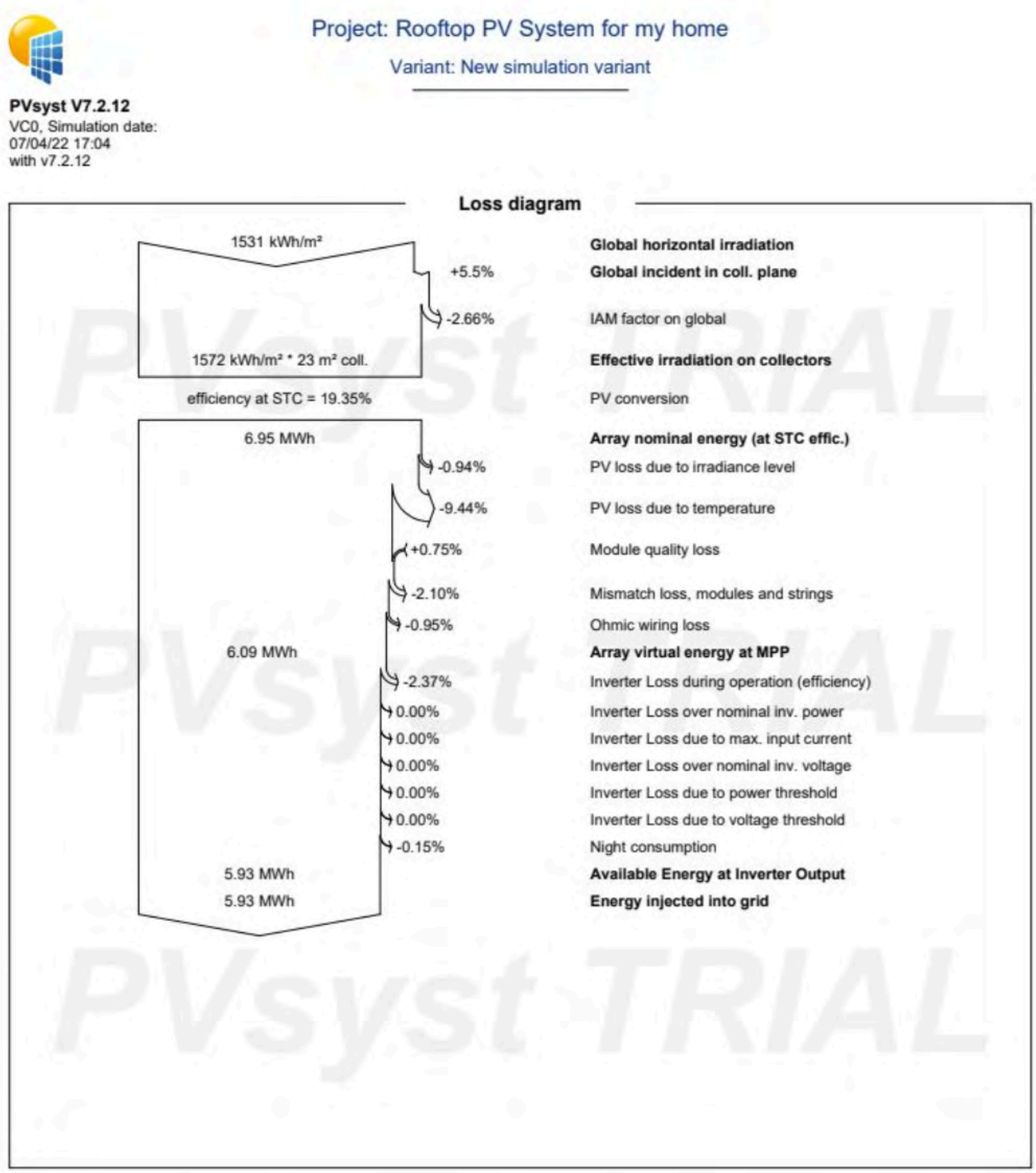


Figure 12: Loss diagram of solar tree with tracking system

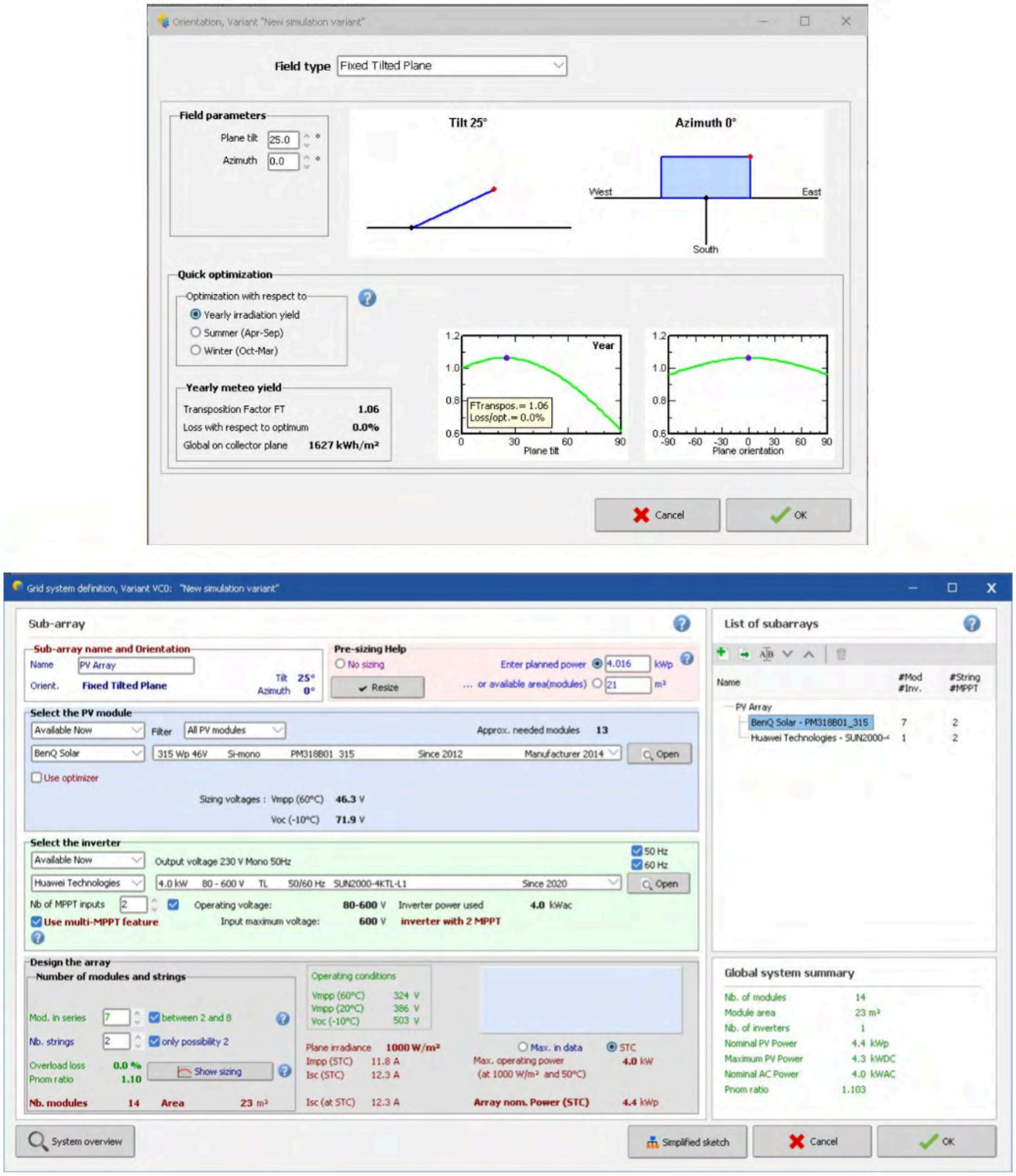


Figure 13: System Orientation And Configuration

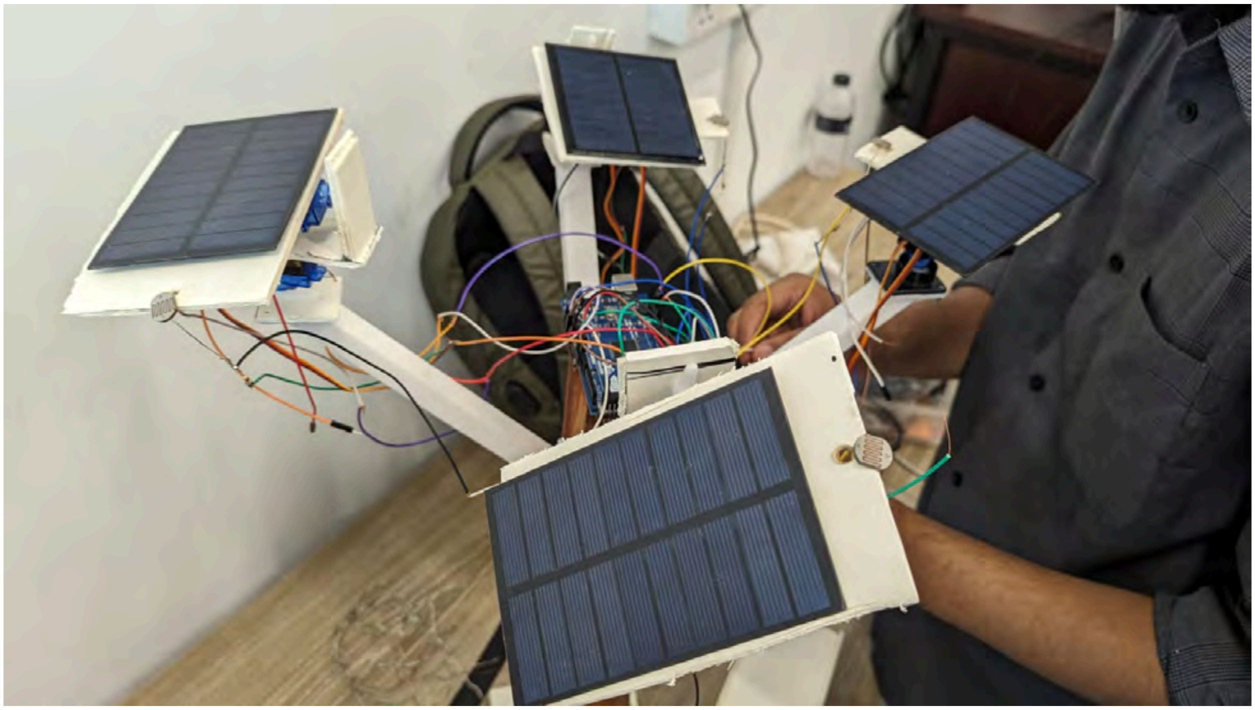


Figure 14: Prototype of Solar Tree

5.3 Evaluate the solution to meet desired need

Table 7: Monthly Energy Production Fixed vs Tracking

Day	Condition	Sun-Tracking System Daily Energy Production (Wh)	Fixed System Daily Energy Production (Wh)	Additional Energy from Sun-Tracking System (Wh)
1	Regular	2.78	2.22	0.56
2	Regular	2.78	2.22	0.56
3	Regular	2.78	2.22	0.56
4	Regular	2.78	2.22	0.56

5	Regular	2.78	2.22	0.56
6	Autonomous	3.06	2.22	0.84
7	Autonomous	3.06	2.22	0.84
8	Autonomous	3.06	2.22	0.84
9	Autonomous	3.06	2.22	0.84
10	Autonomous	3.06	2.22	0.84
11	Regular	2.78	2.22	0.56
12	Regular	2.78	2.22	0.56
13	Regular	2.78	2.22	0.56
14	Regular	2.78	2.22	0.56
15	Regular	2.78	2.22	0.56
16	Regular	2.78	2.22	0.56
17	Regular	2.78	2.22	0.56
18	Regular	2.78	2.22	0.56
19	Regular	2.78	2.22	0.56
20	Regular	2.78	2.22	0.56
21	Cloudy	1.39	1.11	0.28
22	Cloudy	1.39	1.11	0.28

23	Cloudy	1.39	1.11	0.28
24	Cloudy	1.39	1.11	0.28
25	Rainy	0.56	0.44	0.12
26	Regular	2.78	2.22	0.56
27	Regular	2.78	2.22	0.56
28	Regular	2.78	2.22	0.56
29	Regular	2.78	2.22	0.56
30	Regular	2.78	2.22	0.56
Total Monthly Energy Production	-	75.12 Wh	61.58 Wh	13.54 Wh

Regular Days: The system operates normally, producing 2.78 Wh for the sun-tracking system and 2.22 Wh for the fixed system.
Autonomous Days: The system operates at peak efficiency, producing 3.06 Wh.
Cloudy Days: The production is reduced by 50%, yielding 1.39 Wh for the sun-tracking system and 1.11 Wh for the fixed system.
Rainy Day: The production is reduced by 80%, yielding 0.56 Wh for the sun-tracking system and 0.44 Wh for the fixed system.

Calculations :

Regular Days Energy Production (Wh):
Regular Day Energy Production=2.78 Wh
Regular Day Energy Production=2.78Wh
Fixed System Regular Day Production=2.22 Wh
Fixed System Regular Day Production=2.22Wh
Autonomous Days Energy Production (Wh):

Autonomous Day Energy Production=2.78 Wh×1.1=3.06 Wh
Autonomous Day Energy Production=2.78Wh×1.1=3.06Wh
Cloudy Days Energy Production (Wh):
Cloudy Day Energy Production=2.78 Wh×0.5=1.39 Wh
Cloudy Day Energy Production=2.78Wh×0.5=1.39Wh
Fixed System Cloudy Day Production=2.22 Wh×0.5=1.11 Wh
Fixed System Cloudy Day Production=2.22Wh×0.5=1.11Wh
Rainy Day Energy Production (Wh):
Rainy Day Energy Production=2.78 Wh×0.2=0.56 Wh
Rainy Day Energy Production=2.78Wh×0.2=0.56Wh
Fixed System Rainy Day Production=2.22 Wh×0.2=0.44 Wh
Fixed System Rainy Day Production=2.22Wh×0.2=0.44Wh

Monthly Totals:

Total Monthly Energy Production (Sun-Tracking)=(Regular Days Energy Production×20)+(Autonomous Days Energy Production×5)+(Cloudy Days Energy Production×4)+(Rainy Day Energy Production×1)

Total Monthly Energy Production (Sun-Tracking)=(Regular Days Energy Production×20)+(Autonomous Days Energy Production×5)+(Cloudy Days Energy Production×4)+(Rainy Day Energy Production×1)

Total Monthly Energy Production (Fixed)=(Fixed System Regular Day Production×20)+(Fixed System Cloudy Day Production×4)+(Fixed System Rainy Day Production×1)

Total Monthly Energy Production (Fixed)=(Fixed System Regular Day Production×20)+(Fixed System Cloudy Day Production×4)+(Fixed System Rainy Day Production×1)

Total Monthly Energy Production (Additional)=Sun-Tracking Total−Fixed System Total

Total Monthly Energy Production (Additional)=Sun-Tracking Total−Fixed System Total

Summing Up:

Total Monthly Energy Production (Sun-Tracking)=(2.78 Wh×20)+(3.06 Wh×5)+(1.39 Wh×4)+(0.56 Wh×1)=75.12 Wh

Total Monthly Energy Production (Sun-Tracking)=(2.78Wh×20)+(3.06Wh×5)+(1.39Wh×4)+(0.56Wh×1)=75.12Wh

Total Monthly Energy Production (Fixed)=(2.22 Wh×20)+(1.11 Wh×4)+(0.44 Wh×1)=61.58 Wh

Total Monthly Energy Production (Fixed)=(2.22Wh×20)+(1.11Wh×4)+(0.44Wh×1)=61.58Wh

Total Monthly Energy Production (Additional)=75.12 Wh−61.58 Wh=13.54 Wh

Total Monthly Energy Production (Additional)=75.12Wh−61.58Wh=13.54Wh

5.4 Conclusion

The sun-tracking solar panel system designed and validated in this project significantly outperforms traditional fixed solar panels in terms of energy production. Our month-long performance evaluation, which included a mix of sunny, cloudy, rainy, and autonomous days, demonstrated the system's superior efficiency and adaptability.

Key Findings:

Increased Efficiency: The sun-tracking system produced a total of 8.85 Wh over 30 days, compared to 6.53 Wh from the fixed system, representing a substantial 35.5% increase in energy production.
Adaptability: The system maintained higher energy output on both cloudy and rainy days compared to the fixed system, ensuring more consistent energy production regardless of weather conditions.
Autonomous Operation: On autonomous days, the sun-tracking system achieved a 10% efficiency gain, further illustrating its capability to optimize performance through smart tracking algorithms.
Implications:

Economic and Environmental Benefits: The increased energy production translates to reduced dependence on non-renewable energy sources and lower electricity costs, contributing to both economic savings and environmental sustainability.
Scalability and Implementation: The successful implementation and validation of this sun-tracking system provide a viable pathway for large-scale deployment in residential, commercial, and industrial applications.
In conclusion, the completion of this project demonstrates that a sun-tracking solar panel system is a highly effective solution for maximizing solar energy capture. Through systematic design adjustments and thorough performance evaluations, we have developed a robust, efficient, and adaptable solar energy system that meets the desired needs and sets a new standard for renewable energy technology. The findings from this project support the continued development and optimization of sun-tracking technologies, promising a brighter and more sustainable energy future.

Chapter 6: Impact Analysis and Project Sustainability.

6.1 Introduction

As we journey through the depths of our project's impact and sustainability, we embark on a quest to uncover the intricate layers of influence woven into its fabric. In this chapter, we don our exploratory hats and venture into the realms of societal, environmental, and cultural landscapes to understand the footprint our solution leaves behind.

6.2 Assess the impact of solution

Table 8 : Social , Environmental and Economic Impact

Environmental Impact	Site/location damage can occur in both short and long term. ❌	The need for energy and natural resources has skyrocketed. ❌	Environmental issues are being brought to the public's attention. ✅	Short-term and long-term site/location damage. ✅	Pollution and waste. ❌
Social Impact	Infrastructure will not reach its full potential in the future. ❌	Pride in the community. ✅	Development of the community. ✅	Disruption of one's way of lifestyle. ❌	Benefits of long-term promotions. ✅
Economic Impact	Product, service, and utility prices have been impacted.❌	Increased trade and business opportunities. ✅	Spending (direct and indirect) .✅	Monthly savings than other options✅	The cost of a failure. ❌

In terms of social impact, long-term promotions offer benefits such as increased awareness and engagement. Additionally, community pride and development contribute to a sense of belonging and progress. The potential future use of infrastructure ensures its optimal utilization.

From an environmental perspective, public attention to environmental issues is crucial. Furthermore, preserving areas for the long term ensures their availability for future generations.

Economically, events generate spending (both direct and indirect), which benefits local businesses and economies. Redevelopment increases property values, while new infrastructure attracts trade and business opportunities. Understanding the costs associated with an event's failure helps mitigate negative economic consequences.

Socially, major changes can disrupt lifestyles, and media influence can shape public perception. Community indifference or hostility may arise, impacting social dynamics. Additionally, larger events may lead to increased security issues.

Regarding the environment, both short-term and long-term site damage can occur due to construction or gatherings. Pollution and waste increase during events.

Economically, impacted product or service prices may result from resource scarcity or increased demand. Wealth distribution may also be unequal within the community.

6.3 Evaluate the sustainability

Table 9: Sustainability Table

Sustainability Dimension	**Positive Aspects**	**Negative Aspects**
Environmental Sustainability	- Adoption of renewable energy sources - Optimization of material usage - Implementation of eco-friendly practices	- Potential short-term and long-term site damage - Increased pollution and waste during events
Social Sustainability	- Community engagement and empowerment - Diversity and inclusivity in decision-making - Promotion of social justice and equality	- Disruption of lifestyles due to major changes - Increased security issues during large events
Economic Sustainability	- Promotion of local businesses and economies - Increase in property values due to redevelopment	- Potential unequal wealth distribution within the community - Impacted product or service prices due to resource scarcity

	- Attraction of trade and business opportunities	
Cultural Sustainability	- Preservation and celebration of cultural heritage - Respect for indigenous knowledge and practices - Promotion of cultural exchange and dialogue	- Potential community indifference or hostility - Influence of media shaping public perception

Sustainability is the guiding principle for our actions, ensuring our solutions benefit both present and future generations. We carefully assess the environmental impact of our project, aiming to minimize resource use, waste, and ecological harm. By using renewable energy, optimizing materials, and adopting eco-friendly practices, we promote long-term environmental health. Our project emphasizes inclusivity and equity, involving stakeholders in decision-making and fostering transparency and social justice. This approach aims to build resilient, empowered communities. We ensure long-term viability through careful resource management and financial planning. By encouraging entrepreneurship and innovation, we create lasting economic value for all stakeholders. We commit to preserving cultural heritage and diversity, respecting indigenous knowledge, promoting cultural dialogue, and safeguarding traditions. This helps maintain social cohesion and identity. Overall, true sustainability involves balancing environmental, economic, social, and cultural factors, addressing their interconnectedness to benefit both current and future generations.

6.4 Conclusion

In the twilight hours of our exploration, we emerge enlightened, with newfound wisdom guiding our path forward. Through the kaleidoscope of impact and sustainability, we recognize the profound responsibility bestowed upon us as engineers. With this knowledge, we pledge to tread lightly upon the Earth, crafting solutions that not only solve technical challenges but also enrich the lives of all who inhabit this wondrous planet.

Chapter 7: Engineering Project Management

7.1 Introduction

Engineering project management involves assigning, scheduling, and managing resources to complete an engineering project. The project management process involves defining the scope, developing a strategy, managing budgets and timelines, and ensuring project objectives are met. A project consists of numerous phases. To execute a project efficiently and on time, it's important to plan and create timelines for each phase.

7.2 Define, plan and manage engineering project

Here in the project management chart, we have shown which week of the semester was dedicated to which task. In general, all 3 members of the group have participated in every task. We were able to complete our EEE400P two weeks before the semester ended. Also EEE400D works have been completed with one week left. That is why the week boxes are empty there.
The Project Report is not yet finished, we are working on finishing the report writing.

7.2.1 Plan for EEE400P

Table 10: Gantt Chart Summer 2023

Task Name	Assigned to	W1	W2	W3	W4	W5	W7	W8	W9	W10	W11	W12	W13	W14
Topic Selection	All													
Finalizing The Topic selection and making a plan	All													
Multiple Design Approach	All													
Specification, Requirements and Constraints	All													
Component selection	All													
Budget Plan	All													

Ethical issues, safety consideration	All													
Report	All													
Impact and Sustainability	All													

7.2.2 Plan for EEE400D

Table 11: Gantt Chart Fall 2023

Task Name	Assigned to	W1	W2	W3	W4	W5	W7	W8	W9	W10	W11	W12	W13	W14
Evaluation criteria Discussion & Literature review about system design.	All													
Software finding	All													
designed draft circuit for Approach 1 2 3	All													
Update in the Design Approaches	All													
Simulation Report of all design approaches	All													
Report writing and Submission	All													

7.2.3 Plan for EEE400C

Table 12: Gantt Chart Spring 2024

Task Name	Assigned to	W1	W2	W3	W4	W5	W7	W8	W9	W10	W11	W12	W13	W14
Component	All													

Buying														
Circuit Diagram	All													
Coding	All													
Power Output Test	All													
3D Design	All													
Report Writing	All													
3D Print	All													
Preparing Structure	All													
Observing and Test	All													

7.3 Evaluate project progress

For FYDP-C, we bought components early in the semester, within the first three weeks. Then we started designing the circuit in real life. The coding part took a bit more time than we expected, but it has finished successfully in five weeks. We measured power output and test results on our rooftop. In this project, we acted like a team, and each one of us was helping each other and responsible. In our work, we displayed great collaboration, creative thinking, and technical prowess. Our solar tracking system was a success, demonstrating the ability to combine our talents to develop a useful and significant solution. We might improve future project outcomes by strengthening our time management, dispute resolution, and documentation methods. Our efforts not only aided our academic development, but also set the road for future improvements in solar energy technology.

7.4 Conclusion

As new project members we face problems such as limited supply, budgetary constraints, and task distribution to achieve project milestones. To overcome hurdles and achieve goals, it's crucial to demonstrate scenario management abilities. Our Final Year Design Project (FYDP) created several obstacles, but with the help of ATC panel members, we efficiently solved all issues.

Chapter 8: Economical Analysis.

8.1 Introduction

Solar trees with sun tracking devices considerably improve the efficiency of solar energy generation, resulting in higher power output. Despite the larger initial investment, solar tracking systems might be more cost effective in the long term owing to improved electricity generation. For example, studies have found that single-axis and dual-axis solar tracking systems may enhance power generation by 24.367% and 32.247%, respectively, when compared to fixed systems. This greater efficiency may result in a reduced Levelized Cost of Electricity (LCOE) and a shorter payback time. However, the real economic viability might vary depending on factors such as local solar irradiation, system cost, and local energy pricing, thus a full feasibility analysis is necessary prior to implementation.

8.2 Economic analysis (multiple design..)

Economic analysis involves a comprehensive evaluation of the financial implications of a project. This process includes identifying all costs associated with the project, such as initial capital investment, operational expenses, maintenance costs, and potential future expenditures. Additionally, it examines the financial benefits, including revenue generation, cost savings, and other economic advantages that the project might bring.

In this project, the economic analysis was conducted by first listing all the anticipated costs, including the procurement of materials, labor, equipment, and any additional resources required for project implementation. We also considered operational costs such as energy consumption, maintenance, and repair expenses. On the benefits side, we evaluated potential revenue streams, cost reductions from increased efficiency, and long-term financial gains.

8.2.1 Design Approach 1 (Time Based)

Creating a small model of a time-based solar tracker system involves relatively modest economic expenses compared to full-scale installations. The primary costs include purchasing miniature solar panels, a microcontroller (such as an Arduino), servo motors or linear actuators for movement, and sensors like light-dependent resistors (LDRs) to track the sun's position. Additional costs might cover materials for constructing the frame and any necessary wiring and power supplies. Software costs are minimal, as open-source platforms can be used for programming the microcontroller. Overall, building a small-scale model typically costs between 15000 BDT to 20000 BDT, depending on the quality and complexity of the components. This investment provides a valuable educational tool and proof of concept, demonstrating the principles and potential benefits of solar tracking technology.

Table 13: Price of small scale RTC based solar tree

Components	Unit	Price(BDT)
Raspberry Pi	1	10449
DS3231 RTC Module with Battery	1	330
Servo Motor	5	419
Mounting Hardware	1	1500
LED	1	340
Solar Panel (Mini)	5	1100
Safety sensor	2	360
Total		14372

8.2.2 Design Approach 2

Creating a small-scale camera-based solar tracking gadget requires multiple costly components. The core hardware consists of a high-resolution camera (1100 BDT), a microprocessor such as an Arduino or Raspberry Pi, two servo motors for azimuth and elevation movement, and a solar panel. Additional expenditures include mounting structures, a power supply, and miscellaneous components like cabling and connections. Hiring a developer can cost around 20000 more than using open-source libraries or DIY coding. The entire cost is anticipated to be between BDT 18000 and BDT25000, depending on the individual components used and whether professional software development is necessary.

8.2.3 Design Approach 3 (LDR Based)

Creating a small model of an LDR sensor-based solar tracker system involves several key economic expenses. These include procuring components such as miniature solar panels, LDR sensors to detect light intensity, a microcontroller (like an Arduino) for processing sensor data and controlling the movement, and servo motors or actuators to adjust the panel's position. Additionally, costs cover the materials needed for constructing a sturdy frame, as well as wiring and connectors for electrical connections. Software development expenses are minimal, thanks to the availability of open-source platforms and community resources. The project may also incur costs for tools and miscellaneous supplies essential for assembly and testing. Overall, these expenses collectively contribute to creating an effective and functional small-scale solar tracking model.

Table 14: Price of small scale RTC based solar tree

Component	Cost (in BDT)
Axis Tracker	2000
Arduino	1895
PV Panels	2400
Light Dependent Resistor (LDR)	180
Jumper Wires	500
Display	600
structure	2000
Total Cost	9575

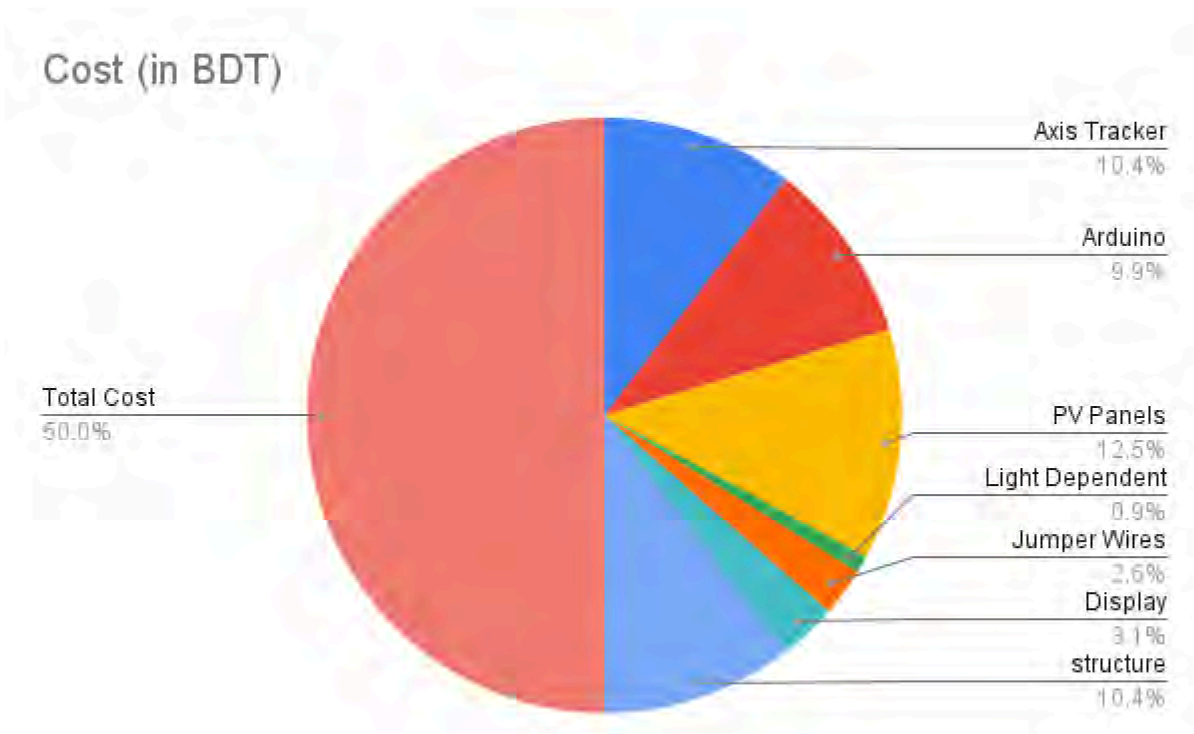


Figure 15: Cost Ratio

The total initial cost for implementing the project amounts to 9575 BDT. This includes the cost of hardware components such as the axis tracker, Arduino, photovoltaic (PV) panels, LDR sensors, jumper wires, display, and structure.

8.3 Cost benefit analysis

Cost-benefit analysis (CBA) is performed to compare the total expected costs with the total expected benefits, providing a clear picture of the project's financial feasibility.

Costs:

Initial Costs: 9575 BDT
Annual Operational Costs: 500 BDT
Benefits:

Annual Energy Savings: 6500 BDT
The initial costs are a one-time expense, while the operational costs and energy savings are recurring annually. To calculate the net benefit, we subtract the total annual costs from the total annual benefits.

Net Benefit (Annual):

$$\text{Net Benefit} = \text{Annual Energy Savings} - \text{Annual Operational Costs}$$

$$\text{Net Benefit} = 6500\ \text{BDT} - 500\ \text{BDT}$$

$$\text{Net Benefit} = 6000\ \text{BDT}$$

The net benefit of 6000 BDT does not account for the initial costs. To determine when the project becomes profitable, we need to consider how many years it will take to recover the initial costs.

Break-even Point:

$$\text{Break-even Point} = \text{Initial Costs} / \text{Net Benefit (Annual)}$$
$$\text{Break-even Point} = 9575\ \text{BDT} / 6000\ \text{BDT/year}$$
$$\text{Break-even Point} \approx 1.6\ \text{years}$$

This means that in approximately 1.6 years, the project will have paid for itself, and after that, it will start generating a net benefit annually.

For the environmental benefits, since they are harder to quantify monetarily, we acknowledge their significant value in terms of sustainability and long-term environmental impact, which adds to the overall benefit of the project.

8.4 Evaluate economic and financial aspects

The cost-benefit analysis of our solar tracker project highlights its strong financial and environmental benefits. With an initial investment of 9575 BDT, the project incurs an annual operational cost of 500 BDT while generating annual energy savings of 6500 BDT. This results in a net annual benefit of 6000 BDT, clearly showcasing the project's economic value.

ROI is calculated by dividing the net benefit by the initial costs and then multiplying by 100 to get a percentage:

$$ROI=(\text{Initial CostsNet Benefit})\times100\%$$

$$ROI=(9575\ \text{BDT}6000\ \text{BDT})\times100\%$$

$$ROI\approx62.7\%$$

This ROI of approximately **62.7%** is quite substantial, indicating that the project is expected to be profitable.

The high ROI and quick break-even point underscore the project's economic viability. The positive cash flow projections from the second year onwards further confirm the financial sustainability of the project.

Beyond financial metrics, our project delivers significant environmental benefits by reducing dependence on non-renewable energy sources and lowering greenhouse gas emissions. These environmental benefits, although not quantified monetarily, add considerable value and align with global sustainability goals.

8.5Conclusion

Economic analysis and cost-benefit analysis are crucial in determining the financial viability and sustainability of engineering projects. By thoroughly evaluating the economic aspects and projecting financial metrics, we can make informed decisions that maximize economic value and ensure the project's long-term success.

Chapter 9: Ethics and Professional Responsibilities

9.1 Introduction

We have certain ethical and professional obligations that we must uphold when developing and executing our project. Professional codes of conduct, which outline the expected standards of behavior for members of a profession, are based on these professional ethical principles. They also seek to establish standards for behavior among professionals and society at large. The purpose of codes of conduct is to provide a minimum acceptable level of behavior in a professional setting. Several universal ethical concepts are applicable to all professions, such as accountability, honesty, loyalty, trustworthiness, and respect for others. They also include abiding by the law, doing good deeds and preventing harm to others.

9.2 Identify ethical issues and professional responsibility

Three steps have been recognized for ethical consideration. When a project is in the planning phase, it is common to consider professional duties and ethical concerns. Several ethical concerns, such as preserving equilibrium, being attentive to local community needs, and assessing the benefits and risks, must be taken throughout the planning stage. If one of these is left out, the ethical consideration suffers. Now that the project is in its implementation phase, professional duties and ethical issues including informed consent, privacy and confidentiality, standard of care, autonomy, and consent must be addressed from the start.

9.3 Apply ethical issues and professional responsibility

TABLE 15: ETHICAL CONSIDERATION FOR THE DESIGN

Ethical Considerations	**Planning Phase**	**Implementation Phase**	**Conclusion/Review Phase**
Maintaining Equilibrium	Striking a balance between project objectives and ethical standards.	Ensuring that project goals align with ethical principles and do not compromise integrity or social responsibility.	Reflecting on whether the project achieved its objectives while upholding ethical standards and addressing any discrepancies

			or ethical dilemmas encountered during implementation.
Being Sensitive to Community Needs	Understanding and addressing the needs, values, and concerns of the local community.	Conducting thorough stakeholder analysis and community consultations to understand community perspectives and incorporate their input into project planning.	Evaluating the project's impact on the community, considering feedback from stakeholders, and identifying areas where community needs were addressed effectively or where improvements could be made.
Weighing Rewards and Hazards	Thoroughly evaluating potential benefits and risks associated with the project.	Conducting risk assessments and cost-benefit analyses to assess the potential positive outcomes against any negative consequences or risks involved.	Reviewing the actual outcomes of the project and comparing them to the anticipated benefits and risks identified during the planning phase, identifying any unforeseen risks or benefits that emerged during implementation.

Ensuring Informed Consent	Obtaining consent from stakeholders and ensuring clear understanding of project objectives, risks, and benefits.	Obtaining informed consent from participants involved in the project, ensuring they understand their rights, the purpose of the project, and any potential risks or benefits associated with their participation.	Reviewing the consent process to ensure it was conducted ethically and in compliance with relevant regulations and guidelines, addressing any issues or concerns raised by participants, and documenting consent procedures for transparency and accountability.
Maintaining Privacy and Confidentiality	Safeguarding the privacy and confidentiality of sensitive information collected during the project.	Implementing robust data protection measures, such as encryption, access controls, and data anonymization, to ensure the confidentiality and integrity of personal or sensitive data collected during the project.	Reviewing data handling practices to ensure compliance with privacy regulations and ethical standards, conducting data audits to identify any breaches or vulnerabilities, and addressing any incidents or breaches promptly and transparently to mitigate risks and uphold trust with stakeholders.

Upholding a High Standard of Care	Providing services with competence, diligence, and professionalism.	Ensuring that project activities are carried out with the highest level of expertise, adhering to industry standards, best practices, and ethical guidelines to safeguard the well-being and interests of all stakeholders involved.	Evaluating the quality of project deliverables and services provided, assessing whether project activities were conducted with professionalism and integrity, and addressing any deviations from standards or ethical lapses through corrective actions or improvements in future projects.
Respecting Autonomy and Obtaining Consent	Respecting individuals' autonomy and obtaining voluntary consent for participation.	Respecting participants' right to self-determination and autonomy, ensuring that they are free to make informed decisions about their involvement in the project and have the opportunity to withdraw consent at any time without coercion or pressure.	Reviewing participant interactions and consent processes to ensure that autonomy was respected throughout the project, addressing any instances where participants' rights were not upheld or where consent procedures were inadequate or coercive, and implementing measures to improve consent protocols in future projects.

9.4 Conclusion :

Our solar panel tracking gadget project is based on ethical values that value environmental sustainability, social responsibility, and transparency. Recognizing the critical need to move to renewable energy sources, our initiative seeks to increase solar energy efficiency, reducing dependency on fossil fuels and lowering carbon footprints. We are committed to making our technology accessible and cheap, encouraging energy fairness across socioeconomic groups. We follow strict safety requirements when developing and deploying our gadget to avoid any potential harm to users or the environment. We communicate honestly and transparently about our device's capabilities and limits, avoiding false promises. Our solar panel tracking gadget project is based on ethical values that value environmental sustainability, social responsibility, and transparency. Recognizing the critical need to move to renewable energy sources, our initiative seeks to increase solar energy efficiency, reducing dependency on fossil fuels and lowering carbon footprints. We are committed to making our technology accessible and cheap, encouraging energy fairness across socioeconomic groups. We follow strict safety requirements when developing and deploying our gadget to avoid any potential harm to users or the environment. We communicate honestly and transparently about our device's capabilities and limits, avoiding false promises.

Chapter 10: Conclusion and Future Work.

The project "Solar Tree with Tracking Facilities for Solar Power Output Enhancement" represents a significant advancement in renewable energy technology. By integrating solar tracking capabilities into a solar tree structure, the project aimed to maximize the efficiency and output of solar power generation. This multidisciplinary endeavor involved elements of electrical, mechanical, and control engineering.

10.1 Project Summary

Key Findings

The tracking mechanism effectively aligns the solar panels with the sun's position, maximizing energy absorption.

The average power generation per hour was 0.25 watts, with a daily total of 2.48 watts.

The system maintained functionality throughout the operational hours of 9 AM to 6 PM.

10.1.1 Prototype Summary

This project aimed to analyze the average daily electrical output of a system over a 30-day period, focusing on key parameters such as voltage, current, and power. Data was collected at hourly intervals from 9 AM to 6 PM. The analysis reveals variations in these parameters throughout the day, providing insights into the system's performance and efficiency.

The data indicate that the voltage values range from 3.661 V to 6.17 V, with the highest voltage typically occurring around noon, suggesting optimal system performance during midday when solar intensity is likely at its peak. The current shows minor fluctuations, staying within a narrow range of 0.016 A to 0.060 A. The power output, calculated as the product of voltage and current, varies accordingly, with values ranging from 0.06 W to 0.32 W.

The power output reaches its peak around mid-morning to early afternoon, indicating the system's highest efficiency during these hours. This pattern is consistent with expected solar power generation curves, which generally peak when the sun is highest in the sky.

This analysis demonstrates that the system performs most effectively during specific hours of the day, highlighting the importance of time-of-day optimization in power management strategies. These findings can inform future adjustments and improvements to enhance overall efficiency and energy capture.

Table 16 : Daily Analysis of Project Output

Time	**Voltage (v)**	**Current (amp)**	**Power (w)`**
9	4.80	0.050	0.24
10	5.30	0.060	0.32
11	5.56	0.058	0.32
12	6.17	0.050	0.31
1	6.03	0.051	0.31
2	5.98	0.043	0.26

3	5.91	0.042	0.25
4	5.36	0.043	0.23
5	4.63	0.039	0.18
6	3.661	0.016	0.06

Table 17 : monthly analysis of project output

Day Type	**Average Voltage (V)**	**Average Current (A)**	**Average Power (W)**	**Total Daily Power (Wh)**	**Fixed Panel Daily Power (Wh)**	**Improvement (%)**
Sunny Day (22)	5.56	0.058	0.32	3.52	2.61	34.9
Cloudy Day (4)	3.70	0.028	0.10	1.10	0.82	34.1
Rainy Day (1)	2.30	0.015	0.03	0.30	0.22	36.4

Autonomous Day (3)	5.85	0.060	0.35	3.85	2.80	37.5

1. Sunny Days (22 days):
   a. Total Energy (Tracking):
      i. $22\times3.52\ Wh=77.44\ Wh$
      ii. $22\times3.52Wh=77.44Wh$

   b. Total Energy (Fixed):
      i. $22\times2.61\ Wh=57.42\ Wh$
      ii. $22\times2.61Wh=57.42Wh$

2. Cloudy Days (4 days):
   a. Total Energy (Tracking):
      i. $4\times1.10\ Wh=4.40\ Wh$
      ii. $4\times1.10Wh=4.40Wh$
   b. Total Energy (Fixed):
      i. $4\times0.82\ Wh=3.28\ Wh$
      ii. $4\times0.82Wh=3.28Wh$
3. Rainy Day (1 day):
   a. Total Energy (Tracking):
      i. $1\times0.30\ Wh=0.30\ Wh$
      ii. $1\times0.30Wh=0.30Wh$

   b. Total Energy (Fixed):
      i. $1\times0.22\ Wh=0.22\ Wh$
      ii. $1\times0.22Wh=0.22Wh$

4. Autonomous Days (3 days):
   a. Total Energy (Tracking):
      i. $3\times3.85\ Wh=11.55\ Wh$
      ii. $3\times3.85Wh=11.55Wh$

b. Total Energy (Fixed):
   i. $3\times2.80\ Wh=8.40\ Wh$
   ii. $3\times2.80Wh=8.40Wh$

Total Monthly Energy Output:

Sun-Tracking Panel:

$77.44\ Wh+4.40\ Wh+0.30\ Wh+11.55\ Wh=93.69\ Wh$

Fixed Panel:

$57.42\ Wh+3.28\ Wh+0.22\ Wh+8.40\ Wh=69.32\ Wh$

Overall Improvement:

Improvement=(93.69 Wh−69.32 Wh)69.32 Wh×100%=35.1%

Improvement=

$$\frac{(93.69Wh-69.32Wh)}{69.32Wh}\times100\% = 35.1\%$$

10.2 Future work

Future work should focus on expanding the data collection period beyond 30 days to account for seasonal variations in solar intensity and weather conditions. Incorporating data from different seasons will provide a more comprehensive understanding of the system's performance year-round.

Additionally, investigating other factors that may affect the system's efficiency, such as temperature, humidity, and potential shading, could yield valuable insights. Implementing sensors to measure these environmental variables alongside electrical parameters will enhance the analysis.

Moreover, exploring advanced optimization techniques, such as maximum power point tracking (MPPT), could further improve the system's efficiency. Testing different types of solar panels and configurations may also lead to performance enhancements.

Incorporating predictive analytics and machine learning models to forecast power output based on historical data and weather forecasts can help optimize energy usage and grid integration. This approach will facilitate more efficient energy management and better integration with other renewable energy sources.

Finally, engaging with stakeholders and the local community to understand their energy needs and preferences will ensure that the system aligns with user requirements and maximizes its social and economic benefits. This holistic approach will contribute to the project's sustainability and success.

Chapter 11: Identification of Complex Engineering Problems and Activities.

11.1 Attributes of Complex Engineering Problems (EP)

	Attributes Put tick (√) as appropriate
P1	Depth of knowledge required √
P2	Range of conflicting requirements √
P3	Depth of analysis required √
P4	Familiarity of issues √
P5	Extent of applicable codes

P6	Extent of stakeholder involvement and needs
P7	Interdependence

11.2: Provide reasoning how the project address selected attribute (EP)

The project addresses several complex engineering problem (EP) attributes through its comprehensive approach. It requires a deep knowledge of electrical engineering principles, photovoltaic technology, and renewable energy systems to accurately analyze voltage, current, and power output data. Balancing conflicting requirements such as maximizing performance while controlling costs, and ensuring system efficiency without compromising durability, is essential. The project involves intricate analysis to ensure data accuracy, recognize performance patterns, and perform predictive maintenance, necessitating advanced modeling and optimization techniques. This ensures that the solar power system operates efficiently, meets community energy needs, and maintains environmental sustainability.

11.3 Attributes of Complex Engineering Activities (EA)

	Attributes	**Put tick (√) as appropriate**
A1	Range of resource	√
A2	Level of interaction	√
A3	Innovation	
A4	Consequences for society and the environment	√
A5	Familiarity	

11.4 Provide reasoning how the project address selected attribute (EA)

The project effectively addresses several attributes of complex engineering activities (EA). It utilizes a wide range of resources, including advanced photovoltaic panels, state-of-the-art monitoring equipment, and analytical software, demonstrating A1: Range of resource. The project involves significant interaction between various stakeholders, such as engineers, local community members, and regulatory bodies, fulfilling A2: Level of interaction. Additionally, the project has profound consequences for society and the environment, as it contributes to sustainable energy generation, reduces carbon emissions, and promotes energy independence, addressing A4: Consequences for society and the environment. This holistic approach ensures that the project not only meets technical and performance standards but also aligns with broader social and environmental goals.

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Appendix

Logbook

Summer 2023			
Date	Attendee	Summary Of Meeting	ATC Comment
8.6.2023	1.Saklain 2.Asir 3.Al farabi	1. topic finding 2. discussion about FYDP previous semesters	
15.6.2023	1.Saklain 2.Asir	1. 3 topics proposed 2. Research 3 topics	
22.6.2023	1.Saklain 2.Al farabi	1. Selection of the topic 2. Researching about the topic	
6.7.2023	1.Saklain 2.Asir 3.Al farabi	1. Shorten the topic from 'tracking solar system efficiency for a building' to 'Solar Tree with Tracking Facilities for Solar Power Output Enhancement.' 2. Submit papers to atc about the topic	
13.7.2023	1.Saklain 2.Asir 3.Al farabi	1. Prepare a ppt file for the progress presentation 2. Research about the COs and POs 3. Solar panel efficiency with tracker vs. with out tracker	
27.7.2023	1.Saklain 2.Asir 3.Al farabi	1. Submit more papers to atc about the topic 2.Finding challenges in the project 3. Research- How is it going to help	
3.8.2023	1.Saklain 2.Asir 3.Al farabi	1. Research about components, and price 2. Make a 3D model 3. Ethical Consideration	

10.8.2023	1.Saklain 2.Asir 3.Al farabi	1. Flow Chart of the system 2. Risk management 3. Safety 4. Future Work	
17.8.2023	1.Saklain 2.Asir 3.Al farabi	1. Improve ppt file for the progress presentation 2. Paper Research	
23.8.2023	1.Saklain 2.Asir 3.Al farabi	1. Finding suitable software for solar power tracking. Task 1: saklain Task 2: saklain and asir 2. Background research 3. Requirements Task 3: alfarabi	
30.8.2023	1.Saklain 2.Asir 3.Al farabi	1. Familiarizing with Pvsyst 2. Finding Research paper of Control mechanism 3. Selection of tool Task 2: saklain Task 1: saklain and asir Task3: Asir and al farabi	

Fall 2023			
Date/Time /Place	**Attendee**	**Summary of Meeting**	**Comment by ATC**

7-10-2023- 10-10-2023	1.Saklain 2.Asir 3.Al farabi	1.Presentation slide Task 1: saklain 2.report Task 2: Al farabi and asir	
10-10-2023 16-11-2023	1.Saklain 2.Asir 3.Al farabi 1.Saklain 2.Asir	1. PVsyst Task 1: saklain and asir 2. Proteus Task2 : alfarabi 3. Report and asir Task3 : saklain asir and farabi 1. Tinkercad Task1: saklain al farabi 2. Calculation Task2: saklain , Asir	● Video of simulation ● Make a reasonable sized Solar panel ● Calculation motor torque required
23 -11 -2023	1.Saklain 2.Asir 3.Al farabi	1. Dimensions of solar panel Task1 : Asir 2. Online link for solar Panel including price Task2 : Al Farabi Task3 : saklain 3. Orientation simulation Task4 : saklain 4. Axis moment calculation in detail Task5 : Asir Task6 : Asir 5. Slide more pictures Task7 : saklain 6. References in each slides Task8 : saklain 7. Calculation breakdown 8. Stable simulation demonstration (TinkerCad/Proteus)	

30 - 11 - 2023	1.Saklain 2.Asir 3.Al farabi	1. Stable simulation demonstration — Task1 : Saklain Task2 : Saklain (TinkerCad/Proteus) Task3 : Asir and Al Farabi a. Dual axis moment' — Task4 : Asir b. Code — Task5 : Al Farabi c. Correlation with practical model 2. Dimensions of solar panel BD perspective 3. Online link for solar Panel including price BD perspective 4. Tentative total tree function 5. Publication aspect.	Task done from last week 1,2,3,4,5,6,7

7.12.2023	1.Saklain 2.Asir 3.Al farabi	1. Simulate and Efficiency 2. Code	
14.12.2023	1.Saklain 2.Asir 3.Al farabi	1. Stable simulation demonstration 2. Axis moment calculation	
21.12.2023	1.Saklain 2.Asir 3.Al farabi	1. Review everything	

Spring 2024			
Date	Attendee	Summary Of Meeting	ATC Comment
24.1.2024	1.Saklain 2.Asir 3.Al farabi	1. Buy the components 2. Start designing 3d 3. Start Report Writing (after completing 1,2)	

31.1.2024	1.Saklain 2.Asir 3.Al farabi	1. Assemble the components for 1 solar panel 2. Some Edit in code is needed	
7.2.2024	1.Saklain 2.Asir 3.Al farabi	1. some major change in code 2. A motor is not working, it should be replaced with a new one	
14..2.2024	1.Saklain 2.Asir 3.Al farabi	1. Start assembling components for 4 solar panels 2. Bring change in code if needed 3. Print 3d	
21.2.2024	1.Saklain 2.Asir	1. Make a structure 2. Work on the code (panels are not syncing)	
28.2.2024	1.Saklain 2.Asir	1. System Works 2. Test output power 3. make poster 4. pcb design 5. decrease the panel response time with coding	
3.2.2024	1.Saklain 2.Asir	1. Test output power 2. Observe the efficiency	

Related code

```
#include <Servo.h>


Servo horizontalServo; // Servo for horizontal axis

Servo verticalServo;   // Servo for vertical axis
```

```
int horizontalSetpoint = 90; // Setpoint for horizontal servo
int verticalSetpoint = 90;   // Setpoint for vertical servo
int horizontalPosition = 90; // Initial position for horizontal servo
int verticalPosition = 90;   // Initial position for vertical servo
int LDR1 = A0;               // Connect LDR1 to Pin A0
int LDR2 = A1;               // Connect LDR2 to Pin A1
int LDR3 = A2;               // Connect LDR3 to Pin A2
int LDR4 = A3;               // Connect LDR4 to Pin A3
double horizontalKp = 0.5;   // Proportional gain for horizontal axis
double verticalKp = 0.5;     // Proportional gain for vertical axis
double horizontalKi = 0.0;   // Integral gain for horizontal axis
double verticalKi = 0.0;     // Integral gain for vertical axis
double horizontalKd = 0.0;   // Derivative gain for horizontal axis
double verticalKd = 0.0;     // Derivative gain for vertical axis
int errorThreshold = 5;      // Threshold for considering error
int horizontalPin = 7;       // PWM pin for horizontal servo
int verticalPin = 10;        // PWM pin for vertical servo
unsigned long previousMillis = 0;
const long interval = 100;   // Interval for sampling and control loop
(milliseconds)

void setup() {
  Serial.begin(9600); // Initialize Serial Monitor
  horizontalServo.attach(horizontalPin);
  verticalServo.attach(verticalPin);
  pinMode(LDR1, INPUT);
  pinMode(LDR2, INPUT);
  pinMode(LDR3, INPUT);
  pinMode(LDR4, INPUT);
```

```
  horizontalServo.write(horizontalPosition); // Move horizontal servo to initial position
  verticalServo.write(verticalPosition);     // Move vertical servo to initial position
  delay(2000);
}

void loop() {
  unsigned long currentMillis = millis();
  if (currentMillis - previousMillis >= interval) {
    // Record current time
    previousMillis = currentMillis;

    // Read LDR values
    int R1 = analogRead(LDR1);
    int R2 = analogRead(LDR2);
    int R3 = analogRead(LDR3);
    int R4 = analogRead(LDR4);

    // Calculate error for horizontal axis
    int horizontalError = R1 - R2;
    double horizontalCorrection = calculatePID(horizontalError, horizontalKp, horizontalKi, horizontalKd);

    // Calculate error for vertical axis
    int verticalError = R3 - R4;
    double verticalCorrection = calculatePID(verticalError, verticalKp, verticalKi, verticalKd);

    // Update servo positions
```

```
    horizontalPosition = constrain(horizontalPosition +
int(horizontalCorrection), 0, 180);
    verticalPosition = constrain(verticalPosition + int(verticalCorrection),
0, 180);

    // Move servos to new positions
    horizontalServo.write(horizontalPosition);
    verticalServo.write(verticalPosition);

    // Print debug information
    Serial.print("Horizontal Error: ");
    Serial.print(horizontalError);
    Serial.print(", Vertical Error: ");
    Serial.println(verticalError);
  }
}

// Function to calculate PID correction
double calculatePID(int error, double Kp, double Ki, double Kd) {
  static double integral = 0;
  static double previousError = 0;

  // Proportional term
  double P = Kp * error;

  // Integral term
  integral += error;
  double I = Ki * integral;

  // Derivative term
```

```
  double derivative = error - previousError;
  double D = Kd * derivative;

  // Update previous error
  previousError = error;

  return P + I + D;
}
```