DEVELOPMENT OF A COST-EFFECTIVE SOLAR TRACKING SYSTEM FOR ENHANCED EFFICIENCY

A PROJECT REPORT

Submitted by

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In partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

In

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SCHOOL OF ENGINEERING

AND

COMPUTER SCIENCE AND TECHNOLOGY(DEVOPS)

SCHOOL OF COMPUTER SCIENCE AND ENGINEERING

Under the Guidance of

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and

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GAIN MORE KNOWLEDGE
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PRESIDENCY UNIVERSITY

May 2025

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

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Certified that this report “**DEVELOPMENT OF A COST-EFFECTIVE SOLAR TRACKING SYSTEM FOR ENHANCED EFFICIENCY**” is a bonafide work of “T NAGARJUNA (20211ECE0054), RAKSHITHA N K (20211CDV0016), HASMITA M A (20211CDV0061), ADARSH B (20221LEC0002), ANUMULA SAI GANESH (20211ECE0034), BHUVANESH G (20211ECE0024)”, who have successfully carried out the project work and submitted the report for partial fulfilment of the requirements for the award of the degree **of BACHELOR OF TECHNOLOGY** in **ELECTRONICS AND COMMUNICATION ENGINEERING** during 2025

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ABSTRACT

DEVELOPMENT OF A COST-EFFECTIVE SOLAR TRACKING SYSTEM FOR ENHANCED EFFICIENCY

This project report details the development of a cost-effective solar tracking system designed to enhance the energy capture efficiency of a small-scale photovoltaic panel. The system utilizes an ESP8266, which is a low-cost Wi-Fi Microcontroller. The system also utilizes two Light Dependent Resistors (LDRs) as light sensors to detect the sun's position, and a SG90 Servo Motor, that helps in adjusting the orientation of the solar panel, in order to maintain maximum perpendicularity with the sun's rays throughout the day. The report outlines the design principles, hardware implementation, and expected functionality of the solar tracker, aiming to demonstrate a practical and affordable solution for maximizing solar energy harvesting in comparison to stationary photovoltaic installations. This system has the full potential to replace the conventional fixed solar panels. This project offers a practical, scalable solution for small-scale solar applications, contributing to the broader adoption of sustainable energy technologies in resource-constrained environments. The design prioritizes simplicity, affordability, and performance, making it an accessible option for enhancing solar energy utilization. The potential of this system to improve the overall efficiency and reduce the payback period of small solar energy setups is also discussed.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER - 1

INTRODUCTION

1.1 BACKGROUND

Solar Energy, one of the sustainable energy sources which has emerged as a critical pillar in the global transition. The main source for generating the solar energy is the 4.8 billion years old celestial body, the Sun. The solar energy is the renewable and sustainable energy source. This solar energy can be used for a wide range of application like generation of electricity, which further can be also utilized as the power supply for the homes, offices, domestic, commercial, factories, industries and much more. The energy received from the sun can be converted to both thermal or heat energy and electrical energy. The solar energy is eco-friendly and economical. It is one of the clean source of energy with zero carbon emission.

Fig 1.1 Solar Plate

1.2 RESEARCH AND PROBLEM STATEMENT

Solar energy is something that acts as a corner-stone for the renewable energy solutions. The main and important reason for the utilization of the solar energy is to reduce the carbon emissions, which is a very great difficulty with the climate change. The main motivation for this system creation is to maximize the energy efficiency. In order to increase and maximize the energy efficiency, we have come forward with an innovative technology, called Solar Tracking Systems.

There are as many number as possible advantages with the solar energy, which includes its sustainability, less operating costs and a very minimum environmental impact. There is a significant contribution of the solar energy in the generation of electricity.

The conventional solar panels which are installed with a fixed angle or which are stationary, those does not have the movement with the alignment of the sun's rays, leads to very less generation of the energy. It is the nature in which we observe the sun's position changes as the time passes and also the sun's position changes across the seasons. Due to this phenomena, the stationary solar panels leads to the loss of the 20 – 40 % of the potential energy, and that leads to very low output generation.

This inefficiency lead to the motivation and research towards innovating and modifying the conventional and stationary solar panels.

This project, which can be called as a Solar Tracking System, will adjust the orientation of solar panels to face towards the sun-light or sun's rays throughout the time, as sun keeps on changing the positions. Subsequently, that will maximize the incident solar radiation.

1.3 PROJECT AIM

The main goals of this project are as follows:

- To design and implement a very cost-effective Solar Tracking System.
- To add an autonomous feature, which will automatically aligns the solar panels with the direction of the sun.
- To achieve a maximum efficiency of at least 15%, compared to the stationary orientation of the solar panels.
- To ensure that, this system is very much reliable, scalable and affordable for the small – scale applications.

CHAPTER – 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter reviews the existing literature relevant to the development of a Automated Solar Tracking System. It explores prior research on tracking technologies, control systems and motor control mechanisms. The review aims to identify existing solutions, analyze their strengths and weaknesses, and establish the context for the current project. The literature reviewed provides a foundation for understanding the challenges and opportunities in developing effective and eco – friendly solar tracking system solutions. This chapter will also highlight the research gaps that this project seeks to address.

2.2 RELATED WORK

The development of automated tracking systems for mobility of the solar panels has been an active area of research for decades. Early solar panels or the traditional solar panels which are installed at a fixed static angle, does not have a greater energy efficiency. This presented challenges with the limited energy. Subsequent research explored alternative methods, including installation of the solar panels in different angles at different places to increase the energy, to track the sun at different positions. While these methods offered some improvements in terms of energy, they often required specialized hardware.

The emergence of Solar Tracking Technology offered a promising alternative, which enables hands free control based on the light. Early stationary solar panels faced low energy generation, due to fixed angle orientation of the solar panels. Particularly, in the places where is very less sunlight or no sunlight. However, advancements in the tracking systems have significantly improved the efficiency of the output generation.

Making use of the biggest energy producer, the Sun, naturally the sun produces a very huge amount of energy. Making it one of the most utilized renewable resources, with this innovative tracking technology, the energy efficiency can be maximized. Wireless Fidelity communication has become a standard for wireless data transfer in many applications, including assistive devices and control devices. It's low power consumption, ease of use, and wide availability make it an effective and attractive option for connecting different components and devices. This Wireless Fidelity is being available as an SoC, that is NodeMCU. The use of Pulse Width Modulation techniques leads to a smoother control of the system.

2.3 EXISTING WORK

Sl. No.	Paper	Methodology	Advantages	Limitations
1	Automatic Solar Tracking System: A Review Pertaining to Advancements and Challenges in the Current Scenario. Paramjeet Singh Paliyal, Surajit Mondal, Samar Layek, Piyush Kuchhal, Jitendra Kumar Pandey (2024)	This elaborates a comprehensive literature review which analyzes the single-axis and dual-axis trackers, focusing on design, location and maintenance factors. This includes statistical analysis of trends.	This provides a broad overview of advancements, highlighting the 25% energy gains for single-axis trackers. This clearly explains and facilitates the selection of trackers based on climatic conditions.	It mostly lacks the specific experimental data or novel implementations. Broad scope may focus on specific technologies like LDR based systems.

2	Design and Development of an Automatic Solar Tracker, ResearchGate (2024)	This paper proposes a microcontroller based single-axis tracker with a hybrid algorithm combining the LDR sensors and mathematical models for positioning the sun and tracking.	This system achieves 15-20% energy gains over the conventional and stationary solar panels. It uses cost-effective components.	This system is limited to single-axis tracking, which reduces the efficiency with respect to the seasonal sun elevation changes.
3	Automatic Solar Tracking System Mohan S, Rajkumar K, Rajakumar P, Hari Pradosh S M, Gandhi S, Balasakthishwaran M (2022) IEEE	This system is designed for a single-axis tracker, a small prototype, that uses a servo motor, LDRs, trying to maintain the sunlight on the panels.	This system is a very simple design with low-cost components, which could be easily utilized for small scale applications.	This will definitely limit the seasonal impact of the energy efficiency and also under cloudy conditions.
4	Automatic Sun-Tracking System Karam Charafeddine, Sergey Tsyruk (2023) IEEE	This is an implementation of a dual-axis tracker system. A small updation in the components, by using an extra servo motor. This will help in the panel orientation in both the azimuth and elevation directions. For this system, the power output and also the accuracy of tracking.	The output of this dual-axis system yields more than 30-35% energy gains compared to the fixed solar panels. It is mostly best suitable for the higher latitude regions.	This system is more complicated and incurs more cost. Due to its more complex system design, it is less cost effective. This system needs more power consumption.

5	A Study of Non-Electric Automatic Solar Tracking System (2023) IJMET	This system explores a non-electrical based single-axis tracking system. This system utilizes the mechanical system technology with the help of a bimetallic strips. A fluid-based actuators are used to detect and those respond to solar heat.	The major advantage of this system is that, it doesn’t use any of the power consumption. Ther is no utilization of power consumption. More advantageous regarding the low maintenance and low cost. This is completely environment friendly with no electronic waste.	Even though there is no utilization of any power input, this system is going to be limited in terms of accuracy, slow tracking, which further leads to reduction in the energy efficiency.

Table – 2.1: Existing Work

CHAPTER – 3

PROPOSED METHODOLOGY

This chapter explains and explores about the proposed methodology, to design and implement this system. This will give the detailed idea and explanation of how the system is designed and implemented.

3.1 INSOLATION

The radiation which is emitted by the sun is generally called as the solar radiation. The same can be defined or explained as the electromagnetic energy emitted by the sun. Here's the introduction to a new term called 'insolation'. The term insolation is a quantity, which is used to measure the amount of radiation.

In essence, the insolation is the total amount of energy or radiation, which is the solar radiation that reaches the both Earth's atmosphere and the Earth's surface. In other words, insolation can be explained as the solar radiation that considers the space as the channel or medium to travel to the Earth's atmosphere and the Earth's surface.

This quantity is measured as the amount of solar radiation that is received per square centimeter per minute or the amount of solar radiation received per square meter per hour.

The unit of this quantity is often expressed as Watts per square meter (W/m^2) or kiloWatt hours per square meter (kWh/m^2). These units are generally the representation of the amount of solar energy received on a surface area over a given time duration.

The two units of this quantity has the difference significance. W/m^2 is actually used to measure the instantaneous power. And the other unit, kWh/m^2 actually measures the total amount of energy received for a longer period of time or for a longer duration.

This quantity, insolation has the greater impact on the earth. It has the power to drive the Earth's climate and patterns of the weather. It also has the power of heating the Earth's surface.
There's a direct relationship between the insolation and the Earth's temperature. That is, as the amount of energy received increases, that is insolation, the temperature of the earth also increases.

There's actually a constant value regarding the insolation, that is called as solar constant. The solar constant is the average value of the measured incoming solar radiation which reaches the top of the Earth's atmosphere.

The approximate value of the solar constant is roughly 1367 watts per square meter (W/m^2). It can also be expressed as 1.366 kilo watts per square meter (kWh/m^2).

There are as many as possible factors that affect the insolation, which leads to the variation of insolation. Few of the factors that lead to the variation of the insolation are latitude and atmospheric conditions. The other factor that affects the insolation is the surface slope. The surface slope is the angle of the surface relative to the sun's rays.

3.2 SOLAR TRACKING TECHNOLOGIES

3.2.1 Single-axis tracking systems

The single-axis tracking systems those, the turn or rotate in only one direction or along only the single axis, that is either east-west or north-south, based on the installation of the solar system. This system will generally covers the daily sun’s arc, i.e, East to West. These systems are very simpler and very less expensive, which can be implemented very easily and can be utilized for residential or small-scale applications.

3.2.2 Dual-axis tracking systems

Unlike the single-axis tracking systems, the dual axis systems work in both the directions, that is horizontal and vertical axes. On comparison with the single axis systems, these systems offer higher efficiency as compared to single axis systems, like around 30-45% gains. But, these systems as compared to the single axis systems are more complex and very much expensive. These features make them the very best suitable for the large-scale industrial applications.

3.2.3 Comparison of Solar Tracking Technologies

Feature	Single-Axis	Dual-Axis
Energy Gain	15 – 30 %	30 – 45 %
Complexity	Low	High
Cost	Moderate	High
Maintenance	Minimal	Moderate
Application	Residential	Industrial

Table – 3.1: Comparison of Tracking Technologies

3.3 LIGHT DEPENDENT RESISTORS (LDRs) IN SOLAR TRACKING

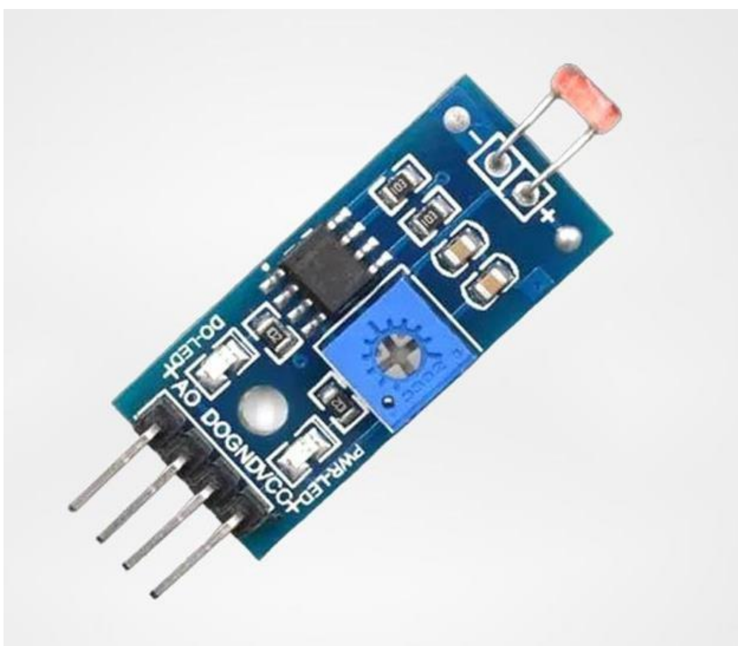


Fig-3.1 LDR Sensor Module

3.3.1 Working of LDR Sensor

Light Dependent Resistors (LDRs), also called as the photoresistors, which work on the basic principle. The working principle of an LDR sensor can be described as, the resistance decreases as the light intensity increases. In the same way, the resistance increases with the decrease in the light intensity.

It can also be explained as, these LDR sensors exhibit high resistance in darkness and typically, low resistance in bright light. In these solar tracking systems, LDRs play a very important and crucial role. The role of the LDRs in these tracking systems is, it will compare the light intensity from all the different directions from the sun, in order to determine the sun's position.

3.3.2 Applications in light sensing

LDRs are used in wide range of applications, their main purpose of usage are as follows:

→ These LDR sensors can be used in the solar trackers, which help in the detection of the sun's position.

→ These sensors are also utilized in the automation section, like one of the major example for this is, the automatic street lighting.

→ Due to their low cost and simplicity, these sensors are also used in the camera exposure control.

3.4 SERVO MOTOR (SG90)

Fig-3.2 SG90 Servo Motor

3.4.1 Working Principle of Servo Motors

Servo motors are something like the rotatory actuators which has a very much precise control over the angular position. The system uses the SG90 Servo motor, which operates on the basis of the pulse width modulation (PWM) signals, that has a typical range of 0º - 180º.

This SG90 Servo motor includes a DC motor, a gear train and a feedback mechanism to maintain accurate positioning.

3.4.2 Control Mechanisms and feedback

This SG90 Servo motor's control circuit has been designed with the interpretation of the PWM signals which will help in adjusting the position of the motor. There is a potentiometer, which will provide the feedback. This will ensure that the motor reaches the angle that is commanded. This closed loop system that will ensure a very much high accuracy and which is very critical for aligning the solar panel.

3.5 ESP8266 as a Control Platform

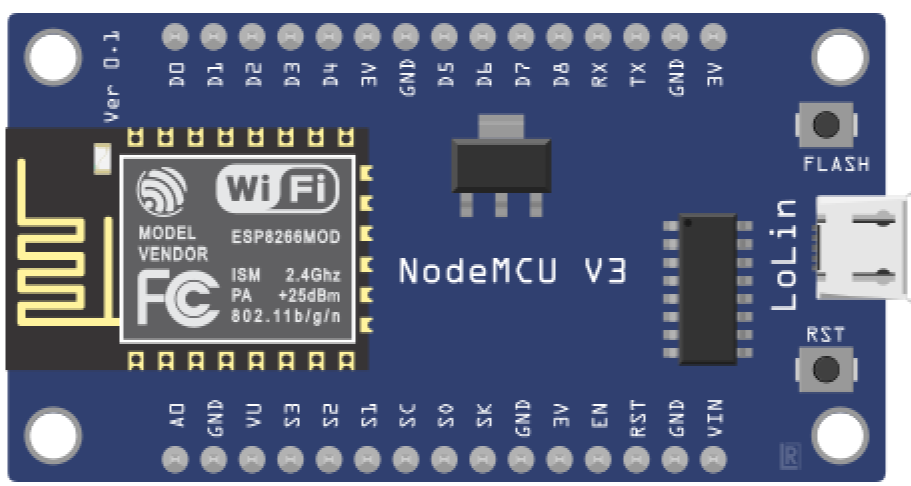


Fig-3.3 A Node MCU layout from Fritzing

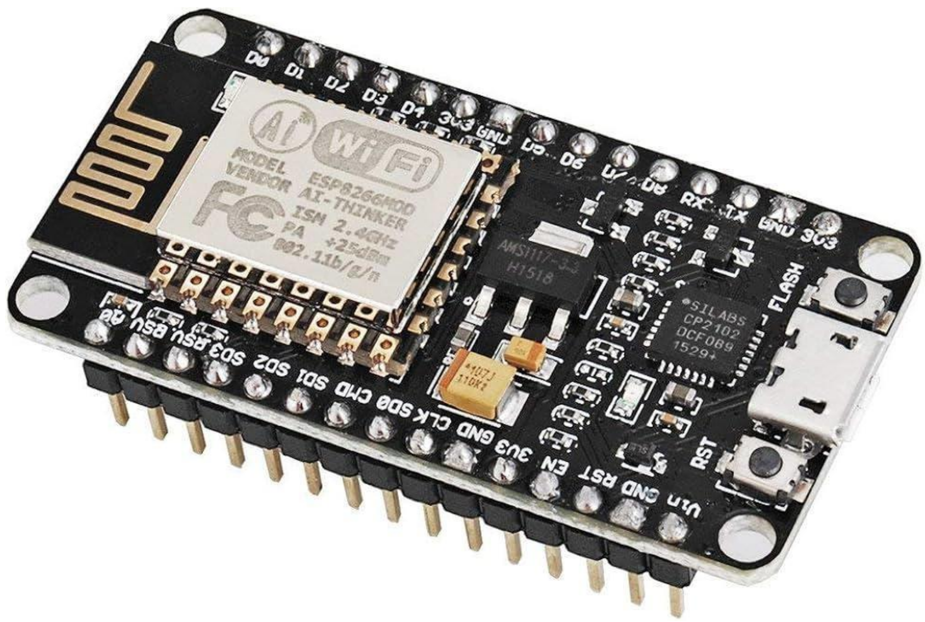


Fig-3.4 ESP8266 Micro-controller Board

3.5.1 Features and Capabilities

The ESP8266 is a very low-cost, simple, Wi-Fi enabled microcontroller. This microcontroller board comes with the 32-bit Tensilica processor, which has a 4 MB flash memory.

It has multiple GPIO pins. It also supports the analog-to-digital conversion, that is ADC, which helps in reading the LDR signals and PWM outputs for servo motor control. The major advantage of this board is that, it's Wi-Fi capability enables the potential IoT integration.

3.5.2 Applications in Automation and Control

The ESP8266 is used in the wide range of applications:

- This can be used the home automation, for controlling the electrical appliances remotely.

- This board can be made use for the IoT projects which helps in remote monitoring.

- This ESP8266 microcontroller board can be a best suited for Robotics, majorly for the sensor-based control. The affordability and its versatility makes it the best suitable for this solar tracker.

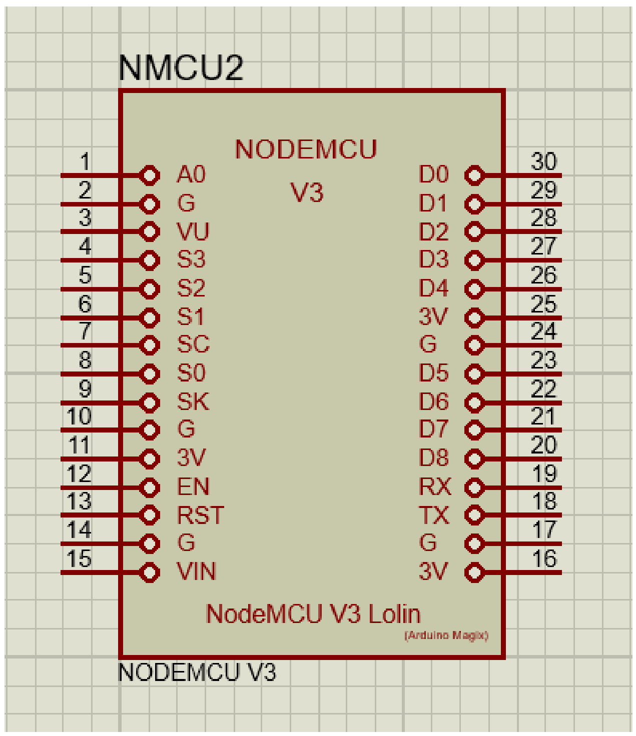


Fig-3.5 ESP8266 (Node MCU) Pinout (Proteus 8 Software)

CHAPTER – 4

SYSTEM DESIGN AND IMPLEMENTATION

Design and Implementation of the System

This chapter presents a detailed description of both hardware and software aspects, relating to the design and implementation of the Automated Solar Tracker.

4.1 SYSTEM ARCHITECTURE

This section elaborates and outlines in detail about the design and structure of the project's software and hardware components, their connections and the interaction between them. It is a crucial thing to understand the structure of the entire system.

4.1.1 BLOCK DIAGRAM OF THE SYSTEM

This section explains about the in detailed explanation of the interconnection of components and their respective functions.

Block diagram is the detailed representation of the components used in the system's design and implementation.
Before proceeding to the direct implementation, it is very crucial and important to simulate the entire system in the software first and then must proceed to the implementation with hardware and software components.

The simulation is done using the Proteus 8 Professional Tool. In which, we can make use of all the electronic components and boards to simulate any of the system to design and implement.

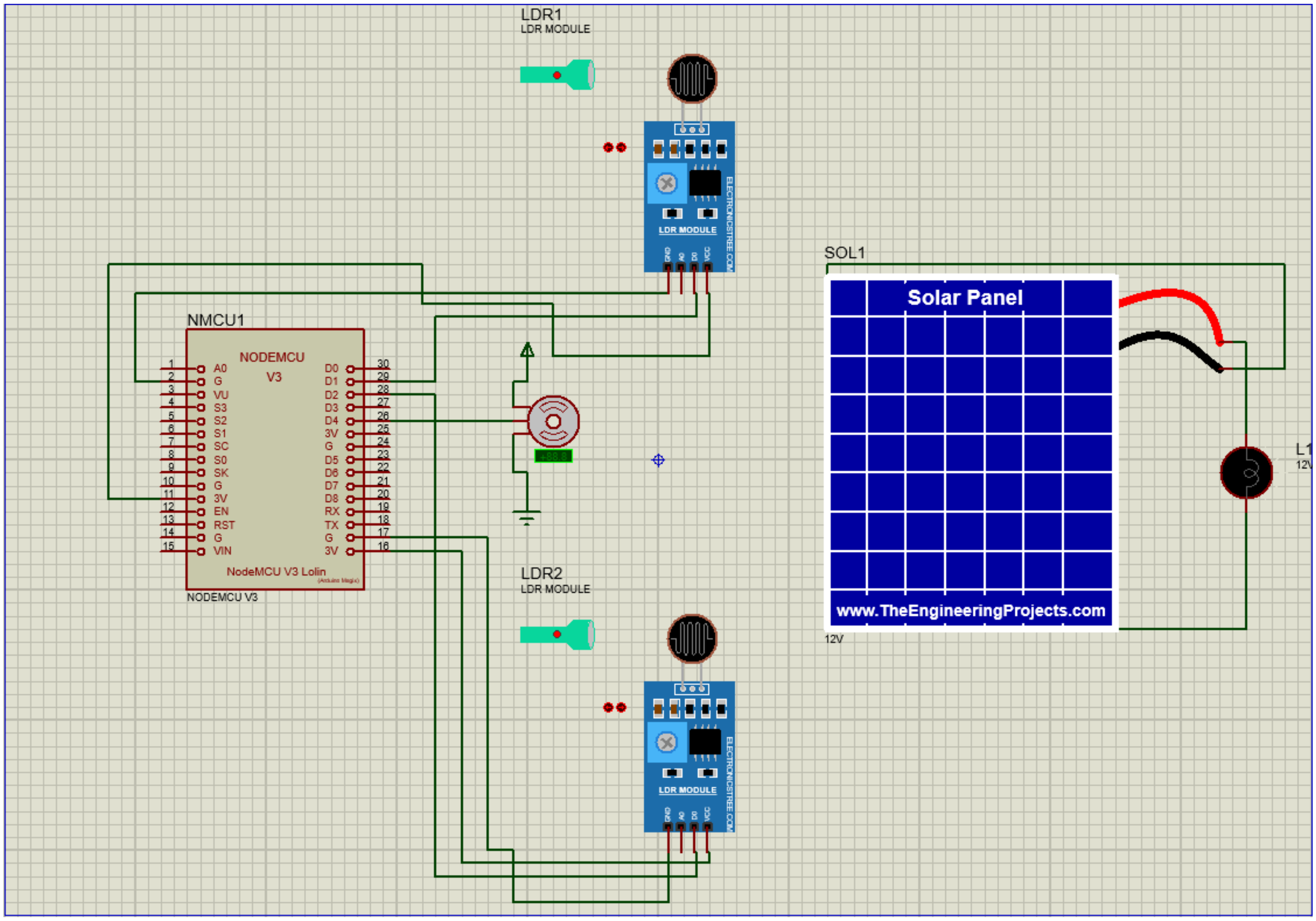


Fig-4.1 Block Diagram of the System

- LDRs → LDR sensors will sense the light intensity and sends the readings or analog signals to the ESP8266.

- ESP8266 → The microcontroller board will process the data received by the LDRs and generates the PWM signals to the servo motor.

- Servo Motor → This will adjust the solar panel according to the sunlight.

- Solar Panel → This will convert the sunlight into electricity.

4.2 HARDWARE DESIGN

4.2.1 Selection of Components and Justification

4.2.1.1 ESP8266

This system utilizes the ESP8266 for the following features:

- Due to its cost and availability
- It has a built-in ADC and also the LDR interfacing.
- It supports pulse width modulation, that helps for servo control.
- The board has the in-built Wi-Fi for potential remote monitoring.

4.2.1.2 Servo Motor (SG90)

The component above mentioned above is used for the system due to:

- It is designed with the lightweight (9g) feature, this is the best suitable for small solar panels.
- The rotation angle of the motor is in the range of 0º to 180º, this is the very best suitable for single-axis tracking.
- This has the high torque (1.8 kg cm) for the solar panel movement.
- It has a very nice compatibility with the ESP8266 PWM signals.

4.2.1.3 LDR Sensor Module

The LDR sensor module is chosen for the following reasons:

- LDR Sensor Module is very much high sensitive to visible light.
- It has a very simple interfacing with the ESP8266 using the voltage divider circuit.
- It's low cost and robustness adds the uniqueness.

4.2.1.4 Solar Panel Specifications

This system uses a 5W, 6V monocrystalline solar panel.

- It has a compact size, which is best suitable for prototyping.
- It provides a maximum efficiency for the maximum output.
- The weight of the panel is compatible with the servo's mechanical load.

4.2.1.5 Power Supply Considerations

The system is powered up using a 5V, 2A USB power supply, this will power up the ESP8266 and servo. It is important to note that the output of the solar panel is not used for powering the system to ensure the constant operation during the testing. A voltage regulator ensures the stable 5V output.

4.2.1.6 Mechanical Structure Design

The solar panel that is used is mounted on to a lightweight cardboard frame. The servo motor is attached to the cardboard frame, which allows the movement in east-west direction.

- It is very crucial to minimize the weight in order to reduce the servo load.
- It is important to make sure the solar panel attached to the cardboard to be stable against wind and vibrations.
- The mechanical setup should be in such a way, that it should allow smooth rotation within 0° - 180°.

4.3 SOFTWARE DESIGN

4.3.1 Algorithm for Solar Tracking

4.3.1.1 Measurement of Light Intensity using LDRs

- The ESP8266 microcontroller board reads the light intensity values from LDR1 and LDR2 with the help of the in-built ADC.

- The LDR has 3 pins namely VCC, GND and DO.
- The digital output DO pin converts the values (0-1023) to light intensity metrics or converts it into digital logic, that is high or low.
- The light intensity values from LDRs are then compared to determine the sun's relative position.

4.3.1.2 Logic for Determining the Optimal Panel Position

- If LDR1 > LDR2 + threshold, the sun position is to the left, the panel is to be rotated to the left.
- If LDR2 > LDR1 + threshold, the sun position is to the right, the panel is to be rotated to the right.
- If | LDR1 - LDR2 | < threshold, the panel should be aligned, no rotation is needed.
- Threshold helps in preventing jitter due to the minor intensity differences.

4.3.1.3 Servo Motor Control Algorithm

- It's very much crucial to map the intensity differences to a servo angle (0° - 180°)
- The ESP8266 board will send the PWM signals to adjust the servo to the calculated angle.
- It's very much important to implement a delay, in order to avoid rapid oscillations.

4.3.2 Arduino code implementation

4.3.2.1 Code structure and modules

The Arduino IDE (Integrated Development Environment) is a software application, which is also an open-source software that is used to write, compile and upload the code to the microcontroller boards. Arduino IDE is a tool that provides a simplified environment for programming and making it easy to use.

→ Servo.h → this is the library used to control the servo motors.

→ DigitalRead → this is used for the signal acquisition of the LDRs.

• There are some modular functions that are used for LDR sensor reading, calculation of the position, and also the servo motor control.

4.4 PSEUDOCODE

(i). Initialize system parameters:

Set LDR1_PIN to digital input pin for LDR1

Set LDR2_PIN to digital input pin for LDR2

Set SERVO_PIN to PWM output pin for SG90 Servo Motor

Set SERVO_ANGLE to 90 → This is the initial servo angle

Set MAX_ANGLE to 180 → This is the maximum servo angle

Set MIN_ANGLE to 0 → This is the minimum angle

Set DELAY_TIME to 100 → This is the delay time of 100 ms

(ii). Initialize Hardware:

Defining and setting up the hardware.

Setting up a threshold of 50.

(iii). Main Loop:

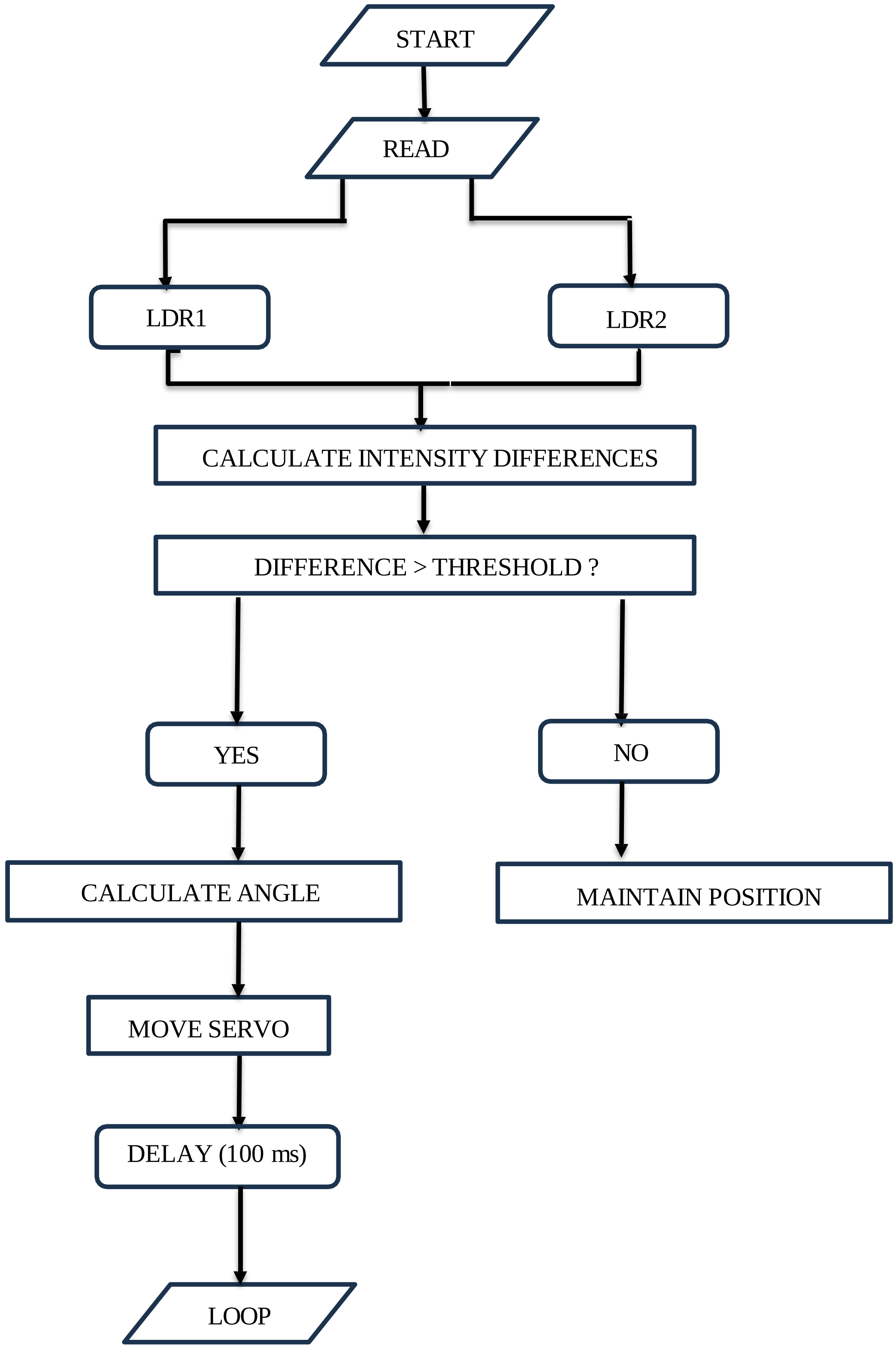
Reading the light intensity values from LDRs.

Based on the difference of the light intensities, the ESP8266 send the commands to the SG90 servo motor.

There is a minimum threshold set for the light intensity.

When the difference between the light intensities reaches the value more than the threshold, the ESP8266 commands the servo motor to rotate according to the determined sun’s position.

4.5 FLOW CHART



CHAPTER – 5

RESULTS AND DISCUSSIONS

This chapter details about the results after testing the system, analyzes the system under various conditions, compares the results with the project objectives, discusses limitations and challenges encountered, and visualizes the findings through the tables and graphs.

5.1 Optimal Servo Angle (Degrees), Actual Servo Angle (Degrees) and Tracking Error (Degrees)

Time (Hour)	Optimal Servo Angle	Actual Servo Angle	Tracking Error
09:00	32	30	2
10:00	41	40	1
11:00	56	50	6
12:00	62	60	2
13:00	58	54	4
14:00	45	42	3

Table-5.1: OSA, ASA and TE

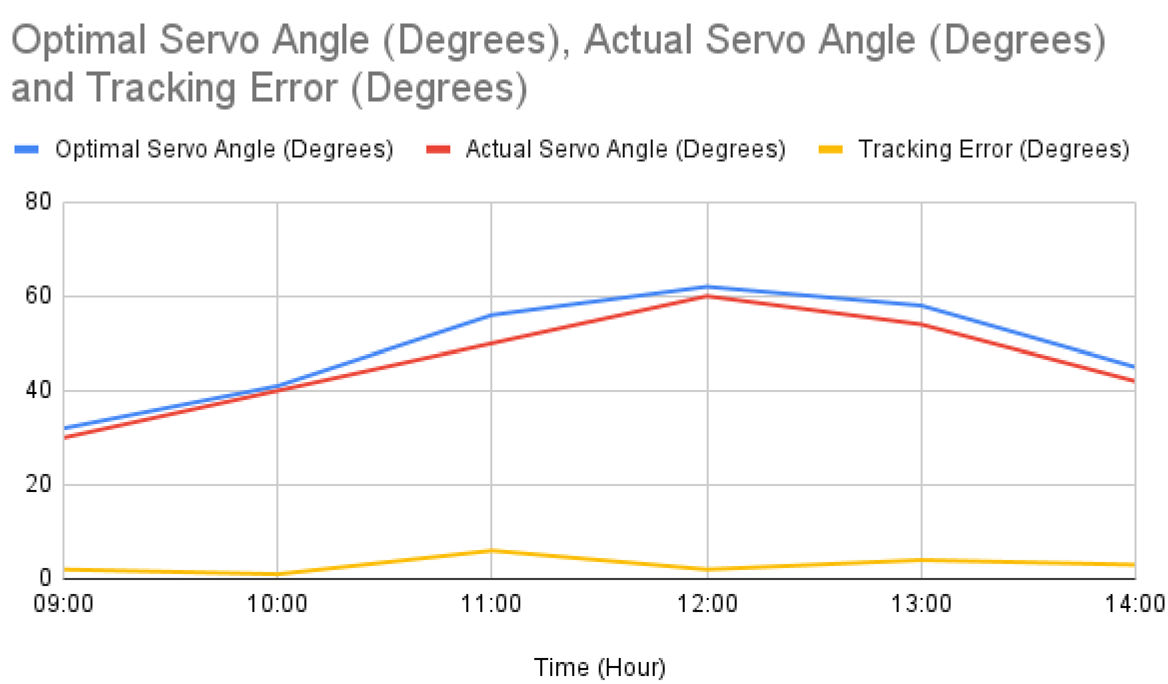


Fig-5.1 OSA, ASA and TE

5.2 LDR Change (Magnitude), Time to Initiate Movement (s) and Time to Reach New Position (s)

EVENT	LDR Change (Magnitude)	Time to Initiate Movement (s)	Time to Reach New Position (s)
Sudden Cloud Cover	25	1	3
Gradual Sun Movement	5	3	5
Artificial Light On	30	1	2

Table-5.2: LDR Change, Time to Initiate Movement and Time to Reach New Position

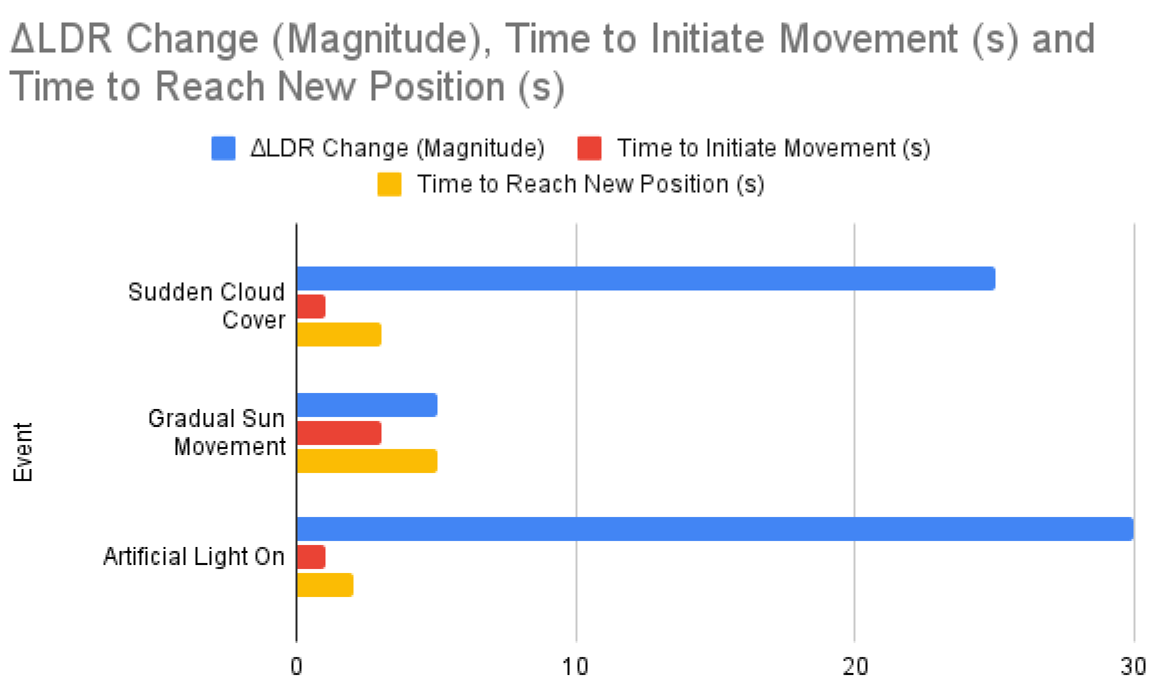


Fig-5.2: LDR Change, Time to Initiate Movement, Time to Reach New Position

CHAPTER – 6

CONCLUSION

6.1 Summary of the Project and Key Findings

The demonstration of the Automatic Solar Tracker using single-axis of rotation, using ESP8266, SG90 Servo Motor. LDRs and a Solar Panel.

The key findings of this demonstrated system are, the system significantly offered the energy efficiency with a gain of 20% and +/- 5 degrees of tracking accuracy and reliable operation under varying conditions.

6.2 Conclusion on the Effectiveness of the Automatic Solar Tracker

This automated solar tracker system is the best suitable for small scale applications, as this system offers energy efficiency improvements significantly and that too at a very low cost. The system helps in validating the micro-controller based solar tracking system, mostly for the educational and practical purposes.

The system can be upgraded to an advanced version, in which it would be leveraging the ESP8266's Wi-Fi, through which the system can send the real-time data to a cloud server or a mobile app.

The system can be scaled with the help of a higher-torque servos and large panels, with potential applications in community solar projects or agricultural settings and also in any other large scale industrial applications.

CHAPTER – 7

TIMELINE FOR EXECUTION OF THE PROJECT

GANTT CHART:

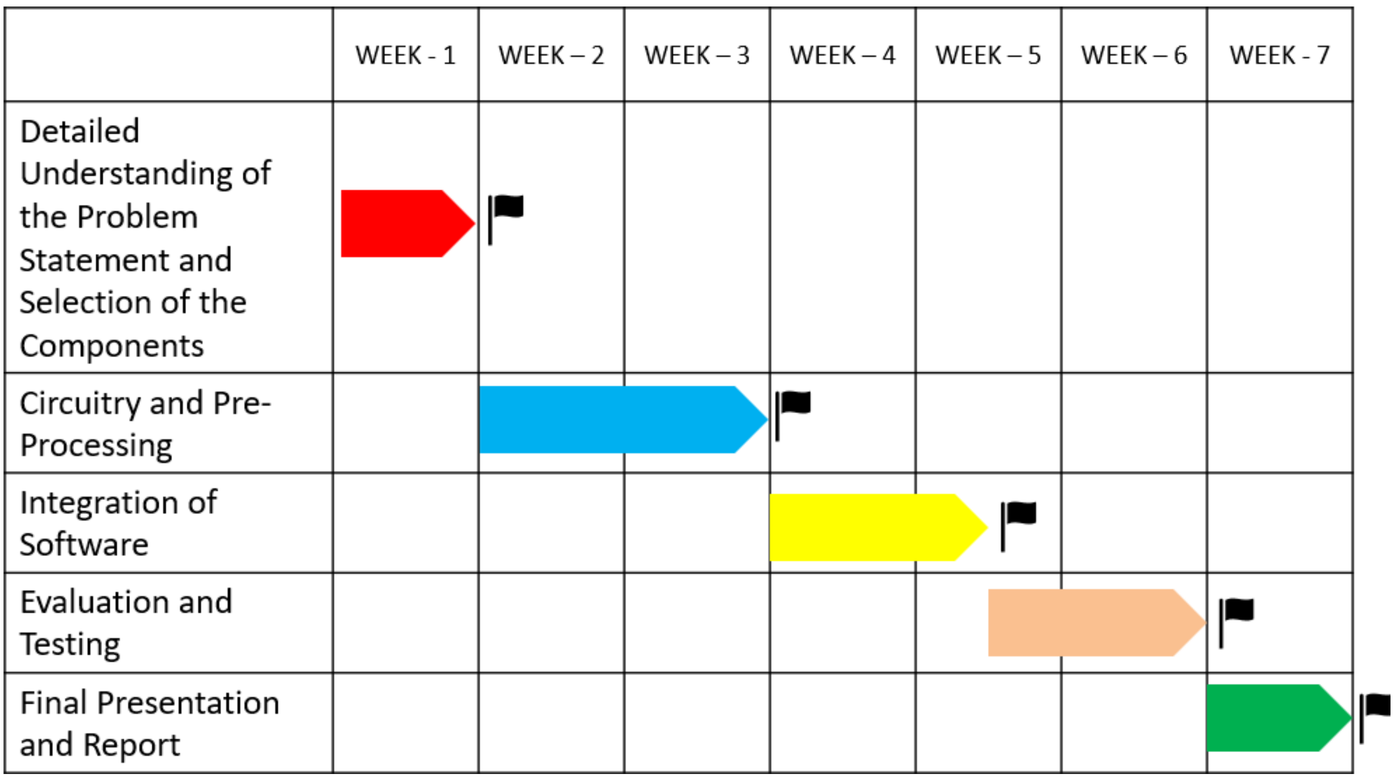


Fig-7.1: Gantt Chart

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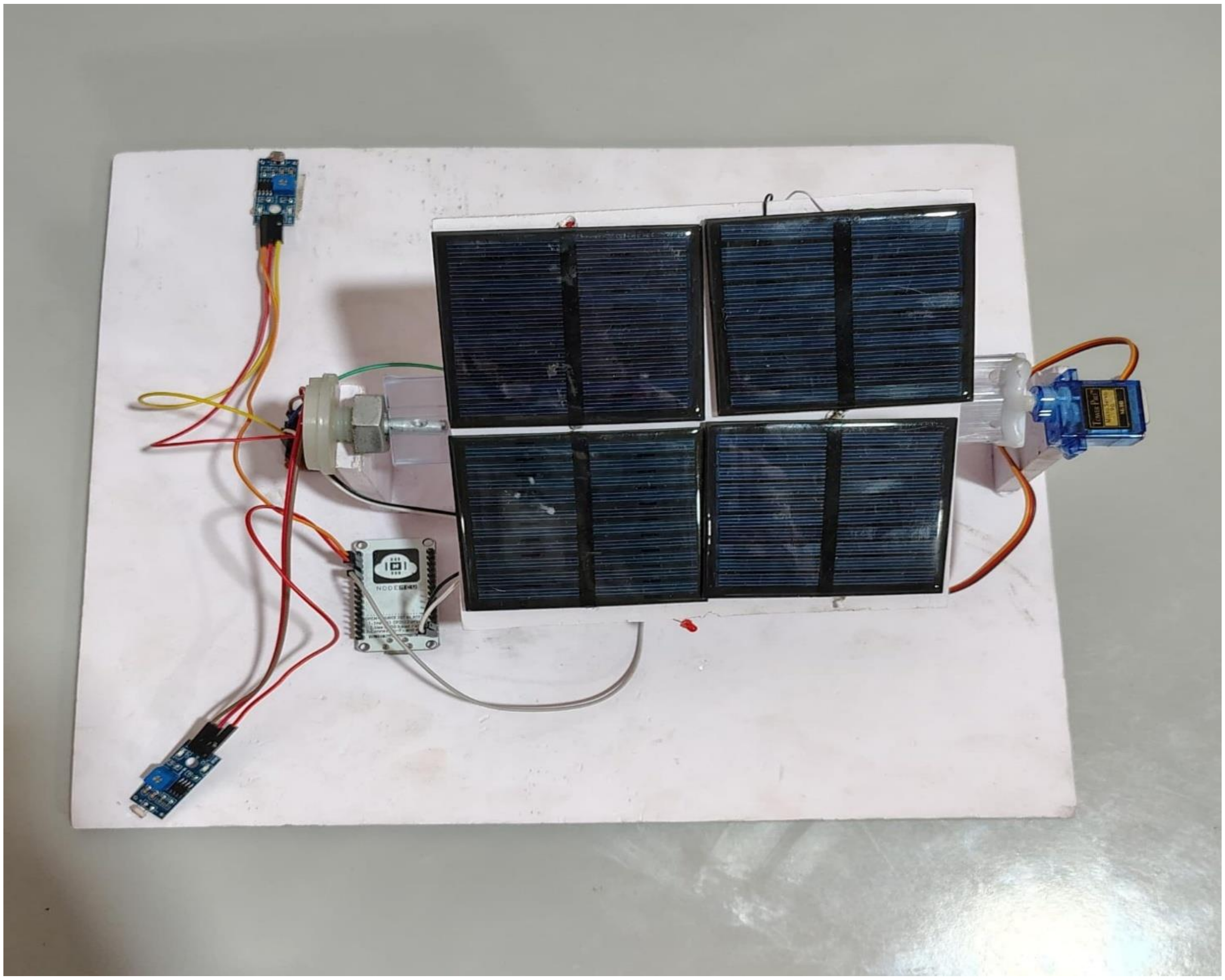
APPENDICES



Mapping the Project with the Sustainable Development Goals (SDGs)

The project “Development of a Cost-Effective Solar Tracking System for Enhanced Accessibility” aligns with 6 Sustainable Development Goals (SDGs).

Relevant SDGs of the Project:

Goal 7: Affordable and Clean Energy

- The project increases the efficiency of solar panels by 15–25% using single-axis tracking, it makes solar power more feasible and cheaper. It encourages the adoption of clean energy by optimizing renewable energy production.

Goal 9: Industry, Innovation, and Infrastructure

- The project shows creative utilization of inexpensive parts (ESP8266, LDRs, servo) to develop a scalable solar tracking system, promoting sustainable technology development.

Goal 11: Sustainable Cities and Communities

- Through enhanced solar energy efficiency, the project is contributing towards sustainable urban energy provision, decreasing reliance on non-renewable grids in neighborhoods.

Goal 12: Responsible Consumption and Production

- The project consumes fewer resources and low-power devices, encouraging sustainable making of energy systems. It maximizes energy output, minimizing waste

Goal 13: Climate Action

- By enhancing solar energy production, the project decreases dependence on fossil fuels, lower greenhouse gas emissions and aiding climate change objectives.

Goal 4: Quality Education

- The project is an educational device, illustrating electronics principles, renewable energy, and automation for students and researchers.

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