



## **Design and Implementation of Dual Axis Solar Tracker Using Arduino**

### **Submitted by:**

|                     |                    |
|---------------------|--------------------|
| Md.Sakil Ahmed Khan | ID: EEE 2202026030 |
| Farid Mia           | ID: EEE 2202026055 |
| Md.Foysal Ahmed     | ID: EEE 2202026071 |
| Sohag kumer Ghose   | ID: EEE 2203027018 |
| Md.Ziaul Mahmud     | ID: EEE 2203027042 |

### **Supervisor**

Md. Ashikur Rahman  
Lecturer, Department of EEE  
Sonargaon University

Department of Electrical & Electronic Engineering  
Sonargaon University  
147/1, Green Road, Panthapath, Tejgaon  
Dhaka-1215, Bangladesh  
Date of Submission: January-2026

## DECLARATION

We hereby, declare that the work presented in this project is the outcome of the investigation performed by us under the supervision of Md. Ashikur Rahman, Lecturer of the Electrical & Electronic Engineering Department, Sonargaon University. We also declare that no part of this project report and thereof has been or in being submitted elsewhere for the award of any degree. We further undertake to identify the university against any loss or damage arising from breach of the forgoing obligation.

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Md. Sakil Ahmed Khan

ID: EEE 2202026030

.....

Farid Mia

ID: EEE 2202026055

.....

Md. Foyisal Ahmed

ID: EEE 2202026071

.....

Sohag kumer Ghose

ID: EEE 2203027018

.....

Md. Ziaul Mahmud

ID: EEE 2203027042

## **CERTIFICATEION**

This is to certify that the project report “**Design and Implementation of Dual Axis Solar Tracker Using Arduino**”, is the confide record of the work done by-for partial fulfillment of the requirement of their degree of B.Sc. in Electrical and Electronic Engineering at Sonargaon University. The project report has been carried out under my guidance and is a confide record of the successful work. I wish them success in future.

### **Supervised By**

.....

**Md. Ashikur Rahman**

Lecturer, Department of EEE  
Sonargaon University

## ACKNOWLEDGMENT

Firstly, we express our sincere thanks and gratitude to the almighty for his divine blessings which made it possible for us to complete this project successfully. We are grateful and express our deepest gratitude to Md. Ashikur Rahman, Lecturer, Department of Electrical and Electronic Engineering, Sonargaon University. The deep knowledge and keen interest of our supervisor influenced me to carry out this project. His infinite patience, scholarly guidance, constant encouragement, constant energetic supervision, constructive criticism, valuable suggestions at all levels made this project possible. The successful completion of this thesis would not have been possible without his constant inspiration and constant guidance. Hence we are extremely pleased to acknowledge our profound gratitude and respect to the maintainer. We would like to express our gratitude to our Head of Department, as this project was completed under the Head of Department of Electrical and Electronics Engineering, Sonargaon University, Bangladesh. We would like to thank our entire course mates from Sonargaon University, who participated in this discussion while completing the course work. The author is grateful to all the respected faculty members of the Department of Electrical and Electronics Engineering for their cooperation and vital assistance in the successful completion of the thesis work.

## **ABSTRACT**

The increasing demand for renewable energy has made solar power one of the most important sustainable energy sources. However, the efficiency of a solar panel largely depends on its orientation with respect to the sun. Fixed-position solar panels cannot continuously face the sun throughout the day, which results in reduced energy harvesting. To overcome this limitation, this project presents the design and implementation of a Dual Axis Solar Tracker using Arduino. The system automatically adjusts the position of the solar panel to track the sun's movement along both horizontal and vertical axes. Light-dependent resistors (LDRs) are used to detect sunlight intensity, while an Arduino microcontroller processes the sensor data and controls servo motors to achieve accurate panel alignment. By continuously orienting the solar panel toward the direction of maximum sunlight, the proposed system significantly improves solar energy utilization compared to fixed-panel systems. The project demonstrates a low-cost, efficient, and practical approach to solar tracking that can be effectively applied in small-scale renewable energy systems and educational applications.

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# CHAPTER 1

## INTRODUCTION

### 1.1 Introduction

Since the last 18 years' people worldwide observing the earth is getting tremendous damage by the extremely high use of fossil fuel. While earth population is getting rapid exploitation day after day at a short period of time these non-renewable energy assets are rapidly decreasing and can no longer be accessible in the near future due to quick exploitation. Bangladesh is capable of producing 22,348 MW of electricity. According to BPDB data, approximately 52% comes from gas-powered plants, 27% from furnace oil-powered plants, 5.86% from diesel-powered plants, 8.03% from coal-powered plants, 1% from hydro, 0.5% from other renewable energies, and the remaining 5.27% is imported. The country generates 12,000 - 13,000 MW of electricity per day, compared to a demand of 14,000 - 14,500 MW [1]. Thinking all these sceneries the project aims at to increase power generation using renewable energy sources to meet up the demand. Solar Photo Voltaic (PV) cell will be used in this proposed project to collect photon energy and convert it to electric energy. The optimal angle for photovoltaic cells facing the sun is  $45^\circ$  in the spring and  $20^\circ$  in the summer, when the sun is high in the sky. Now the main point comes that is to track the sun continuously and all day long. A dual axis solar tracking system is proposed to solve this problem by tracking the sun from different angles and holding the PV panel towards the sun to create a better angle of collecting solar radiation. This smart device can run automatically by charging own power cell attached to the device. In other word it can be said that, with a view to obtain maximum output from the solar will be incorporated in the project.

A literature review provides an overview of existing technologies, research work, and system designs related to the proposed project. In the field of solar energy, numerous studies and practical implementations have focused on improving the efficiency of photovoltaic systems through better orientation and tracking mechanisms. This chapter reviews existing solar tracking methods, compares fixed and, tracking systems, and discusses the use of microcontroller-based control systems. The aim is to identify limitations in existing approaches and justify the need for a dual axis solar tracker using Arduino [2].

## **1.2 Background**

The growing global demand for energy and the rapid depletion of fossil fuel resources have increased the importance of renewable energy sources. Among various renewable options, solar energy is widely recognized due to its abundance, cleanliness, and long-term sustainability. Solar photovoltaic (PV) systems convert sunlight directly into electrical energy and are commonly used in residential, commercial, and industrial applications. One of the major challenges in solar energy systems is the efficient utilization of available sunlight. The amount of power generated by a solar panel depends on the angle at which sunlight strikes its surface. In traditional fixed solar panel installations, the panel remains stationary and cannot follow the sun's movement throughout the day, which limits energy collection. To overcome this limitation, solar tracking systems have been introduced. These systems automatically adjust the orientation of solar panels to face the sun continuously. A dual axis solar tracker is capable of tracking the sun in both east-west and north-south directions, allowing more accurate alignment compared to single axis trackers. This project focuses on the design and implementation of a dual axis solar tracking system using Arduino and light sensors [2].

## **1.3 Problem Statement**

Fixed solar panel systems are widely used due to their simplicity and low cost. However, such systems cannot maintain optimal alignment with the sun throughout the day and across different seasons. As a result, a significant portion of available solar energy is not effectively utilized. Manual adjustment of solar panels is impractical and inefficient, especially for continuous operation. Therefore, there is a need for an automatic solar tracking system that can dynamically adjust the panel orientation based on sunlight intensity. The challenge lies in developing a reliable, low-cost, and easy-to-implement system that can track the sun accurately without complex hardware or expensive sensors.

## **1.4 Objective.**

The main objectives of this project are:

- To design a dual axis solar tracking system using an Arduino microcontroller.
- To use LDR sensors for detecting the direction and intensity of sunlight.

- To control servo motors for adjusting the solar panel orientation along both horizontal and vertical axes.
- To develop an automatic tracking mechanism that operates without manual intervention.
- To demonstrate improved solar energy utilization compared to a fixed panel system.

### **1.5 Scope of the Project**

The scope of this project is limited to the development of a prototype-level dual axis solar tracking system. The project includes real-time detection of sunlight direction using LDR sensors, signal processing using an Arduino microcontroller, and mechanical movement of the solar panel using servomotors. The system is suitable for small-scale solar applications, academic demonstrations, and educational purposes. The project focuses on tracking accuracy and system functionality rather than large-scale power generation or commercial deployment.

### **1.6 Limitation**

Despite its effectiveness, the proposed system has certain limitations. The performance of LDR sensors can be affected by environmental factors such as cloud cover, shadows, and dust. Servo motors have limited torque and may not support heavy solar panels. Additionally, the system is designed as a prototype and does not include weather protection, long-term durability testing, or energy storage integration. Further improvements are required for outdoor and commercial applications.

### **1.7 Fixed Solar Panel Systems**

Fixed solar panel systems are the most commonly used type of solar installation due to their simple structure, low cost, and minimal maintenance requirements. In these systems, the solar panel is mounted at a fixed angle, usually optimized for average sunlight conditions of a specific location. Although fixed systems are easy to implement, they cannot adapt to the changing position of the sun throughout the day and across seasons. As result, the angle of incidence between sunlight and the panel surface is total ways optimal, which limits the overall energy collection capability.

## **1.8 Single Axis Solar Tracking Systems**

Single axis solar trackers were introduced to overcome some limitations of fixed panel systems. These trackers allow the solar panel to rotate along one axis, typically the east-west direction, following the sun's daily movement. Single axis systems provide better sunlight alignment than fixed systems and are relatively simple in design. However, they cannot adjust for seasonal changes in the sun's elevation, which reduces tracking accuracy during different times of the year.

## **1.9 Dual Axis Solar Tracking Systems**

Dual axis solar tracking systems allow movement along both horizontal and vertical axes. This enables the solar panel to follow the sun's daily path as well as its seasonal variation. As a result, dual axis trackers provide more accurate alignment between the panel surface and sunlight. Due to their increased mechanical complexity and control requirements, dual axis trackers are generally more expensive and complex than single axis systems. However, their ability to maintain optimal orientation makes them suitable for applications where maximum energy utilization is desired.

## **1.10 Microcontroller-Based Solar Tracking**

With the advancement of embedded systems, microcontrollers have become widely used in solar tracking applications. Microcontroller-based systems offer flexibility, programmability, and real-time control capabilities. Arduino-based solar trackers are popular in academic and prototype-level projects due to Arduino's simplicity, availability, and large community support. By using sensors such as light-dependent resistors (LDRs), the microcontroller can determine the direction of maximum sunlight and control motors accordingly.

## **1.11 Research Gap Identification**

Based on the review of existing systems, several gaps can be identified. Fixed and single axis systems cannot maintain optimal alignment under all sunlight conditions. Many existing dual axis systems use complex hardware or high-cost components, which limits their accessibility for educational and small-scale applications. There is a need for a low-cost, easy-to-implement dual axis solar tracking system that uses simple sensors and a programmable microcontroller.

This project addresses these gaps by implementing a dual axis solar tracker using Arduino, LDR sensors, and servo motors.

### **1.12 Summary**

This chapter reviewed different types of solar panel systems, including fixed, single axis, and dual axis trackers. It also discussed the role of microcontrollers in solar tracking applications. The analysis highlights the limitations of existing approaches and establishes the motivation for developing a dual axis solar tracker using Arduino.

## **CHAPTER 2**

### **METHODOLOGY**

#### **2.1 Introduction**

Introduce the basic engineering theories and methods that were used or implemented in the project. A country always wants to fulfill the ever-growing electricity demands in the most efficient way possible. But to generate electricity the system and sources they use are old and not environmentally friendly. For some years the world leaders have agreed to one point that the dependency on fossil fuel to generate electricity must be less by 2030. So, all the government in the world are trying to be as less dependent as possible on fossil fuel and trying to be more dependent on the renewable sources like air, water, solar, biomass, geothermal. But every government is facing difficulties because every renewable energy station takes a loaf large area and they can't generate as much as fossil fuel. So, this proposed project is to make electric it more efficiently. Many sensors and parts have been added to this project to make it more efficient. LDR sensor is used to detect sunlight, allowing the solar panel to face the sun directly. UV sensor to detect sun radiation, so that on cloudy days when the lights are not visible to the LDR, the UV sensor can detect sun radiation and direct the solar panel toward the sun to absorb more radiation. To freely rotate the panel servomotors were used. This chapter includes brief explanations of the equipment as well as its consequences and essential diagrams. This chapter also includes a block diagram of its internal process and a schematic representation of the whole design. As a result, this chapter will supply sufficient information on the general structure and operating mechanism of the project.

The overall architecture and working principle of the Dual Axis Solar Tracker using Arduino. The system is designed to automatically orient a solar panel toward the direction of maximum sunlight by tracking the sun's movement along both horizontal and vertical axes. The design integrates light sensors, a microcontroller, and motor control mechanisms to achieve continuous and automatic tracking. The objective of the system design is to provide an efficient, low-cost, and reliable solar tracking solution suitable for small-scale and educational applications [3].

## **2.2 Working Principle**

The proposed tracking system more effectively tracks sunlight by allowing PV panels to rotate along two different axes. The tracker is made up of four LDR sensors, two stepper motors and a PIC microcontroller. A pair of sensors and one motor tilt the tracker in the east-west direction of the sun, and a second pair of sensors and a motor fixed to the tracker's bottom in the north-south direction of the sun. This system makes use of two stepper motors in total. Stepper motors in the upper panel holder and the base track the sun's linear and parabolic motion, respectively. These sensors and stepper motors are connected to a microprocessor. On the basis of LDR sensor input, the microcontroller instructs the motors to rotate in the proper direction along with the sun. It shows the LDR sensors send a signal to the microcontroller when they detect light. The microcontroller compares the signals from the LDR sensors and determines which signal is stronger when determining the rotation direction of the stepper motors. The microcontroller, an intelligent device, activates the motor driver circuit based on sensor input. The controller activates the driver circuits and moves the stepper motors to ensure that the light falling on the sensor pairs is identical. If there is a discrepancy, the motor moves the panel until the light falling on the sensor is identical [3].

## **2.3 Overall System Architecture**

The dual axis solar tracking system consists of three main subsystems: the sensing unit, the control unit, and the actuation unit. The sensing unit detects sunlight intensity from different directions using light-dependent resistors (LDRs). The control unit processes sensor data using an Arduino microcontroller and determines the required movement of the solar panel. The actuation unit consists of servo motors that physically adjust the panel position along two axes [4].

## 2.4 Block Diagram Description

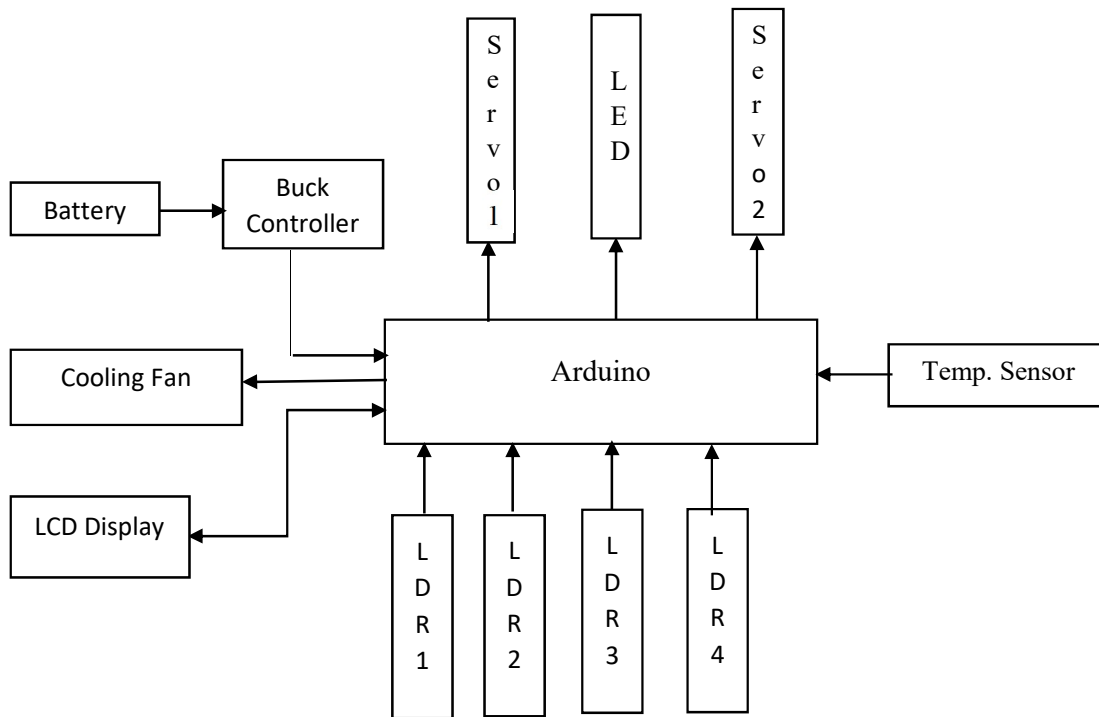


Fig. 2.1: Dual Axis Solar Tracker Block diagram

**The block diagram of the system includes the following components:**

- LDR Sensors: Measure sunlight intensity from multiple directions.
- Arduino Microcontroller: Acts as the central processing unit.
- Servo Motors: Control the movement of the solar panel along horizontal and vertical axis.
- Solar Panel: Mounted on a mechanical structure connected to the motors.
- Power Supply: Provides required operating voltage to the Arduino and motors.

## 2.5 Working Principle of the Dual Axis Solar Tracker

The working principle of the dual axis solar tracker is based on the difference in light intensity detected by multiple LDR sensors. When sunlight falls unevenly on the sensors, the Arduino identifies the direction of higher light intensity. Based on this comparison, the Arduino sends control signals to two servomotors. One servo motor controls horizontal movement (east-west direction), while the other controls vertical movement (north-south direction). The motors

rotate until the light intensity on all sensors becomes approximately equal, indicating optimal alignment with the sun.

## **2.6 Design Considerations**

Several design considerations were taken into account during system development. The use of LDR sensors allows simple and low-cost sunlight detection. Servo motors were selected for precise angular control and ease of interface with Arduino. The system is designed to operate as a prototype, emphasizing simplicity, reliability, and educational value rather than large-scale power handling.

## **2.7 Summary**

This chapter described the system overview, architecture, block diagram, and working principle of the dual axis solar tracker. The design integrates sensing, control, and actuation units to achieve automatic solar tracking using Arduino. This structured design forms the foundation for the hardware implementation discussed in the next chapter.

## CHAPTER 3

### HARDWARE AND SOFTWARE IMPLEMENTATION

#### 3.1 Introduction

This chapter describes the hardware components, circuit connections, and physical implementation of the Dual Axis Solar Tracker using Arduino. The hardware design focuses on simplicity, low cost, and ease of implementation while ensuring reliable solar tracking operation. Each component plays a specific role in detecting sunlight, processing sensor signals, and controlling the mechanical movement of the solar panel [4].

This chapter describes the software design and implementation of the Dual Axis Solar Tracker using Arduino. The software is responsible for reading sensor inputs, processing data, controlling servo motors, managing temperature-based cooling, handling user input through a push button, and displaying system status on an LCD. The program is written using the Arduino programming framework and integrates multiple libraries to support I2C communication, servo motor control, and display functionality.

#### 3.2 Hardware Components Used

**Table No. 3.1: List of components**

| Sl | Name of components                        | Quantity | Unit |
|----|---|----------|------|
| 01 | Arduino Uno R3 SMD                        | 01       | NOS  |
| 02 | 16x2 LCD Display                          | 01       | NOS  |
| 03 | I2C LCD Adapter Module                    | 01       | NOS  |
| 04 | LM2596 Buck Converter – DC Step-Down      | 01       | NOS  |
| 05 | Light Dependent Resistors (LDRs)          | 04       | NOS  |
| 06 | Servo Motors                              | 02       | NOS  |
| 07 | Solar Panel (small-scale prototype panel) | 1        | NOS  |
| 08 | Resistors-1k                              | 1        | LOT  |
| 09 | Mechanical Mounting Structure             | 1        | LOT  |
| 10 | Connecting Wires                          | 1        | LOT  |
| 11 | 3.7V battery                              | 2        | NOS  |
| 12 | Temperature sensor                        | 1        | NOS  |

### 3.3 Arduino Uno R3 SMD:

The Arduino Uno is a series of open-source microcontroller board based on a diverse range of microcontrollers (MCU). It was initially developed and released by the Arduino company in 2010. The microcontroller board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable. It can be powered by a USB cable or a barrel connector that accepts voltages between 7 and 20 volts, such as a rectangular 9-volt battery. It has the same microcontroller as the Arduino Nano board, and the same headers as the Leonardo board. The hardware reference design is distributed under a Creative Commons Attribution Share-Alike 2.5 license and is available on the Arduino website. Layout and production files for some versions of the hardware are also available.

#### Key Pin Functions:

- Digital I/O (0-13): General purpose input/output.
  - PWM (3, 5, 6, 9, 10, 11): Pulse Width Modulation for analog-like outputs.
  - Analog Inputs (A0-A5): For reading analog sensors.
  - Serial (0=RX, 1=TX): For communication via USB/UART.
  - SPI (10=SS, 11=MOSI, 12=MISO, 13=SCK): For high-speed communication.
  - I2C (A4=SDA, A5=SCL): For two-wire communication.
  - Power Pins: 5V, 3.3V, GND, VIN (Input Voltage).
  - AREF, Reset, IOREF: Reference Voltage, Reset, and Shield Voltage Adaptation pins
- [8].

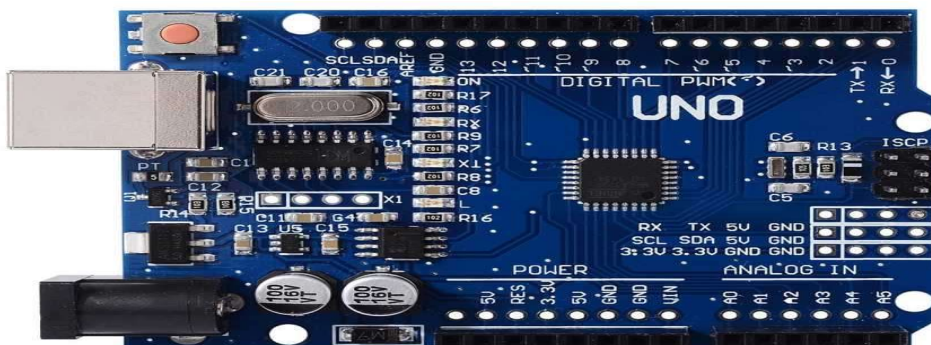


Fig-3.1: Arduino Uno R3 SMD

### 3.4 16x2 LCD Display

A 16x2 LCD display shows 16 characters per line across 2 lines, using a 5x8 pixel matrix for each character, controlled by chips like HD44780, commonly runs on 5V, and supports 4-bit or 8-bit parallel communication, offering a simple, low-power way to display text with options for backlight (blue, green) and I2C adapters to reduce pin usage for Arduino projects.

#### Key Features & Specifications

Display: 16 characters  $\times$  2 lines (1602 LCD).

Resolution: Each character uses a 5 $\times$ 8 dot matrix.

Controller: Usually HD44780 or compatible (e.g., SPLC780D1).

Operating Voltage: 4.7V to 5.3V (typically 5V).

Current:  $\sim$ 1mA (without backlight),  $\sim$ 120-200mA (with backlight).

Communication: 4-bit or 8-bit parallel [9].



Fig-3.2: 16x2 LCD Display

## 16x2 LCD Display Pinout

Table No. 3.2: 16×2 LCD Display Pinout

| Pin No: | Pin Name:       | Description  |
|---------|-----------------|--|
| 1       | Vss (Ground)    | Ground pin connected to system ground  |
| 2       | Vdd (+5 Volt)   | Powers the LCD with +5V (4.7V – 5.3V)  |
| 3       | VE (Contrast V) | Decides the contrast level of display. Grounded to get maximum contrast.   |
| 4       | Register Select | Connected to Microcontroller to shift between command/data register  |
| 5       | Read/Write      | Used to read or write data. Normally grounded to write data to LCD   |
| 6       | Enable          | Connected to Microcontroller Pin and toggled between 1 and 0 for data acknowledgement  |
| 7       | Data Pin 0      | Data pins 0 to 7 forms a 8-bit data line. They can be connected to Microcontroller to send 8-bit data. These LCD's can also operate on 4-bit mode in such case Data pin 4,5,6 and 7 will be left free. |
| 8       | Data Pin 1      | It can be connected to microcontroller to send 8-bit data.   |
| 9       | Data Pin 2      | It can be connected to microcontroller to send 8-bit data.   |
| 10      | Data Pin 3      | It can be connected to microcontroller to send 8-bit data.   |
| 11      | Data Pin 4      | It can be connected to microcontroller to send 8-bit data. This leaves the point free when LCDs also operate in 4-bit mode.  |
| 12      | Data Pin 5      | It can be connected to microcontroller to send 8-bit data. This leaves the point free when LCDs also operate in 4-bit mode.  |
| 13      | Data Pin 6      | It can be connected to microcontroller to send 8-bit data. This leaves the point free when LCDs also operate in 4-bit mode.  |
| 14      | Data Pin 7      | It can be connected to microcontroller to send 8-bit data. This leaves the point free when LCDs also operate in 4-bit mode.  |
| 15      | LED Positive    | Backlight LED pin positive terminal  |

### 3.5 LM2596 Buck Converter – DC Step-Down Module

The LM2596 series of regulators are monolithic integrated circuits that provide all the active functions for a step-down (buck) switching regulator, capable of driving a 3-A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3 V, 5 V, 12 V, and an adjustable output version. Requiring a minimum number of external components, these regulators are simple to use and include internal frequency compensation,

and a fixed frequency oscillator. The LM2596 series operates at a switching frequency of 150 kHz, thus allowing smaller sized filter components than what can be required with lower frequency switching regulators. Available in standard 5-pin TO-220 package with several different lead bend options, and a 5-pin TO-263 surface mount package [10].

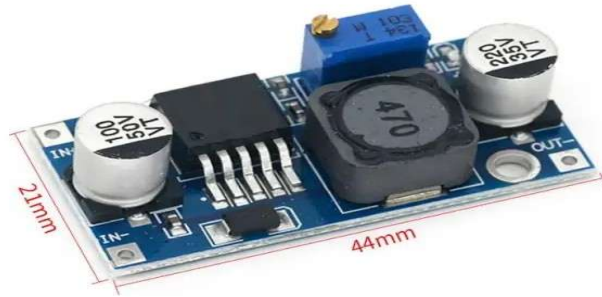


Fig-3.3: LM2596 Buck Converter

### 3.6 LDR Sensor

Light Dependent Resistors (LDRs) are used to sense sunlight intensity. Each LDR is connected in a voltage divider configuration using a fixed resistor. The output voltage of the divider varies according to the amount of light falling on the LDR. These analog voltage signals are connected to the analog input pins of the Arduino. Multiple LDRs are placed in different directions to detect the relative position of the sun [11].



Fig-3.4: LDR Sensor

### 3.7 Servo Motors

A servomotor (or servo motor or simply servo) is a rotary or linear actuator that allows for precise control of angular or linear position, velocity, and acceleration in a mechanical system. It constitutes part of a servomechanism, and consists of a suitable motor coupled to a sensor for position feedback and a controller (often a dedicated module designed specifically for servomotors). Servomotors are not a specific class of motor, although the term servomotor is

often used to refer to a motor suitable for use in a closed-loop control system. Servomotors are used in applications such as robotics, CNC machinery, and automated manufacturing [12].



Fig-3.5: DC Servo motor

### 3.8 Solar panel

A solar panel is a device that converts sunlight into electricity by using multiple solar modules that consist of photovoltaic (PV) cells. PV cells are made of materials that produce excited electrons when exposed to light. These electrons flow through a circuit and produce direct current electricity, which can be used to power various devices or be stored in batteries. Solar panels can be known as solar cell panels, or solar electric panels.



Fig-3.6: Solar panel

### 3.9 1K Resistor

A 1k resistor is a fundamental electronic component with a resistance of 1k ohm (1,000 ohms), identified by the prefix 'k' for kilo. These common resistors limit current, set voltage levels, and filter signals in countless circuits, typically found in 1/4 Watt (0.25W) or 1/2 Watt (0.5W) power ratings, often with brown, black, red, gold color bands indicating  $1-0 \times 10^1$  (1000) ohms with 5% tolerance [13].



Fig-3.7: 1k Resistor

### 3.10 Circuit Diagram

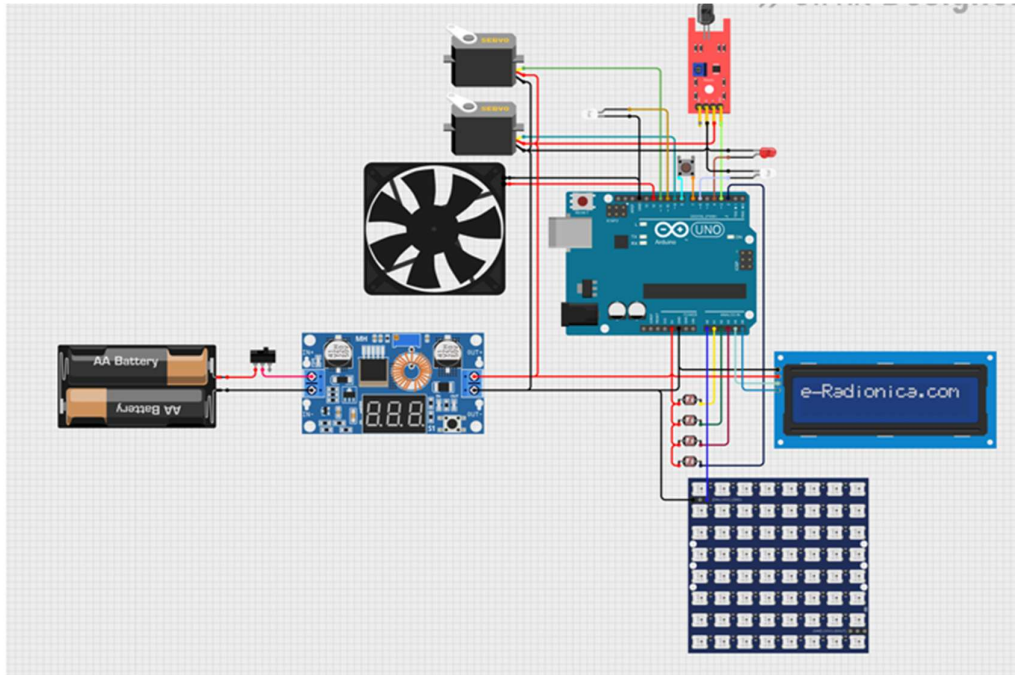


Fig-3.8: Circuit Diagram

### 3.11 Software Tools and Libraries Used

The following libraries and software tools are used in the project:

- Arduino IDE: Used for writing, compiling, and uploading the program.
- Wire's: Used for I2C communication with the LCD.
- LiquidCrystal\_I2C.h: Used to control the 16x2 LCD display.
- Servo's: Used to control servo motors for panel movement.

These libraries simplify hardware interaction and improve program reliability.

### 3.12 Program Structure Overview

The software is organized into multiple functional sections to improve readability and maintainability. The main functional blocks of the program are:

- Sensor reading and data averaging.
- Solar tracking decision logic.

- Servo motor movement control.
- Temperature-based fan control.
- Button handling with de-bounce logic.
- LCD display update.

### **3.13 Sensor Data Acquisition**

#### **3.13.1 LDR Sensor Reading**

Light Dependent Resistors (LDRs) are used to detect sunlight intensity from different directions. Both digital and analog readings are used, depending on sensor configuration. The software compares the values from the upper and lower LDRs as well as the left and right LDRs to determine the direction of maximum sunlight. This comparison forms the basis of the tracking decision [11].

#### **3.13.2 Solar Voltage Measurement**

The solar panel output is connected to an analog input pin. To reduce noise and fluctuations, multiple readings are stored in a buffer and averaged before processing. The averaged value is converted into a voltage level and displayed on the LCD, providing real-time feedback on solar panel output.

### **3.14 Dual Axis Tracking Algorithm**

The tracking algorithm calculates the difference between opposing LDR sensor values. If the difference exceeds a predefined dead zone, the system determines which axis requires adjustment. Only one axis is adjusted at a time to ensure smooth and stable movement. The target position for each servo motor is updated gradually, preventing sudden or jerky motion [7].

### **3.15 Servo Motor Control Logic**

Servo motors are controlled using a step-based movement mechanism. Instead of moving directly to the target angle, the servo position is incremented or decremented step by step at fixed time intervals. This gradual movement approach reduces mechanical stress on the motors and improves tracking accuracy [12].

### **3.16 Temperature Monitoring and Fan Control**

A digital temperature sensor is used to monitor system temperature. When the sensor output indicates a high-temperature condition, the cooling fan is automatically activated. The fan remains off during normal temperature conditions. This feature protects system components from overheating during prolonged operation.

### **3.17 Push Button Control and De-bouncing**

A push button is implemented with software de-bouncing to prevent false triggering caused by mechanical noise. Each valid button press toggles the state of an indicator LED. This functionality demonstrates user interaction and manual control within the system.

### **3.18 LCD Display Management**

A 16x2 I2C LCD is used to display system information. The first row displays the measured solar voltage, while the second row shows the temperature status of the system. The LCD is updated at fixed time intervals to ensure stable and flicker-free display output [9].

### **3.19 Summary**

This chapter presented the software implementation of the dual axis solar tracker, including sensor data processing, tracking logic, servo control, temperature protection, user input handling, and LCD display management. The structured software design ensures reliable system operation, smooth solar tracking, and real-time monitoring of system status. This chapter presented the hardware implementation of the dual axis solar tracker, including component selection, circuit description, motor control, and power supply arrangement. Proper hardware integration ensures accurate sunlight detection and smooth mechanical movement, which supports effective solar tracking.

## CHAPTER 4

### IMPLEMENTATION AND TESTING

#### 4.1 Implementation

This chapter describes the hardware components, circuit connections, and physical implementation of the Dual Axis Solar Tracker using Arduino. The hardware design focuses on simplicity, low cost, and ease of implementation while ensuring reliable solar tracking operation. Each component plays a specific role in detecting sunlight, processing sensor signals, and controlling the mechanical movement of the solar panel. The software design and implementation of the Dual Axis Solar Tracker using Arduino. The software is responsible for reading sensor inputs, processing data, controlling servo motors, managing temperature-based cooling, handling user input through a push button, and displaying system status on an LCD. [6] The program is written using the Arduino programming framework and integrates multiple libraries to support I2C communication, servo motor control, and display functionality.

#### 4.2 Result

- Successful implementation of dual axis solar tracking using Arduino.
- Real-time sunlight detection using LDR sensors.
- Smooth and controlled panel movement using step-based servo control.
- Integration of temperature monitoring and automatic cooling fan control.
- Real-time voltage monitoring and display using an LCD.
- Reliable system operation using structured and modular software design.

#### Project Picture

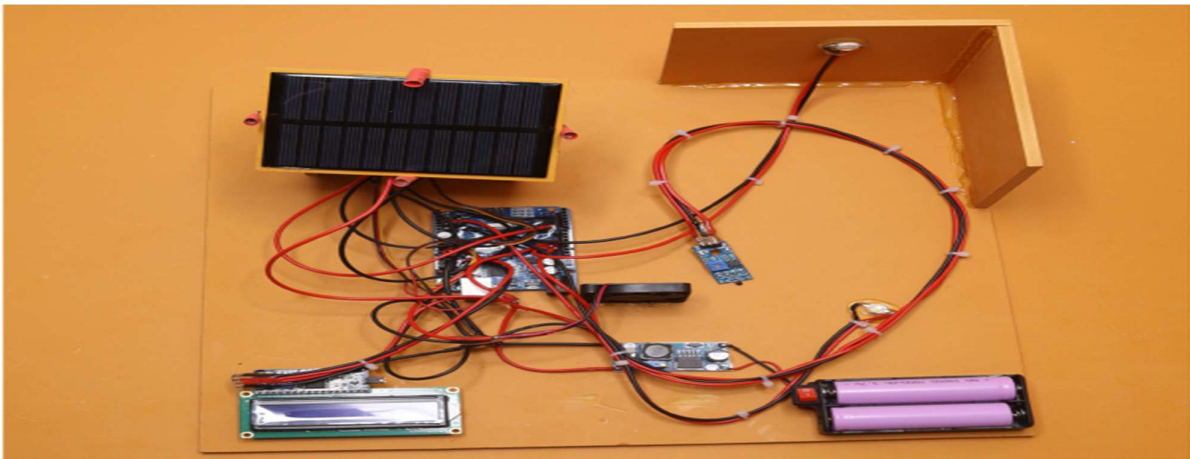


Fig. 4.1: Project Picture

## CHAPTER 5

### SAFETY, ETHICS AND LIMITATIONS

#### 5.1 Introduction

This chapter discusses the safety considerations, ethical responsibilities, and technical limitations associated with the Dual Axis Solar Tracker using Arduino. Since the system involves electrical components, moving mechanical parts, and outdoor exposure, safety and responsible usage are essential factors in system design and implementation.

#### 5.2 Safety

##### 5.2.1 Electrical Safety

Electrical safety was considered during the design and testing of the system. Low-voltage components were used to minimize electrical hazards. Proper grounding was maintained between the Arduino, sensors, servo motors, and power supply to ensure stable operation. The system includes controlled power distribution to prevent excessive current flow to sensitive components such as the microcontroller and sensors.

##### 5.2.2 Mechanical Safety

The solar panel is mounted on a movable structure controlled by servo motors. Sudden or rapid movement can damage mechanical components. To avoid this, the software implements gradual step-by-step servo movement, reducing mechanical stress and preventing abrupt motion. All mechanical joints are secured to avoid loosening during operation.

##### 5.2.3 Thermal Safety

A temperature monitoring mechanism is implemented in the system. When high temperature is detected, a cooling fan is automatically activated to reduce heat accumulation. This feature protects electronic components from overheating during extended operation in direct sunlight.

### **5.3 Responsible Use of Renewable Energy Technology**

The project promotes the ethical use of renewable energy by improving solar energy utilization through automated tracking. It is intended for educational and experimental purposes and does not claim certification for commercial or industrial deployment.

### **5.4 System Reliability and Transparency**

The system behavior is fully defined by the programmed logic, and no hidden or autonomous decision-making processes are involved. Users are informed about system limitations and are encouraged not to rely on the prototype for critical energy infrastructure.

### **5.5 Environmental Responsibility**

The project encourages clean energy usage and reduces dependence on fossil fuels. However, electronic waste considerations must be addressed by proper reuse and recycling of components after project completion.

### **5.6 Limitations**

#### **5.6.1 Sensor Limitations**

LDR sensors are sensitive to shadows, dust, and sudden changes in light conditions. Cloud cover and reflections may affect tracking accuracy.

#### **5.6.2 Mechanical Limitations**

Servo motors used in the project are suitable for lightweight prototype solar panels only. They may not support large or heavy panels without mechanical reinforcement or higher-torque motors.

#### **5.6.3 Environmental Limitations**

The system does not include weather protection. Rain, strong wind, and dust can affect long-term outdoor performance. The project is intended primarily for controlled or semi-outdoor environments.

#### **5.6.4 Prototype-Level Design**

This project is developed as a prototype and does not include energy storage, grid integration, or long-term durability testing. Further enhancements are required for real-world deployment.

#### **5.7 Summary**

This chapter outlined the safety measures, ethical responsibilities, and technical limitations of the dual axis solar tracker system. While the project demonstrates effective solar tracking, it remains a prototype with defined operational constraints that must be acknowledged.

## CHAPTER 6

### CONCLUSION AND FUTURE WORK

#### 6.1 Conclusion

This project successfully demonstrates the design and implementation of a Dual Axis Solar Tracker using Arduino. The system is capable of automatically tracking the sun's movement along both horizontal and vertical axes by using light-dependent resistors and servo motors.

The Arduino-based control logic continuously compares light intensity from multiple directions and adjusts the solar panel position to maintain optimal alignment with the sun. Additional features such as temperature-based fan control, real-time voltage displays on an LCD, and user interaction through a push button enhances system functionality and safety. The project fulfills its primary objective of improving solar energy utilization compared to fixed-position solar panels. Its low-cost hardware, simple control logic, and modular design make it suitable for educational demonstrations and prototype-level renewable energy applications.

#### 6.2 Key Achievements

The major achievements of this project include:

- Successful implementation of dual axis solar tracking using Arduino.
- Real-time sunlight detection using LDR sensors.
- Smooth and controlled panel movement using step-based servo control.
- Integration of temperature monitoring and automatic cooling fan control.
- Real-time voltage monitoring and display using an LCD.
- Reliable system operation using structured and modular software design.

#### 6.3 Limitations

Despite its successful implementation, the system has certain limitations. The accuracy of LDR-based tracking can be affected by shadows, clouds, and environmental conditions. The servo motors are suitable only for lightweight panels and may not support large-scale installations. The project does not include energy storage, weather protection, or long-term

outdoor durability testing. As a result, it remains a prototype rather than a commercial-grade solar tracking system.

#### **6.4 Sensor Improvements**

Future versions of the system may replace LDR sensors with more accurate sun-position sensors or integrate hybrid sensing techniques to improve tracking reliability under varying weather conditions.

#### **6.5 Mechanical Enhancements**

High-torque motors and robust mechanical structures can be used to support larger solar panels. Adding limit switches can further improve movement safety and precision.

#### **6.6 Power Management and Storage**

Energy storage systems such as batteries and charge controllers can be added to store excess energy. This would allow the system to operate independently of real-time sunlight conditions.

#### **6.7 Smart Monitoring and IoT Integration**

Future enhancements may include wireless monitoring using IoT platforms to track panel position, voltage levels, and temperature remotely through a mobile or web application [6].

#### **6.8 Summary**

This chapter concluded the project by summarizing its objectives, implementation, and outcomes. The Dual Axis Solar Tracker using Arduino demonstrates a practical and effective approach to solar tracking. With further enhancements, the system has the potential to evolve into a more advanced and real-world applicable renewable energy solution.

## REFERENCES

- [1] Catarius, A., & Christiner, M. (2010). Azimuth-altitude dual axis solar tracker. Worcester Polytechnic Institute, 80. Solar system Books.
- [2] Mishra, A. K., Oli, D., Thike, R., Maharjan, S., & Awasthi, S. (2010). Dual Axis Solar Tracker. Tribhuvan University Institute of Engineering.
- [3] Alexandro, C., & Pozna, C. (2010). Simulation of a dual-axis solar tracker for improving the performance of a photovoltaic panel. Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, 224 (6), 797-811.
- [4] Clifford, M. J., & Eastwood, D. (2004). Design of a novel passive solar tracker. Solar Energy, 77(3), 269-280.
- [5] Yazidi, A., Betin, F., Notton, G., & Capolino, G. A. (2006, July). Low cost two-axis solar tracker with high precision positioning. In 2006 first international symposium on environment identities and Mediterranean area (pp. 211-216). IEEE.
- [6] Said, M. N. A. M., Jumaat, S. A., & Jawa, C. R. A. (2020). Dual axis solar tracker with IoT monitoring system using arduino. International Journal of Power Electronics and Drive System (IJPEDS), 1, 451-458.
- [7] Fathabadi, H. (2016). Novel high efficient offline sensor less dual-axis solar tracker for using in photovoltaic systems and solar concentrators. Renewable Energy, 95, 485-494.
- [8] [https://en.wikipedia.org/wiki/Arduino\\_Uno](https://en.wikipedia.org/wiki/Arduino_Uno).
- [9] <https://www.elprocus.com/lcd-16x2-pin-configuration-and-its-working>.
- [10] [http://wiki.sunfounder.cc/index.php?title=LM2596S\\_DCDC\\_Power\\_Supply\\_Step\\_Down\\_Module](http://wiki.sunfounder.cc/index.php?title=LM2596S_DCDC_Power_Supply_Step_Down_Module).
- [11] <https://en.wikipedia.org/wiki/Photoresistor>.
- [12] [https://en.wikipedia.org/wiki/Servo\\_%28radio\\_control%29](https://en.wikipedia.org/wiki/Servo_%28radio_control%29).
- [13] <https://en.wikipedia.org/wiki/Resistor>.