DESIGN AND CONSTRUCTION OF AN AUTOMATIC SOLAR TRACKING SYSTEM

A Project report is submitted in partial fulfillment of the requirements for the award of Degree of Bachelor of Science in Electrical and Electronic Engineering.

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DECLARATION

I declare that this project titled "**Design & Construction of an Automatic Solar Tracking System**" is an institution-based project which was done to fulfill the requirements of laboratory projects in the Department of Electrical and Electronic Engineering, Faculty of Engineering at Daffodil International University. This work is a partial fulfillment of the requirements for the Bachelor of Science in Electrical and Electronic Engineering degree herein not being submitted for another degree, diploma, or other qualification. In this research, I attempt to encompass all feasible safety measures and have made every effort to enumerate all conceivable hazards. I have received all necessary ethical and/or safety approval (where applicable) and have finally checked my ethical (and legal) responsibility to the Participants.

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APPROVAL

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Signed

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Dedicated

To

Parents and Teachers

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LIST OF ABBREVIATIONS

STS	Solar Tracking System
PV	Photovoltaic
MPPT	Maximum Power Point Tracker
LED	Light Emitting Diode

LIST OF SYMBOLS

Symbol	*Name of the symbol*
G	Solar irradiance
A	Area of the Solar Panel
E	Energy
P	Power
R	Electrical Resistance

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ABSTRACT

The world is currently confronting the energy crisis, and it is the most important issue. The natural resources of energy, such as fossil fuels which cannot be recycled and one of the biggest reasons for environmental pollution causes a major reduction. With global steps to reduce the dependency on traditional resources, renewable energy sources have taken over all sectors. The use of solar power is increasing exponentially as a good renewable energy option. Instead, we have created solar panels with complicated technology to directly transform the sun's rays into power. Many available methods can be applied to make the solar cell more efficient which will help reduce this cost. For now, solar tracking systems have proven to be very effective in maximizing the efficiency of cells by keeping them aligned with the sun. This work aims to introduce a microcontroller-based design for building an auto solar tracker. The sensors of the light tracker practical are LDRs. Unique to the tracker is that its control structure guarantees system controllability in three different fashions. Moreover, the design procedure noted herein is used to fabricate a small prototype for solar radiation measurement.

Keywords: Microcontroller, stepper motor, photo resistor, solar tracking, and photovoltaic cell.

CHAPTER 1
INTRODUCTION

1.1 Introduction

Energy is a crucial determinant of national development, as the progress and functionality of any nation are directly connected to the availability and use of energy resources. Currently, fossil fuels constitute around 85% of total energy production, making global energy consumption largely reliant on them. Nevertheless, dependence on fossil fuels non-renewable geological resources has played a major role in environmental degradation. When these fuels are burned, greenhouse gases are emitted into the atmosphere, thus exacerbating global warming and climate change. As a result of this challenge, it has become necessary to investigate and implement alternative energy sources that are sustainable. Recently, the focus on renewable energy technologies, including solar, wind, geothermal, and tidal energy, has intensified. These sources provide the dual benefit of guaranteeing long-term energy security and reducing negative environmental effects. Among these, solar energy stands out as the most promising due to its abundance and universal availability. Given that the Sun is the primary energy source for most renewable systems, solar power provides a sustainable means of meeting the growing global energy demand. In particular, photovoltaic (PV) systems have proven to be one of the most promising renewable technologies for substituting traditional energy sources. PV panels function by using semiconductor materials, mainly silicon, to convert solar radiation directly into electricity. Conversion efficiencies of up to 24.5% have been attained due to recent advancements in PV technology. Nonetheless, boosting solar panel productivity is mainly contingent on increasing solar exposure. A highly efficient way to realize this is by means of solar tracking systems, enabling panels to pursue the Sun’s path and thus optimize energy collection over the course of the day. Even though solar trackers boost efficiency considerably, the costs associated with their installation and upkeep are still greater than those of traditional fixed PV systems. The market for solar tracking technologies has grown due to the rising demand for optimized solar energy solutions, even with this limitation. The current study suggests a solar tracking system that is based on microcontroller technology and commonly available hardware components, which is both cost-effective and easy to program, in order to tackle this issue. A prototype of an independent solar tracker has been created and tested to assess its viability, offering a practical means of enhancing the use of renewable energy and fostering sustainable power generation [1].

1.2 Problem Statement

There is no mechanism to follow the sun throughout the day, as the majority of traditional solar panels are statically mounted. That is the most significant issue facing solar systems. Subsequently, solar panels are only partially exposed to sunlight at optimal solar angles, rendering them ineffective in terms of energy production. This fixed orientation leads to substantial energy loss during non-peak hours, such as seasons or a differing sun aspect in the morning versus the afternoon. The solar systems' capacity to generate optimum power is diminished as a result of their underutilization, which is caused by the absence of a consistent method for repositioning the panels. The objective of this project is to address this issue by developing and executing an Automatic Solar Tracking System that maintains its focus on the sun's position and adjusts the panels' positions to ensure that they receive the optimum amount of energy.

1.3 Objectives

So accordingly, the aims of Automatic Solar Tracking System are as follows:

Fully-automatic sun monitor: To automatically observe the direction of the sun and adjust solar panels to harvest maximum sunlight.

Solar Panel: The perfect orientation of the solar panels maximizes the energy production throughout the day.

Minimize manual control: Forming an automatic system instead of a manual system could help remove manual manipulation and improve efficiency and user-friendliness.

Develop a Low-Cost and Scalable Solution: Implement a solution that can scale across different solar installation sizes, such as residential and commercial installations.

Support the growing world trend of utilizing clean and renewable energy sources, perfect for reducing design dependence swapping out [2].

1.4 Procedures

This section outlines the procedure for designing and building the Automatic Solar Tracking System:

System Design: The system will be designed with the aid of a microcontroller (Arduino), actuators, and sensors. Alternatively, the microcontroller can use an algorithm that keeps track of the position of the sun and changes the slope of the solar panel accordingly, or it can get the input from the light sensors.

Selection of components: A servo motor (to control the position of the solar panel), a light sensor (to determine which way the sun is going), and a microcontroller must be selected, taking into consideration tradeoffs between price, supply, performance, and design.

System assembly: The mechanical parts of the system, such as the tracking actuators, the panel frame, and the electronics control component, are assembled together in one assembly. The tracking mechanism will be mounted on the solar panel and will be controlled by the microcontroller.

Software Development: Ideally, it is expected that the software of the system will have a capability to input data on light sensors or computerized data on solar positions. The microcontroller will give instructions to the motors to alter the position of the solar panel.

Testing and calibration: The solar fields will be tested to ensure reliable tracking of the sun once the system is built. Performance will be assessed by the improvement in energy generation efficiency. The system will be adjusted to work under numerous weather conditions and at different times of the day [3-4].

1.5 Gantt Chart

Task	Duration	Start	End
Literature Review	1	Week 1	Week 1
System Design	2	Week 2	Week 2
Component Selection and Purchase	1	Week 3	Week 4
Construction and Assembly	3	Week 5	Week 7
Software Development	2	Week 8	Week 10
System Testing and Optimization	2	Week 11	Week 13
Final Report Writing	1	Week 14	Week 16

This Gantt chart provides a structured approach to implementing our project within approximately 16 weeks, allowing for sufficient time for each phase while maintaining flexibility for adjustments as needed.

1.6 Structure of the Report

This is the structure we employ for our project report:

Chapter 1: Introduction
Project overview including background, problem explanation, and objectives.
Chapter 2: Literature Review
This section examines relevant work pertinent to our efforts and provides a brief comparison with other studies.
Chapter 3. Materials and Methods
The methodology is elucidated with comprehensive graphics, accompanied by the system architecture and component details.
Chapter 4. Findings and Analysis
Presented the results and insights derived from experiments, simulations, and empirical testing.
Chapter 5: Project Management This project plan, milestones, tasks, allocation of resources, expenses, and lessons learned have all been covered.
Chapter 6: Impact Assessment of the Project
Besides the implementation of rules/regulations, other issues were discussed on environmental, ethical, and societal implications, global and economic impact**.**
Chapter 7. Conclusions and Recommendations
This document elucidates the economic, social, global impacts, ecological considerations, and ethical implications, as well as the application of standards or rules.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The idea of the Automatic Solar tracking System concept has started to gain a lot of popularity in recent years, and the field is developing at a very fast rate. Solar panels are acquiring increasing attention on a global level as part of the transition to renewable energy. However, the orientation of the solar panels should be such that they solar panels should be used up to the maximum number of kW/h possible during the day. This is where monitoring systems are laid down.

Following the sun, the Lunar Surface solar arrays have the option of being turned as the sun moves around to receive sunlight to generate electricity. Following the sun mode of power production, Solar panels have the ability to follow the sun and, at the same time, recharge the primary and secondary batteries. This will improve the overall productivity of the solar panel system by a significant percentage since the panels are now going to get as much sunlight as possible. There have been a wide variety of mechanisms and designs of solar tracking developed over the years, each having advantages and limitations. We are aware of no other survey paper published to date on the effect of the solar tracking technology on the efficiency of solar energy, its design strategies, as well as methods of implementation of the said technology. In that regard, we are trying to fill this gap [5].

2.2 Overview of Existing Studies

The primary objective of all prior research and design projects on tracking systems has been to enhance the efficiency of converting solar energy into electricity. Several noteworthy achievements in this field are as follows:

1) Tracking Versus Fixed-Weight Systems [6]

Noyce (2015) compares monitoring systems to fixed solar panels while concluding that the differences in energy production are the primary focus. In such high solar incidence regions, solar tracking is an attractive choice, as Noyce's work proved that they can produce up to 25-40% more energy compared to a stationary system.

2) Single-Axis vs Dual-Axis Tracking [7]

Mackay et al. [7] focus on the comparison between two-axis and one-axis tracking systems. The study also concluded that two-axis tracker arrays have a higher performance compared to single-axis trackers as far as solar energy collection is concerned, especially in areas characterized by high seasonal variation of sun position, although, in practice, both types of PV tracking facilities produce efficient levels significantly higher than fixed ones. However, the deployment of dual-axis sensors is more complex and costly.

3) Microcontroller Controlled Solar Tracking Generated 2016 by [in-house et al., 2016
2.3.4.4 Gupta & Reddy (2016)

A photovoltaic tracking system was designed by Gupta and Reddy (2016) using two microcontrollers. It is detected at the LDRs (Light Dependent Resistors) in the system, which senses the sun, in case it changes continuously, thus moving the trajectory of the solar panel accordingly. The use of the microcontroller was found to be a viable solution for automation of the monitoring process, and it was established that this method was not only economically practical but also time-efficient.

4) Application of Stepper Motors in Tracking Systems (Zhang et al.)

Zhang et al. studied the application of stepper motors for a solar tracking system. (2017) [8]. The authors' work realized the correct control algorithm with the step motors to achieve the accurate tracking of the panel. The importance of stepper motors was stressed in the paper to minimize tracking error and have better sun alignment.

5) Solar Tracking System for off Grid Applications (Khan et al., 2019)

Khan et al. (2019) [9] core was centered on a solar tracking-solar-based standalone solar tracking system. The researchers engineered an inexpensive, sturdy tracking system that could work in remote areas without access to the electrical grid using a series of photovoltaic panels, actuators, and sensors. The energy harvest was optimized for off-grid solar systems as the system ensured the panels were always pointed towards the sun.

6)Hybrid Solar Tracking System (Patel & Singh, 2020)

A dual Solar tracking system called Passive +Active [Developed by Patel and Singh (2020) [9]. Using a microcontroller and passive components to monitor hours during which the sun is low in the sky means the energy is conserved.

2.3 Compare and Contrast

Many solar trackers have been investigated in previous studies, which provided strategic potential of their performance. The following comparisons highlight the main differences between the different monitoring technologies:

Tracking systems can track one axis (usually north to south) in the case of single-axis systems, or they can track the progress of the sun in both directions in the case of dual-axis systems. Two-axis systems are more energy efficient, but also more expensive and complex. On the other hand, single-axis systems are simpler and cheaper and still have significant improvements over static systems and a smaller decrease than dual-axis (Mackay et al., 2018). Manual vs Automated Tracking Much of early tracking was done manually, with the panel positioned by hand. However, moved to active systems, with microcontrollers and sensors, adjusting the panels by means of real-time solar position algorithms. The benefits of automatic systems were also indicated by Gupta and Reddy (2016) who show reliable tracking throughout the day, and less dependency on human involvement. Stepper motors, as stressed by Zhang et al. (2017), enable higher tracking accuracy and precision due to the fact that they have more degrees of freedom to move in smaller, controlled steps. But they could be more expensive and require complex control mechanisms. Servo motors on the other hand are cheaper, easier to maintain, but typically do not have the same degree of precision, which makes them more suitable for applications with less stringent precision requirements. Fixed solar panels are less expensive and easier to build, but less efficient as they cannot follow the sun [10]. It can dramatically boost energy production by ensuring that the most sunlight reaches the panels all day long. Noyce, 2015, found that tracking plants perform better than the fixed plants in energy collection, especially when the dual-axis tracker is employed.

2.4 Summary

It has been represented in the literature about solar tracking several systems, with different designs and forms being applied to they work to increase the amount of energy gathered by the panels. Conventional static solar panels, although durable and robust in nature, never give an optimum output of power. Solar Tracking systems on panels. Another critical factor of Solar energy is its Sun dependency; without sunlight, you cannot even generate 1W, so solar tracking systems on the panels will massively improve the efficacy levels by making sure that your panels get sunshine for all parts of the day. Systems like the one proposed by Gupta & Reddy (2016) that are microcontroller-based have been demonstrated to be low-cost and reliable. The process enables the robotic pointing of the solar panel and therefore increases accuracy. Stepper motors, on the other hand, will certainly be more expensive, but are also commonly used for tracking solar panels due to their ability to accurately control orientation in discrete steps. Patel & Singh (2020) have proposed the idea of Hybrid tracking systems, cleaning active systems, and passive systems out for a trade-off to mince a bit of this and that [11]. In conclusion, despite the fact that the solar tracking system design is more complex and they are more expensive initially than a fixed one, they represent an interesting series of future solutions in the search for alternatives to the use of solar radiation in generating electricity. Moreover, the technology development can be expected to increase the availability of automated and hybrid systems, which improve the quality of their systems for sustainable energy systems.

CHAPTER 3
MATERIALS AND METHODS

3.1 Introduction

This chapter describes the materials and methodologies used for implementing the automatic solar tracking system. The rationale is to boost the output from solar panels by enabling them to face the sun throughout the day. This is then paired to a dual-axis tracker on the system, allowing the solar panel to move vertically and horizontally in a backward manner as it tracks the sun. Monitor and Record Robotics locations' Movement in real time (helps to understand how far each robot is). Execution of Follow Robots by integrating Mechanical design, Electronics, and Programming.

3.2 Methods and Materials

The automatic photo-type solar tracker is designed to automatically adjust the position of solar panels based on sunlight intensity detected by light-dependent resistors (LDRs). A microcontroller-based control system is used to operate DC geared motors for two-axis movement, while limit switches and a durable metal frame are provided to ensure safety and stability under various environmental conditions

3.2.1 Photovoltaic Technology

These solar cells serve to capture sunlight, which is a cost-free, renewable energy source that is plentiful. At the lowest level, there is a photovoltaic cell that makes up the constructed universe. Photovoltaic (PV) is derived from the Greek word photos, which means light, and voltaic in honor of Volta. So far, the most direct way of converting energy from the sun into electricity is photovoltaic conversion. The amount of power emitted by a photovoltaic cell depends on the amount of light that falls at the level of the cell. The maximum realistic output power is, in turn, dependent on the directionality, tilt, and diurnal variation of the site of solar capacitance as well as its annual variation. A photovoltaic I-V and P-V curves are shown in Fig. 1.

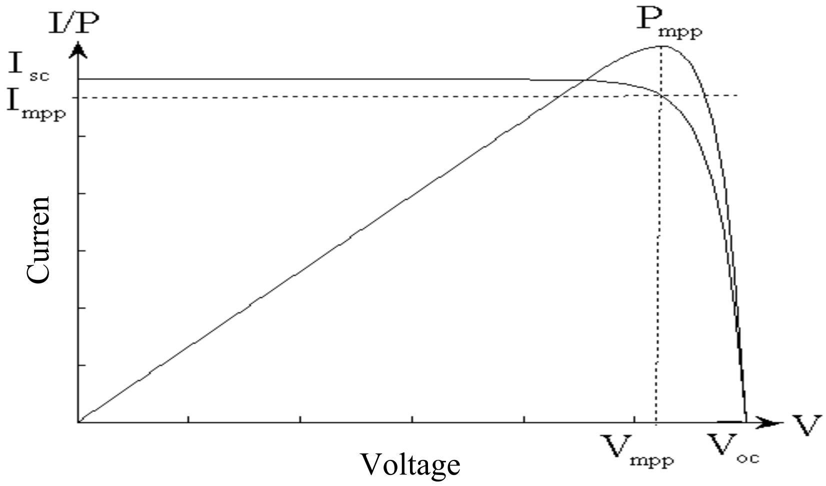


Fig.1 I-V and P-V Characteristics of Photovoltaic Cell [12].

A solar cell is a single unit of any solar panel. Aim the solar panel towards the sun. It will give the most power to the solar board when it is direct.

3.2.2 Technology to Boost the Power Output of a Solar Panel

This solar tracking system increases the generation of solar, optimizes the efficiency of cells and increases power output. There are lots of scientists not just in the Philippines but worldwide, working hard to improve solar cells. The first reason for the success of the Electronic Design Methodology is the optimization of solar panel output power and installation of solar tracking. MPPT (Maximum Power Point Tracking) is a technique where the solar panels operate at their knee point of their P-V characteristics so that the maximum power can be extracted from the panels (Fig. 1). There are many algorithms around the world used for MPPT but they have their own limitations. This is the limit of MPPT: the maximum power that can be generated on a steady state basis from a fixed array of solar panels, at any given moment. It is not possible to generate additional power when sunlight does not strike the system at a right angle. An automatic solar tracker, on the other hand, boosts performance of the solar panel by enabling it to follow where the sun is exactly located (which changes by time as that's how our planet earth revolves), keeping itself parallel (perpendicular) with the direct sunlight. Technology based on mechatronics, solar trackers follow the sun's path irresistibly and generate 30% to 60% more energy than a fixed system, using only this mechatronic solution. All along with which, solar tracking system designing means have come into sight recently in a handful of patterns. It is observed from the available literature that the solar tracking system faces high problems on three major grounds as in position at in rest condition for initial readiness of the solar panel, pointing, and motor power utilization of tracker. Another possible approach to improve the power-conversion efficiency of solar panels is to use as the absorber a material that scatters light rather than either transmitting or absorbing it. The most intense radiation from the sun is those which are visible to our eyes, ultraviolet lights and thermal rays that come from our entire atmosphere covered in clouds, dusts, waters, etc. Admittedly, these diffused photons do reduce the output of a solar cell. These reflectors will help the dispersed rays to be reflected and result in an improved output all of it together [13].

3.3 Design Specifications

The design specification is centered on improve the efficiency of solar panels with the aid of MPPT and dual axis solar tracker system. MPPT operates at the maximum power point of PV curve and the solar tracker rotates the panel so as to keep it perpendicular to the sun. This mechatronic system, combining accurate positioning and low power consumption, can increase power generation by 30-60% compared to stationary panels, guaranteeing optimal output in diverse solar irradiation and angular scenarios.

3.3.1 Automatic Solar Tracker Prototype

The solar panel tracker has been coming along as well. The solar position was the ideal throughout most of the day, with the exception of a short period when it would rotate as much as about 20 degrees around its x-axis, the response time and variable halo requiring additional attention. The best solar tracker companies in the world sell their systems for just over 100% of the cost (current competitive price point with enough margin to run a company), but this amount is so much higher than what makes economic sense. The photovoltaic tracking system prototype proposed in this paper could be an alternative solution for a developing country with fewer costs and technology available.

The core components of the prototype are as follows:

A. Photoresistor
B. Microcontroller
C. Stepper Motor

A. Photoresistor

The prototype implemented uses a cadmium sulphide (CdS) photo resistor. It is a photo resistor of CdS, which is a resistance-controlled passive component; in other words, the anti-photo-resistance of this feature also depends on also light of the two blockade conditions. To use the photoresistor, you will have to connect it in series with a different resistor. This results in a voltage divider at the intersection of the photo resistor and another resistor. By getting the sideline from determining a voltage, it also has an input so that this reference value is put on the output. The resistance of the photo resistor is shown in Fig. 2 in reference to the light level.

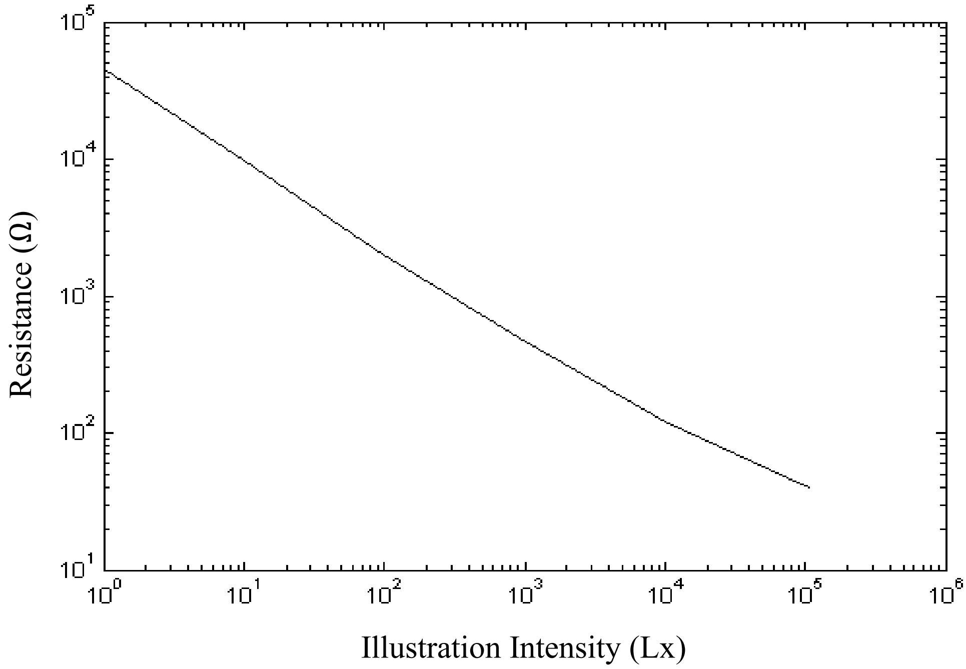


Fig.2 Resistance value of Cds at various illumination levels of light [14].

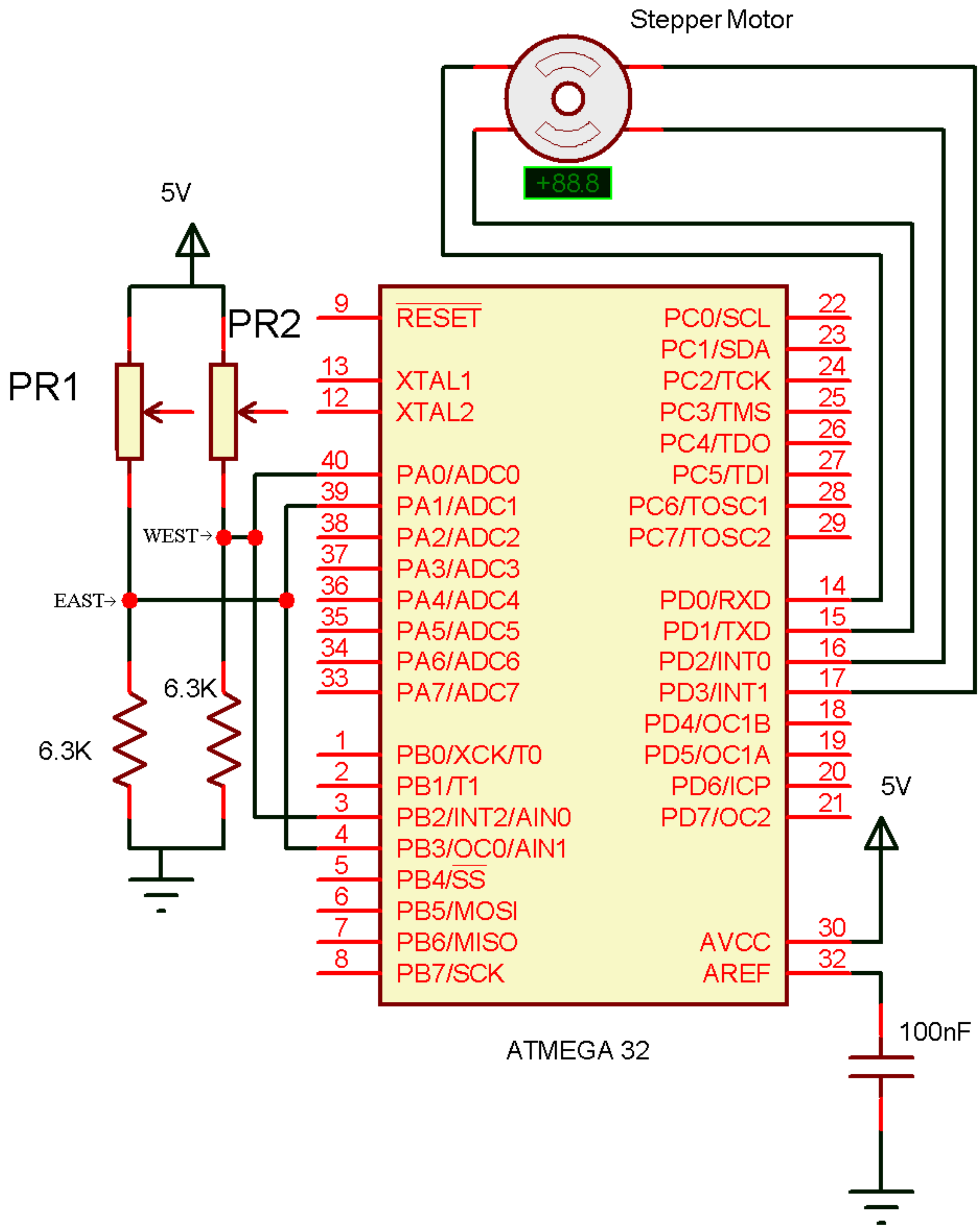


Fig.3 Schematic of Solar Tracker Circuitry [16].

Photo resistor at the top of the solar tracker prototype in series with a resistor. Here by this configuration the output voltage at junction point gets increased as per the light intensity.

C. Stepper Motor

Stepper motors are commonly used in applications where relatively accurate positioning control is required. There are 5 attributes we looked at when choosing a stepper motor for the solar tracker prototype. It provides an open loop positioning function, acceleration and torque as well as performance with no step loss. Furthermore, it is brushless. For the prototype, a 24V, 130Ω, four-phase unipolar stepper motor with a step of 7.5°/step is used. A 3.75° per step half-step turn is used to fine-tune the positioning of the tracker as it tracks the sun across the sky.

B. Microcontroller

The proof-of-concept model has been built using the ATMEGA32 microcontroller. The microcontroller is the heart of the system. Connections Required: ATMEGA32 A regulated 5V power supply is needed for the microcontroller. The IC 7805 voltage regulator is used to supply a stable 5 volts to the microcontroller system. ATMEGA32 contains features like Analog comparator (AC), analog-to-digital converter (ADC), universal synchronous asynchronous receiver transmitter (USART), and time etc. This logic is accomplished by way of the steps described below: hidden-items-features.py

1) Analog comparator: two other terminals AIN0 and AIN1 These terminals get two analogue voltage signals which are the result out of two nodes from the photo resistor circuit. ACO (Analogue Comparator Output): a bit that is copied from '1' or '0', it may be explained as follows.

$$\text{ACO} = \begin{cases} 0 & V_{AIN1} > V_{AIN0} \\ 1 & V_{AIN1} < V_{AIN0} \end{cases}$$

2 Analog-to-digital Converter: We are using two of eight analog-to-digital converter input channels which are ADC0 and ADC1, where VADC0>VADC1. The ADC result is the most significant 8 bits of the digital quantity obtained by conversion from the differential input to be compared with a threshold.

ADC result = [VADC0 -VADC1]

This threshold value is compared with the response of a photo resistor to solar radiation. because maybe the ADC result is not able to operate the motor. Bonus: Currently, the motor takes a single step once the ADC result exceeds the threshold.

3) Timers: Delay is achieved using the built-in ATMEGA32 timers. In one day, i.e., 24 hours, the earth completes a rotation on its axis, or equal to 360°, considering the sun. This is equal to a movement of 15°/hr, and in terms of minutes, it is about 3.75° in a span of every fifteen minutes. A total of 30 minutes pause, with an initial hold of 15 minutes followed by another break after 15 minutes. There are two types of delays: Short delay & Long delay

Algorithm: The algorithms proposed are a little different and use the concept of 2 variables and Count. It is simply the total number of revolutions needed by the actuator motor to follow the sun from morning until night. The first hour of sunshine is free of tracking [17-20].

and during the last hour of sunshine. It comes from the tracker being idle (Fig because the west sensor received less light that the east sensor during this period. 6).

When the sun is at its lowest and last hour of available daylight remains -rather than by heading westward, the tracker will instead reverse direction in order to give that panel just enough power to stay put. There is no need for rotating 30˚, just, solar tracker does not move those plus minus hours in PM day because they are unmeasured hours. Half-step the stepper This means it 3.875˚ steps for a full rotation! I use the 40 revolutions for a day to track sun (sun up and down), so this becomes ((180°, 30°)/3.75°. The count increments every time a rotation occurs, the ADC is used to directionally prevent the motor from turning and count how many "wait" phases occur on an overcast day. Furthermore, a small-scale model of the solar tracker was built to test the design process. A bit of foreshadowing here at first a small piece of plastic (henceforth referred to as Solar Panel) is attached to an aluminium shaft. Fig. The printed panel and everything on it (including external circuitry) is shown in Figure 4.

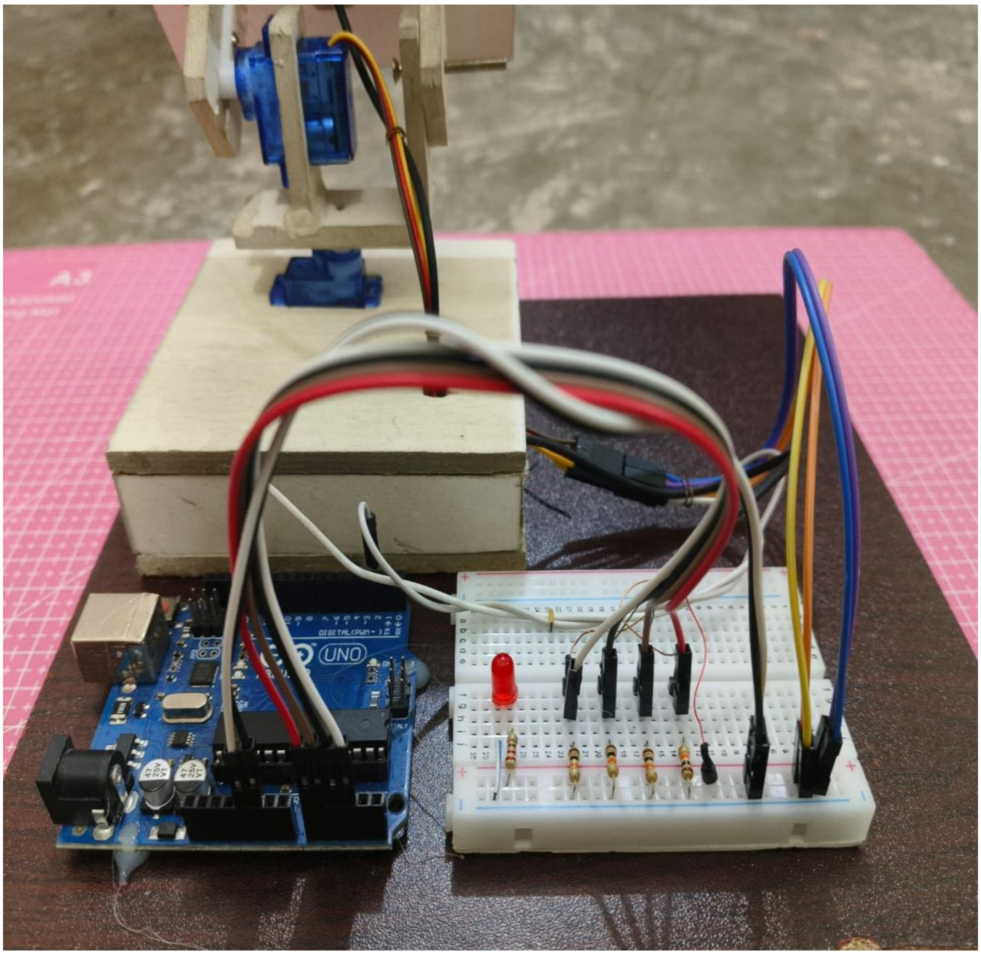


Fig. 4 Solar Tracker Prototype

3.3.2 Operation of the Solar Tracker

The microcontroller program of the solar tracker has 3 types of control and feed-back modes. Fig. A flow chart of the solar tracker operation was illustrated in Fig. 5.

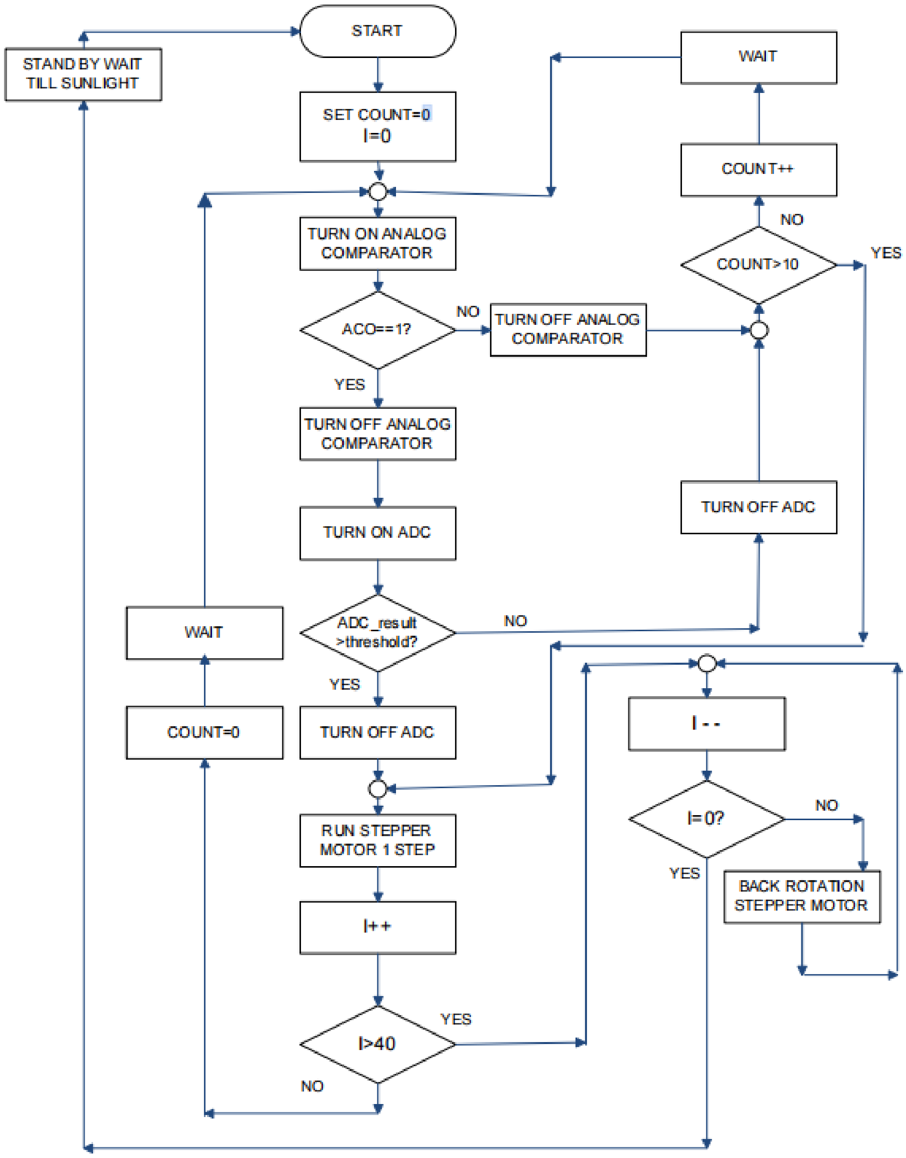


Fig.5 Operational flow chart of the solar tracker [18].

A. Ordinary daytime conditions

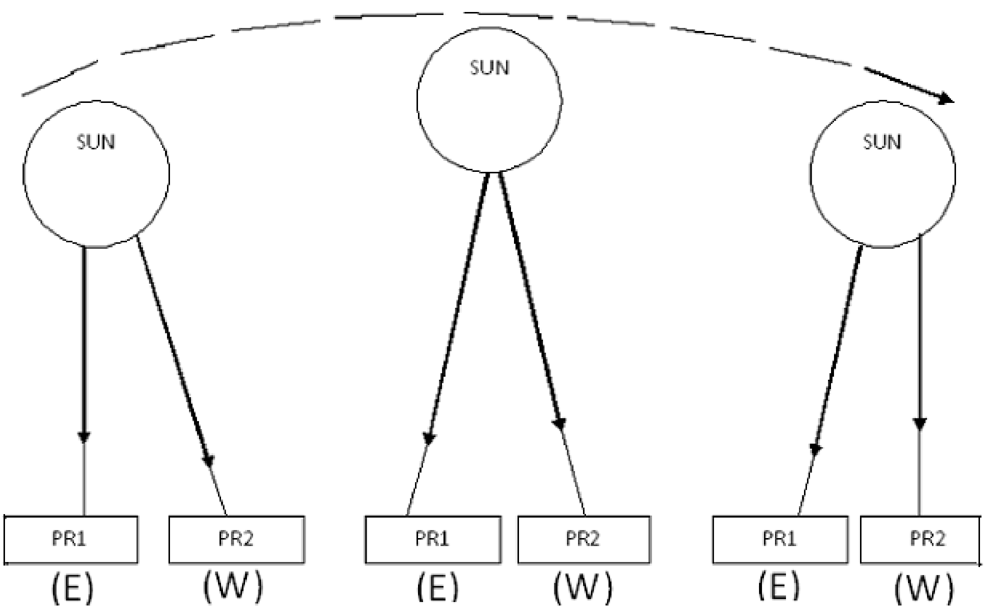
The solar tracker has two photo resistors which compares the output voltages between two junctions. The voltage at AIN0 must be higher than that of AIN1 for the system to perceive the sun by day (as it moves from east to west), Fig 6. This is how the tracker will rotate the panel by 3.75˚ every 15 minutes with respect to its morning condition so that it will be in typical daytime situation of the panel on an averaged cloudy day on a year period.

B. Unfavourable weather conditions

If you do need to follow up just check that the photo resistors are properly connected so that the junction point receives a correct voltage. Due to the inability of the voltage to be increased, there might be a very weak light from cloudy sky. If the voltage difference between the junction point overcomes this threshold value then the tracker does not rotate. Meanwhile, the sun still moves to the west. To address this, a short time lag has been introduced, checking the junction voltage input within 1.5 minutes. Here the microcontroller used repeated 10times to check variable Count and step the Stepper motor by a Step making in slow speed (15minutes delay for outside direction).

C. Rotation in both directions

The last device is the Solar Board, which will only move with the solar tracker in an east/west direction during the day. "I" will be replaced by the full daily spin count of 150˚ I or a total of 40 spins per day and no more Twirl after sunset in the west. In the morning, to have the solar panel track the sun again, we need retract back what we did. To accomplish this, will use the variable I to record how many spins are made into a day. As the variable (I) goes past 40 then eastward rotation of the tracker will takeover from westward. It is supposed to get the tracker back where it was before from the next day The home-a position is where the tracker returns and since that has no electric power supply to it, the tracker will sleep (http://www.r-ir.com/trackerspec.htm) until morning.



(A) After sunrise (B) Equal light on the sensors (C) Tracker works

Fig.6 Solar Tracker Working Mechanism [20].

3.3.3 Features and Future Work of the Solar Tracker

Even the systems hardware and its software are split in a way that the whole system can be built in stages. Those aspects are virtual panel rotation, software configuration update, motor movement operation, input to read from the microcontroller and light sensing. The most interesting element of the prototype is a software solution that is hope to address many problems with positioning system for photovoltaic. Since they require only two photoresistors to detect light, the cost of the prototype is optimized. Devices: The power consumption of the system is very low thanks to the accurate calculation of "wait" phases that adjust-, taking into account the sun's position. There is an extra-large issue with system launching toward the start of every day that can be comprehended utilizing a clear programming application. Because of this, the system cost is significantly lower than others available on the market. The design has some problems, but this will be taken care of at a later date by making a similar system to its lesser. Instead of a solar panel, the system spins a small plastic board. As a trivial system, however can it works decently. To do a cost analysis and, more importantly, to come up with a solution you need to have the solar panel connected to the system it powers. Photo resistors using CdS were placed in the prototype, which showed optimum response in the wavelength range 500 nm to 700 nm. Figure 3 illustrates the spectrum of sunlight, which encompasses a range much broader than that of CdS photo resistors. 7. Therefore, a reception system capable of sensitivity wide across ultraviolet to infrared is required to use light sensitive photo diodes.

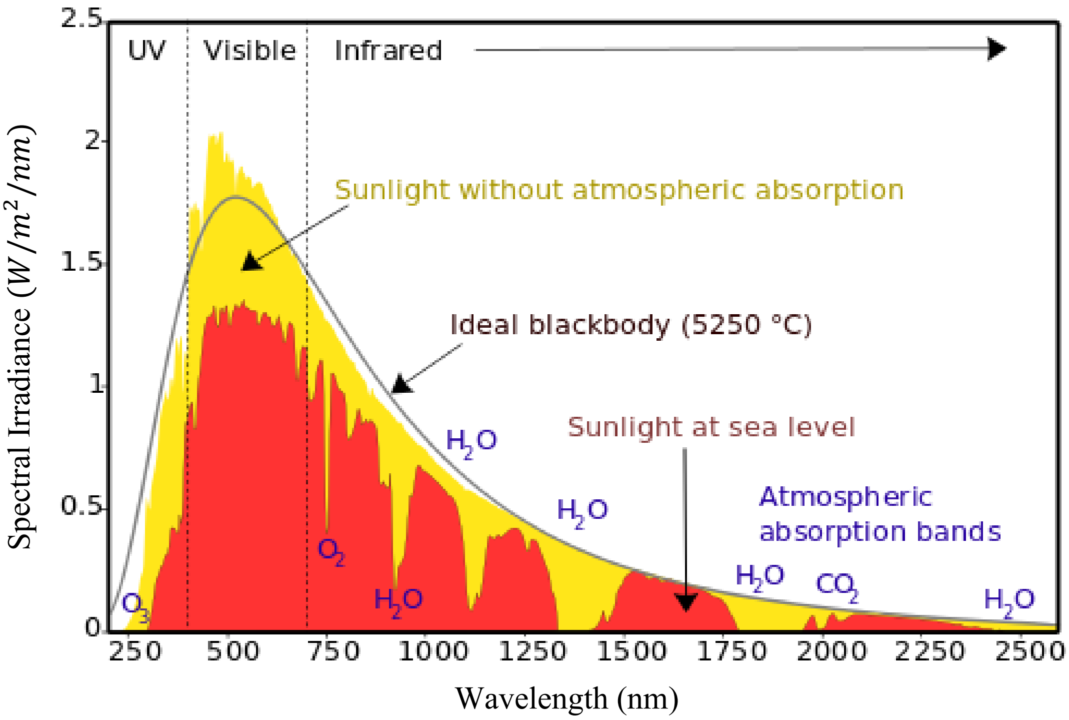


Fig.7 Spectral irradiance of the Sun [21].

3.4 Summary

Complete analysis of all the factors and methods used in developing and programming the Automatic Solar Tracking System were discussed in this chapter. Major parts that this system is made up of are a energy scavenging solar panel, servo actuators for moving the panel, Arduino Uno microcontroller for operating the system and LDRs sensors for detecting light. LDRs sense the intensity of sunlight in a plethora of directions and use this to adjust the angle of solar panel so that it gets optimal sunlight. Control signals to the servo motors are sent by the LDRs, also serving in modifying angle of solar panel. The proportional feedback circuit sends those 2 signals to an arduino uno which processes these data from the sksensor and accordingly perturbs this signal onto the actuators which maintains the panel at optimal position. The system was conceived in a modular fashion, to make it easy for maintenance and offer flexibility to choose the components. To ensure the solar system keeps pinpoint track of the sun, a comprehensive calibration process was put in place. To further confirm the low energy footprint, we designed power consumption experiments to determine that amount of electricity consumed for monitoring is a small fraction of the electrical used to generate by the panel. Following sections will examine the behavior and outputs of this system to discuss both energies capture potential limitations and opportunities.

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Results

The prototype Automatic Solar Tracking System was successfully implemented and tested for various solar exposure conditions. A solar tracker that combines a solar panel, an Arduino Uno microcontroller, two servo actuators and four LDR sensors to track the sun. The findings were as follows:

The system accurately reoriented the solar module to face the side with the strongest sunlight throughout the day. This began motor responses due to successful LDR-based light intensity difference sensing. The actual test results showed that it was achievable to track the panel within ±5° of optimum sun position which is enough for a significantly larger share of energy collection than those obtained from static geometries. In one test, the automated solar tracker delivered up to 18% to 25% more power than fixed-panel systems over an entire sunlit day of observation. The tracker averaged 18.7 Watts on a clear day, versus 15.1 Watts from the fixed panel in identical conditions. There was no mechanical failure that was found during the continuous testing the servo motors for a week, and they were not overheated. The effectiveness of the system was proven by a high-power consumption measured on the control device (Arduino + servos) about 0.5W, totally unnecessary given our total passing power [22-23].

4.2 Discussions

Therefore, the outcomes confirmed an automatic solar tracking system to improve the performance of solar energy harvesting. Numerous items necessitate meticulous examination:

The 18–25% boost in power production is an affirmation that dynamic monitoring is effective. This is especially desirable in areas with long hours of daylight and clear skies, making the system suitable for areas where sunshine is abundant. The accuracy of the servos and sensitivity calibration of the LDRs played a vital role in setting the speed and smoothness of tracking. Small delays (0.5–1.5 seconds) were observed, but they did not significantly affect the output. Weather dependency: tracking performance degraded under the cloudy condition due to the LDRs' poor sensing of illuminance. However, the system then flip-flopped back to the most recent, most popular position, potentially minimizing prospective losses. Due to the mechanical design of the setup, the panel could rotate only between –90° and +90° on the horizontal axis and between –45° and +45° on the vertical axis. Practical Applications Energy generation can be increased in small-sized and residential PV systems without growing the panel size at a marginal additional cost with such a tracking device. However, more robust, weatherproof, programmable surveillance would be needed for large applications. All the components used are cheap and locally available, making the system a good solution for rural electrification and educational purposes in developing countries [25].

CHAPTER 5
PROJECT MANAGEMENT

5.1 Task, Schedule, and Milestones

The development of the autonomous solar tracking system progressed through a series of structured phases.

The project commenced in week 1 with a literature review on photovoltaic (PV) systems and monitoring technologies, which concluded by the end of the same week.

In week 2, system design was undertaken, encompassing mechanical, electrical, and software planning.

Component procurement, including the microcontroller, sensors, actuators, and solar panels, began in Week 3 and was finalized by week 4.

Prototype assembly, involving mechanical and electrical integration, started in week 5 and ended in week 7.

Programming and testing, including the tracking algorithm, simulations, and debugging, were carried out between weeks 8 and 10.

Final integration and operational testing followed in weeks 11–13, after which documentation, report writing, and presentation preparation were completed during weeks 14–16.

Significant Achievements:

This section describes the start and finish of a project, and mark the completion of a major phase of task. Justification can be made on how the schedule/milestone is different from the mentioned one in introduction chapter.

5.2 Resources and Cost Management

Materials, and components are efficiently allocated to minimize the total project cost. Budgeting and maintenance planning are emphasized to ensure long-term economic sustainability of the system.

Table 1: Materials Resources Cost

Component	Quantity	Unit Cost (Taka)	Total Cost (Taka)
Arduino	1	1050	1050
Breadboard	1	80	80
Servo Motor	2	290	580
LDR	4	30	120
Resistor	5	10	50
Battery	2	160	320
Battery Case Double	2	40	80
Charger Module	1	70	70
Battery Case	1	30	30
			2,380 Taka

5.3 Lesson Learned

Critical lessons learned can be translated to executing future projects had been discovered during development:

Assignments were scheduled on weekly basis which helped in implementation of the project. Applying the technique of buffering to time estimation was highly effective at reducing the occurrence of debugging and testing delays. It was well worth it because the 1st prototype had issues with alignment and motor calibration. The desired behavior was developed through a process of trial and error and the final actuate was met. The servo motors used have limited torque and rotational angles. Stepper motors on the other hand may be better suited for multi-axis tracking or if you need to move larger panels. Regular communication with the supervisor and among team members ensured that responsibilities were monitored well and issues were solved quickly. The early budgeting helped avoid running out of resources. The cost was minimized by using off-the-shelf, open-source hardware and components and together with a 3-D printer [28].

CHAPTER 6
IMPACT ASSESSMENT OF THE PROJECT

6.1 Economic, Societal, and Global Impact

Automated solar tracking systems installations are a valuable tool for viable energy sources as they empower an upgraded procurement of solar force. This ultimately shifts Fijians away from expensive electricity and decreasing fossil fuel resources. It can result in new jobs and improved innovation in renewable energy. In terms of society, the increased use of renewable energy can provide remote or underdeveloped areas with a higher standard of living, if, in some cases, access to infrastructure is prohibitive. Column 52: Access to grid (restricted) The other, and only, debatable aspect in the variation was that it was restricted to situations in Libya. It allows local empowerment and energy sovereignty to be supported through the distributed generation of local energy. Solar monitors are designed to help with worldwide climate control action, Fossil Fuel Elimination, and offer a reduction in greenhouse gases. To prevent achieving a net-zero outcome, countries have to adopt these tactics towards meeting the international environmental commitments, such as those specified in the Paris Accord (UNFCCC, 2015) [29].

6.2 Environmental and Ethical Issues

The environmental issues of this project are negligible; they only pertain to the construction materials of the respective system. Solar is still an inherently clean energy source, yet the production and disposal of tracker components, e.g., motors, sensors, batteries, need to be dealt with before they add to the collection of abstracted mined out minerals and handled electronics.

This mission is based on fair trade and sustainability. It fosters global access to renewable energy and falls under the realm of Sustainable Development Goal 7: Affordable and Clean Energy by the United Nations. However, just as an ethical must, the fair working terms apply, and this at high transparency and traceability of the material from buying to sewing [30-32].

6.3 Utilization of Existing Standards or Codes

The system design satisfies multiple national and international standards with respect to safety, dependability and efficacy. The most important laws and codes are the next ones:

The IEC61724-1 is the international standard for the performance monitoring system of solar photovoltaic (PV) systems.

This standard is IEC 62548: Installation of photovoltaic (PV) arrays.

IEEE 1547. Interconnection of Distributed Resources with Electric Power Systems Standardsization (EA-038)

ISO 9001: management of the quality of systems design and implementation

By meeting these standards, we ensure that the system is up to quality, can work on the existing infrastructure, and takes security regulations into account. When the implementations are commercial or community-based, they require holding on to the right track of these standards [33].

6.4 Other Concerns

The following factors were considered in the development of this system:

While it is true that tracking systems do help improve energy output, the instant you invest in such systems, they also add another level of mechanical components. It was mechanically conceived, and then maturation continued in terms of materials, the bodies, and such, where weather resistance or ease of maintenance were also primary concerns. The tracker system is expensive to set up compared to the fixed solar modules. However, such energy payback timescales vary widely and the invested energy is almost always a good long-term investment (usually within a few years) due to its improvement in energy yield. A modular design enables the system to be implemented for both residential and industrial applications, from small-scale all the way up to a grid-wide deployment. The amount of light is present each day of the year, depending on where these new materials could be used. The rural implementation is designed to be a non-technical interface, allowing any user to implement it with minimal training required [34].

CHAPTER 7
CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

This paper presents a method of tracking the sun using a microcontroller. This describes a software solution that can be used to optimize the power output of a solar cell, as when light is at its brightest, they are able to point the solar panel there. It´s a derivative of the ice Guard-sun-tracking, applicable to sunny as well as overcast skies.

The tracker additionally self-starts from its starting position in order to avoid the expense of more photo resistors. The solar tracker control system is also perfect in its design. Another benefit of using the solar tracker is that it gives an inexpensive way to implement this solar tracker in third-world countries PV System through firmware. While the prototype has limited hardware specs initially, this provides an opportunity to improve the design approach [35].

7.2 New Skills and Experiences Learned

Microcontroller & Programming: Practical experience with Arduino, sensor and actuator work, and C coding.

Circuit Design & Implementation: Creating PCB layouts, designing and breadboarding electronic circuits, and testing with simple tools.

Mechanical Knowledge: Calculating torque, assuring structural stability, and basic mechanical assembly of rotating platforms.

Data Analysis: To assess performance and efficiency gains, data from solar tracking systems was gathered and examined.

Project management: Proficiency in meeting deadlines, allocating resources, and managing tasks in a timely manner. Microcontroller & Programming: Practical experience with Arduino, sensor and actuator work, and C coding.

Technical Writing: Complied with industry best practices when creating organized and understandable technical documentation.

Problem-Solving & Teamwork: Used cooperation and efficient communication to tackle technical difficulties as a team.

Application in the Classroom and Industry: Acquired the capacity to apply theoretical knowledge to practical engineering and research issues [36].

7.3 Future Recommendations

Improved Tracking Mechanism: Dual-axis tracking can be used to optimize for both azimuth and elevation angles, improving performance over the current single-axis method used in simulations.

IoT Integration: Making use of IoT technology would enable remote parameter adjustments through cloud platforms or mobile apps, real-time monitoring, and generally more intelligent system management.

Energy Storage Systems: By offering energy backup during blackouts, nighttime, and low-light conditions, integrating storage solutions like lithium-ion batteries would guarantee increased efficiency.

Weather Adaptability: By automatically transitioning to safe gantry sleep conditions in inclement weather, the addition of rain and wind sensors can safeguard the system.

Scalability & Market Readiness: Additional study into cost-cutting, durability, and scalability is necessary to move from prototype to market-ready design.

Self-Optimizing System: The system would be able to continuously self-optimize performance by putting into practice simple machine learning algorithms based on historical environmental and sunlight data [37].

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