REPORT on
Design and Development of Sun Tracking solar Tree

Summary

The renewable-energy sector is fast gaining ground as a replacement growth area for various countries with the vast potential it presents environmentally and economically. Solar power plays a vital role as a primary source of energy, especially for geographical area. This project presents the look and development of sun tracking solar tree using Arduino platform. Furthermore, the last word objective of this project is to trace the utmost sunlight source to power the solar array.

The project is split into two stages, which are hardware and software development. In hardware development, four light dependent resistor (LDR) has been used for capturing maximum light. Two servo motors are wont to move the solar battery at maximum light location sensing by LDR. In software, the code is built using C artificial language and targeted to Arduino UNO controller.

The efficiency of the system has been tested and compared with static electrical device on several time intervals, and it shows the system react the simplest at the to-minutes intervals with consistent voltage generated. Therefore, the system has been proven working for capturing the most sunlight source for top efficiency solar harvesting applications.

Table of Contents

Certificate ……………………………………………………………………………………………………(ii)

Declaration…………………………………………………………………………………………………(iii)

Acknowledgements………………………………………………………………………………………(iv)

Summary ……………………………………………………………………………………………………(v)

Table of Contents…………………………………………………………………………………… (vi)

List of Tables…………………………………………………………………………………………(x)

List of Figures……………………………………………………………………………………………(xi)

Nomenclature…………………………………………………………………………………………(xii)

Abbreviations and Acronyms………………………………………………………………………(xiii)

Chapter-1: Introduction……………………………………………………………………………01

1.1 Heading 2……………………………………………………………………………………02

1.2 Heading 2……………………………………………………………………………………03

Chapter-2: Background Theory

2.1 Background Theory to be Written in Various Sub-Sections…………………04-07

Chapter-3:Aim and Objectives………………………………………………………………08-09

3.1 Title of the Project…………………………………………………………………………08

3.2 Aim of the Project…………………………………………………………………………08

3.3 Objectives of the Project…………………………………………………………………08

3.4 Methods and Methodology………………………………………………………………09

Chapter-4: Problem Solving ………………………………………………………………10-20

1. Design and Development ……………………………………………………………10-11
2. Design and Implementation…………………………………………………………12-13
3. Component Description………………………………………………………………13-19
4. Psuedo Code……………………………………………………………………………………19
5. Flowchart………………………………………………………………………………………20

Chapter-5: Results

Chapter-6: Project Costing

Chapter-7: Conclusions and Suggestions for Future Work

References

Appendices

List of Tables

Table 1 Specifications of arduino……………………………………………………………………14-15

Table 2 Light Intensity measurement……………………………………………………………………16

List of Figures

Figure 1.1 Solar Tracking system…………………………………………………………………………3
Figure 1.2 Solar PV cell………………………………………………………………………………………4
Figure 1.3 Single Axis Solar Tracker ……………………………………………………………………5
Figure 1.4 Dual Axis Solar Tracker ………………………………………………………………………6
Figure 1.5 Solar PV tree……………………………………………………………………………………10
Figure 1.6 Trestle design of solar PV tree…………………………………………………………11
Figure 1.7 Block diagram of the system……………………………………………………………12
Figure 1.8 Circuit diagram of the system……………………………………………………………13
Figure 1.9 Arduino UNO board……………………………………………………………………………13
Figure 1.10 LDR (light dependent sensor)…………………………………………………………15
Figure 2 Servo Motor…………………………………………………………………………………………16
Figure 2.1 PMW analog signal is converting to digital signal to control the servos…17
Figure 2.2 servo motor PMW timing diagram……………………………………………………17
Figure 2.3 solar panel…………………………………………………………………………………………18
Figure 2.4 Flow chart of the overall process……………………………………………………22

Nomenclature

I	current (A)
V	Voltage (V)
P	Power (W)
R	*Resistance(R)*
I	*Inductance(H)*
C	*Capacitance*

Abbreviation and Acronyms

LDR	Light Dependent Resistor
Solar PV	Solar Photo Voltaic
SPT	solar PV tree
USB	Universal serial bus

1. Introduction

1.1

Nowadays, global climate change on globe is at a critical level. temperature change is divided into two categories, human and natural causes. Natural causes of climate changes are current, solar variations, and earth orbital changes. the most parts of climate changes caused by human are man-made greenhouse gases. heating or climate changes is seen through a number of them phenomenon just like the effect on crops and extreme atmospheric condition round the world.

Renewable-energy is an energy which comes from natural resources like sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished) [I]. Renewable-energy is that the best growing energy source on the world. Renewable energy may be a source of energy that does not consume the finite resources of the world and may be easily and quickly replenished. Renewable-energy plays a key role during a country's energy needs; enabling businesses to assemble energy cost investments and also revenue thus controls the result of climate changes. Solar energy is that the energy derived from the sun through the shape of radiation. The sun is that the most inexhaustible, renewable source of energy known to man. Alternative energy provides light, heat and energy to all or any living things. There's no price and also no pollution created by solar power, environmentally friendly and therefore the solar energies are interminable supplies. As for solar power, it's pertinent that its lots of benefits and downsides when it involves compare other energy sources. The elemental issue of utilizing alternative energy isn't a matter of lack of other sources of energy but it is a matter of environmental concern as some conventional energy sources contribute high emissions to the environments [2].

Solar energy generation through the photovoltaic route has been identified because the renewable energy source which will compete with fuel based conventional sources of energy .The solar PV technology is mature enough for commercial use and doesn't involve any material procurement costs at the time of its operation, which makes it a highly attractive alternative for giant scale electrification. Despite its numerous merits, PV technology suffers from poor conversion efficiency and consequent need for big areas of useful land to fulfil energy demands. Solar PV tree could be a PV system level technique, which consists of panels arranged on a metal structure (like leaves of a tree) rather than being laid come in the shape of an array. This tree like orientation of panels reduces the burden of giant land requirement in PV systems. However, the random orientation of panels ends up in each panel producing different amount of power at any particular instant during the day, leading to inverter losses. Hence this makes the solar PV tree unsuitable for grid synchronization. It also makes sun tracking very challenging. Such drawbacks have limited the employment of solar PV tree to small scale stand-alone applications like battery charging and street lighting [3].

The major objectives of a solar PV tree (SPT) are as follows-

- To reduce land requirement for a PV system
- To enhance sunlight capture with the help of a 3D structure
- To improve public acceptability and perception of solar PV technology
- To raise awareness among citizens about renewable energy and sustainable development

1.1.1 Sub Heading

- **Sun tracking system**

  Solar tracking is a commonly used, well-proven technology that boosts energy output by guiding or concentrating photovoltaic panels to follow the sun's path from dawn to dark. For a longer period of time, the instantaneous solar radiation gathered by photovoltaic modules combined in a tracking system is higher than the critical irradiance level than in stationary systems [4]. Solar trackers come in a variety of sizes, pricing, performance, and sophistication. As shown in Fig.1.1, there are static solar panels, single-axis solar trackers, and dual-axis solar trackers.

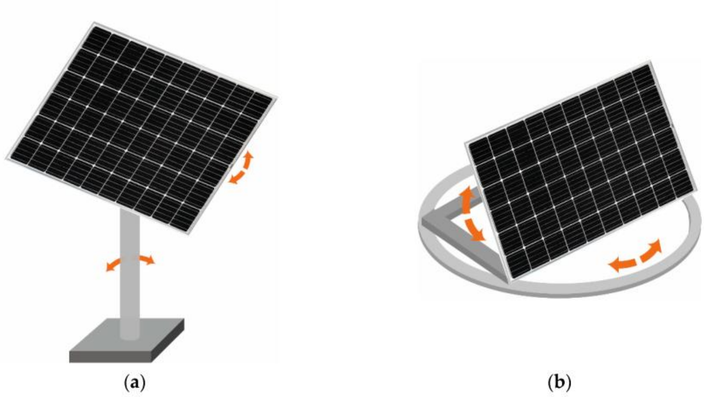

Fig 1.1 Solar Tracking System

When a tracking system is used instead of a stationary array, it is anticipated that the yield from solar panels can be enhanced by 30-60% [5]. A variable elevation solar tracker can produce up to 40% more electricity each year [6]. The usage of a high-efficiency dual-axis solar tracker is proposed in this research. It starts with a presentation of the project's system design. The study then goes on to discuss specific design techniques for LDRs, servo motors, solar panels, programmer selection, and software/system operation. The report finishes with a discussion of the findings as well as future research. With Arduino as a programming platform, the dual-axis tracker is a very compatible system to design. The primary controller receives an analogue input from the Light Dependent Resistor (LDR) and converts it to a digital signal using an Analog-to-Digital converter as part of the overall system. The movement of the solar panel is determined by the servo motor's output.

2.Background Theory

2.1 Background Theory(or Theoretical basis) :

This chapter deals with review of some technical papers, books, articles regarding the concepts of working of the solar PV cell and Sun tracking system. It also deals with the background theory of various components used in this project.

<u>Solar pv cell</u>

A solar photovoltaic cell is an electrical device that generates direct current when exposed to sunlight. Solar cells are made of photovoltaic materials such as monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulphide. A solar photovoltaic module is made up of these cells that are electrically coupled together.

Theory of operation of solar pv cell

The photovoltaic effect is used to power the cells. When photons collide with electrons in a solar panel, they excite them to a higher energy state and act as charge carriers for an electric current. The panel structure generates an electric field, which, when paired with the flow of electrons, results in an electric current.

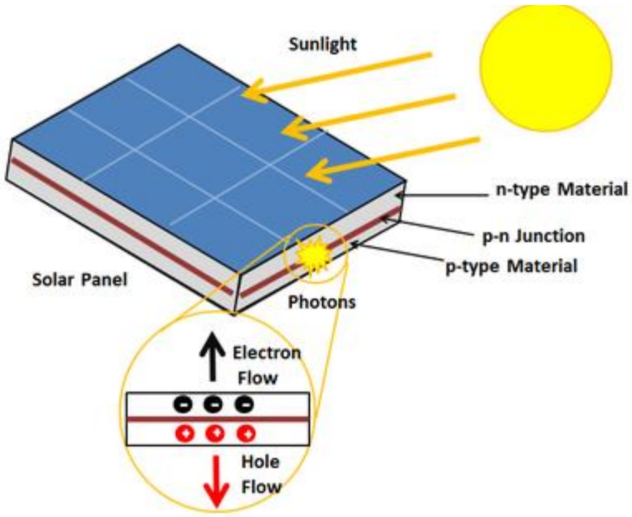

Fig 1.2 Solar PV cell

Solar tracker

A system that allows an object to be positioned at an angle to the Sun. Placing photovoltaic (PV) panels (solar panels) so that they remain perpendicular to the Sun's beams and positioning space telescopes so that they can identify the Sun's direction are two of the most prevalent uses for solar trackers. PV solar trackers change the orientation of a solar panel to match the position of the Sun in the sky. More sunlight strikes the solar panel when it is kept perpendicular to the Sun, less light is reflected, and more energy is absorbed. This energy can be transformed to electricity[7].

The sun’s position in the sky varies both with the seasons (elevation) and time of day as the sun moves across the sky. Hence there are also two types of solar tracker:

- Single Axis Solar Tracker
- Dual Axis Solar Tracker

Single Axis Solar Tracker: A horizontal or vertical axle can be used in single axis solar trackers. In tropical places where the sun rises quite high at noon yet the days are short, the horizontal type is utilised. In high latitudes, when the sun does not rise very high but summer days can be very lengthy, the vertical type is employed.

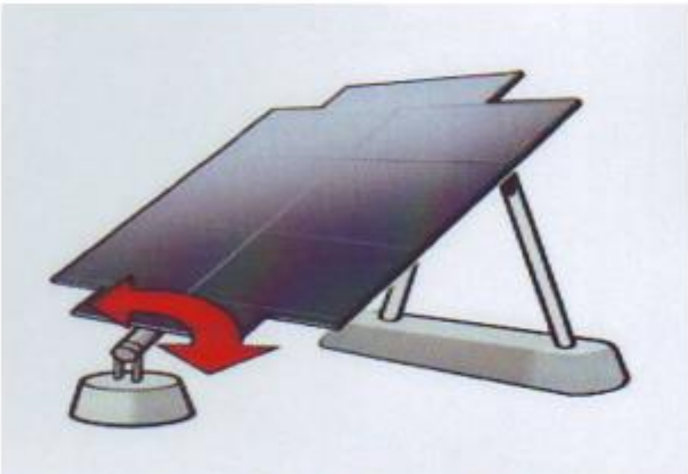

Fig 1.3 Single Axis Solar Tracker

Dual Axis Solar Tracker: Solar trackers with both a horizontal and vertical axle can precisely track the sun's apparent motion everywhere on the planet. Because this type of system is commonly used to control astronomical observatories, there is plenty of software available to anticipate and track the sun's journey across the sky automatically.

Dual axis trackers follow the sun from east to west as well as north to south for increased power output (about a 40% increase) and convenience.

Fig 1.4 Dual Axis Solar Tracker

In actual life, complicated devices are used to determine the location of the Sun in relation to the object being aligned. Computers, which can execute intricate algorithms that allow the system to follow the Sun, and sensors, which transmit information about the Sun's location to a computer or, when coupled to a solar panel with a basic circuit board, can track the Sun without the need for a computer.

The power production of a solar panel is affected by the angle of light, according to studies. A solar panel that is perfectly perpendicular to the Sun generates more power than a solar panel that is not. The influence of small angles from perpendicular on power production is less than that of greater angles. In addition, the Sun's angle shifts from north to south during the year and from east to west on a daily basis. As a result, whereas tracking east to west is vital, tracking north to south has a less influence.

Solar trackers have a lot of benefits for renewable energy. Solar tracking can boost electricity generation by 30 to 40 percent. The increased power output promises to expand solar power's market. Solar trackers, on the other hand, have a number of significant drawbacks. A static solar panel may come with a decades-long warranty and require little to no maintenance. On the other hand, solar trackers have substantially shorter warranties and require one or more actuators to move the panel. Active tracking devices may also utilise a modest amount of energy, which increases installation costs and reduces reliability (passive systems do not require additional energy). Because they contain fast-evolving electronic components with parts that may be difficult to replace in relatively short periods of time, computer-based algorithm solar trackers are more expensive, require more maintenance, and become obsolete much faster than static solar panels[8].

3. Aim and Objectives

- **Title**
  - **Sun tracking solar tree**
- **Aim**
  - To construct solar tree with sun tracking capability for better harness of solar energy
- **Objectives**
  - To review literature on solar tree and sun tracking application used for solar energy generation.
  - To design the proposed model of solar tree for sun tracking application.
  - To design the circuit for the harness of the power from the solar panel.
  - To implement the proposed model and to incorporate the load circuit with the model
  - Testing of the model for working
- **Methods and Methodology/Approach to attain each objective**

Objective No.	Statement of the Objective	Method/ Methodology	Resources Utilised
1	To review literature on solar tree and sun tracking application used for solar energy generation.	Literature survey is carried out by referring books, scholar patent materials and related Pdf's and Documents	IEEE paper, journals and conference papers

2	To design the proposed model of solar tree for sun tracking application.	Aggregation of solar tracking system with the solar tree	IEEE paper, journals and conference papers
3	To design the circuit for the harness of the power from the solar panel.	To develop the circuit for load circuit (USB chargeable devices).	Solar panel Voltage regulator Boost converter
4	To implement the proposed model and to incorporate the load circuit with the model	To develop the complete working model of the proposed system.	Arudino uno Stepper motor LDR
5	Testing of the model for working	• Test the system for sun tracking and power output • Demonstration of the developed prototype.	Arudino uno Stepper motor LDR Solar panel Voltage regulator Boost converter

4. Problem Solving

1. Design and Development

The solar PV tree is made up of PV panels that are arranged like leaves on a metallic structure to give it a tree-like look. It looks like a tree, but it's made of steel and has solar panels. During the day, it seeks to gather sunlight from all directions while utilising less land. Fig.1.5 shows the main components of a solar PV tree. PV modules convert incoming sunlight into electricity in this system**.** By putting wires through the tree's branches, this energy is delivered to the load or batteries. The stored energy can be utilised to power streetlights, laptops, and mobile phones, among other things[9].

Fig 1.5 Solar PV Tree

A solar PV tree's (SPT) goal is to collect sunlight from various orientations throughout the day. Solar PV panels, on the other hand, perform better with direct beam radiation, hence the proposed model is built to cover a location's Sun path, i.e. track the Sun. For the solar PV tree, a trestle design is used. The model's view is depicted in Fig.1.6, which shows the variations in tilt angle to track the Sun throughout the day.

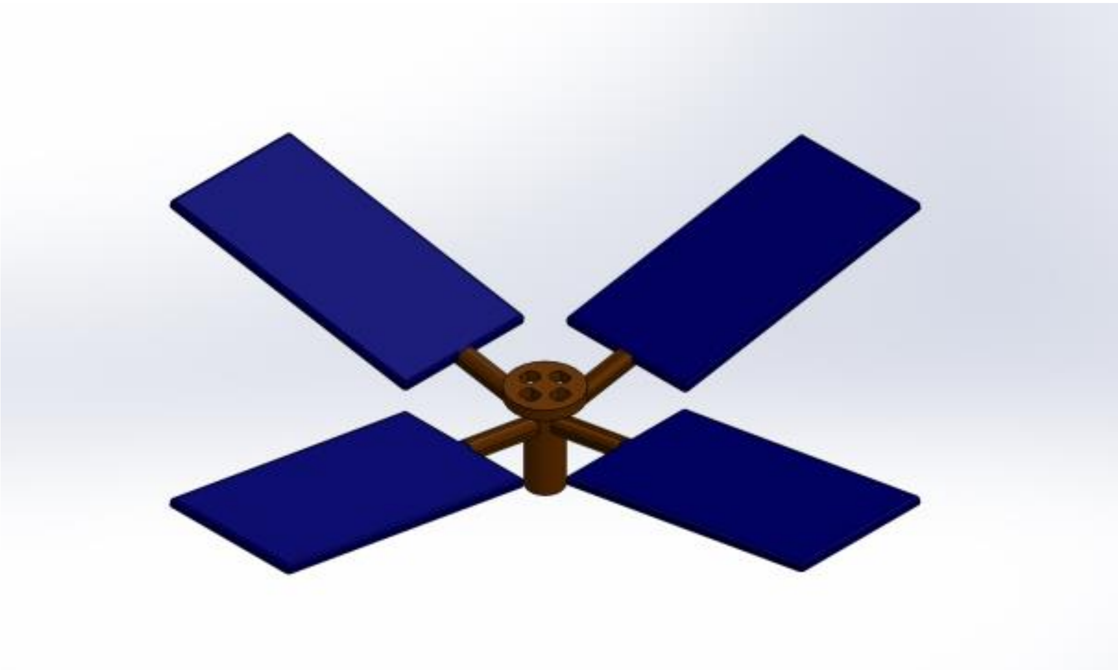

Fig 1.6 Trestle design of solar PV tree

2 Design Implementation

Hardware implementation

In this chapter, the design and implementation of sun tracking solar system is discussed.

This project's main goal is to create a high-quality sun tracking solar system. There are two aspects to the project: hardware and software. It is made up of three primary components: inputs, main controller, and output, as indicated in Figure 1.7.The analogue values of LDR and Arduino are used as inputs.

Block diagram:

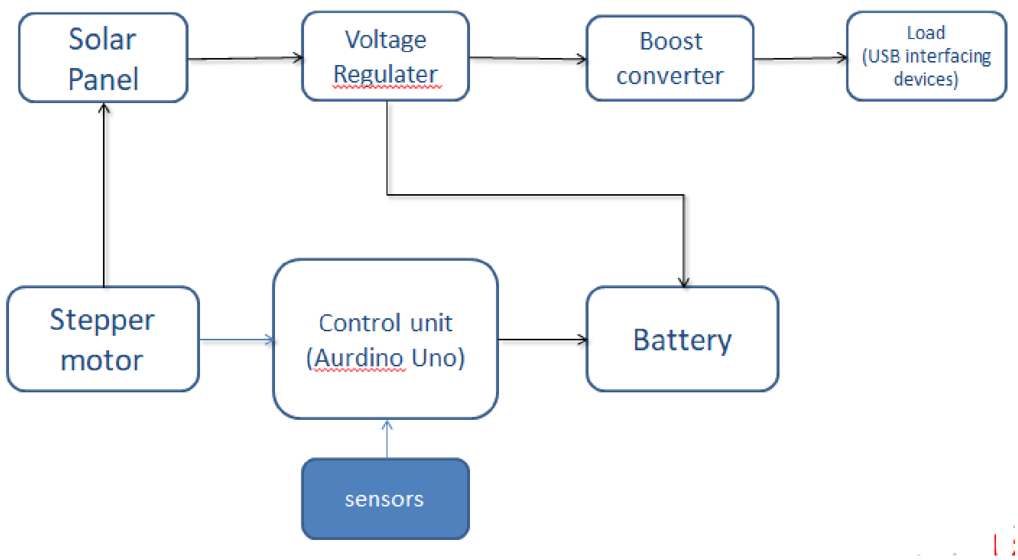

Fig 1.7 Block Diagram

Circuit Diagram:

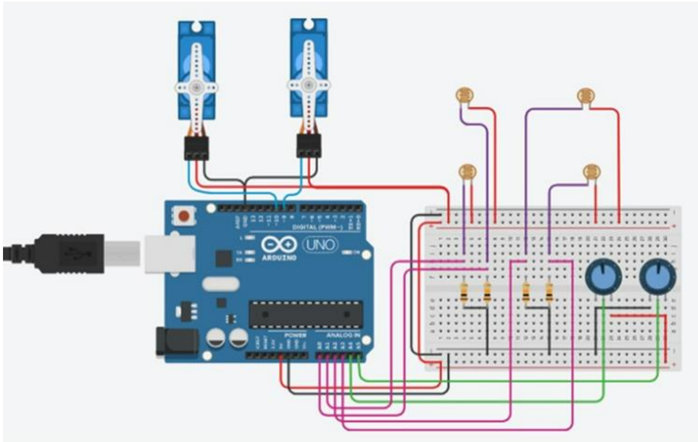

Fig 1.8a Circuit Diagram for servo

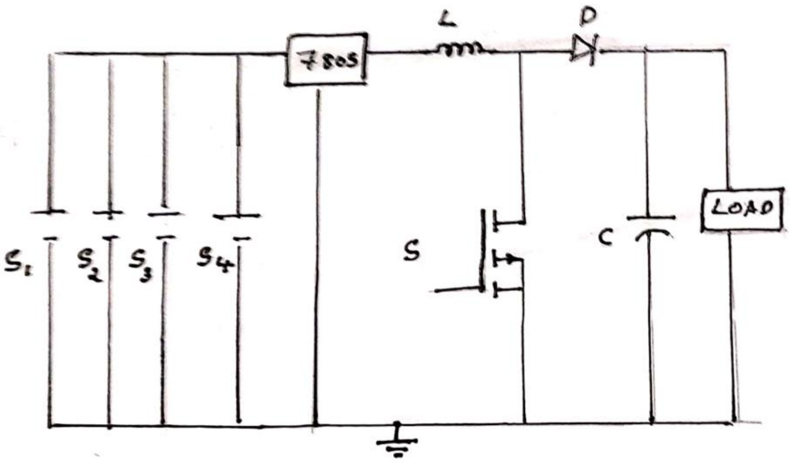

Fig 1.8b Circuit Diagram for Load Circuit

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Components Description

1) Arduino Uno

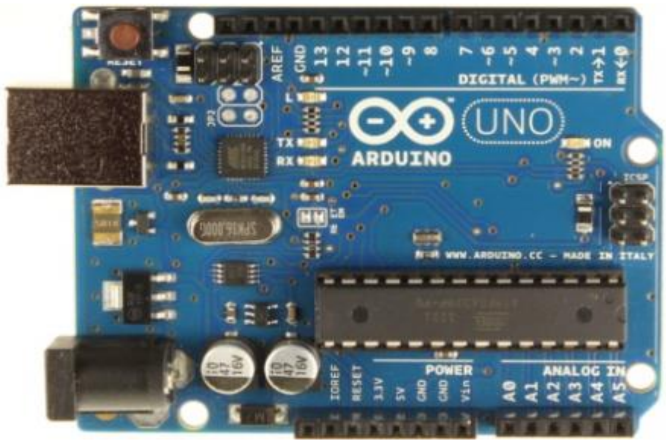

Figure 1.9: Arduino Uno board

The Arduino Uno board is a microcontroller based on the ATmega328. It has 14 digital input/output pins in which 6 can be used as PWM outputs, a 16 MHz ceramic resonator, an ICSP header, a USB connection, 6 analog inputs, a power jack and a reset button. This contains all the required support needed for microcontroller. In order to get started, they are simply connected to a computer with a USB cable or with an AC-to-DC adapter or battery. Arduino Uno board varies from all other boards and they will not use the FTDI USB-to-serial driver chip in them. It is featured by the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

There are various types of Arduino boards in which many of them were third-party compatible versions. The most official versions available are the Arduino Uno R3 and the Arduino Nano V3. Both of these run a 16MHz Atmel ATmega328P 8-bit microcontroller with 32KB of flash RAM 14 digital I/O and six analogue I/O and the 32KB will not sound like as if running Windows. Arduino projects can be stand-alone or they can communicate with software on running on a computer. For e.g. Flash, Processing, Max/MSP. The board is clocked by a 16 MHz ceramic resonator and has a USB connection for power and communication. You can easily add micro SD/SD card storage for bigger tasks. The specifications of Arduino MEGA microcontroller board is as tabulated in Table 2.

Table 1: Specifications of Arduino Uno

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by boot loader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (Atmega328)
Clock Speed	16 Hz

2) **Light Dependent Resistor (LDR) :**

Fig 1.10 LDR (Light Dependent Resistor)

Photo resistor or light dependent resistor (LDR) is a resistor which resistance decreases with increasing incident light 44 intensity or exhibits photoconductivity. LDR output voltages for light intensity are shown in Table 2. The light intensity is measured in lab experimental. The resistance of an LDR is extremely high, sometimes as high as 1 Mohms. The light resistances will drop dramatically when illuminated.

Light Intensity	LDR Output(V)
Dark	0.6
Average	4.0
Bright	4.6

Table 2 : Light Intensity measurement

3) Servo Motor :

Fig 2 Servo Motor

Servo motor, or servos for short, is a three-wire DC motors. A servo motor consists of several main parts, the motor and gearbox, a position sensor, an error amplifier and motor driver and a circuit to decode the requested position. There are two types of servo motor required, either 4.SV or 6V supply to operate. Servo motor only rotates up to the maximum of ISO degrees. Pulse Width Modulation (PWM) is used to control the motor. PWM analog signal will go through an electronic circuit and convert the analog signal to a digital signal. The flow of the signal changes is shown in Fig 2. PWM in servos is used to control the direction and position of the motor. The center position is usually attained with [.3- 1.5 ms wide pulses, while pulse width varying from 0.7- 1 ms will command positions all the way to the right, and pulse widths of 1.7-2.0 ms all the way to the left. The servo motors PWM Timing Diagram (Voltage vs. Period) is shown in Fig1.10.

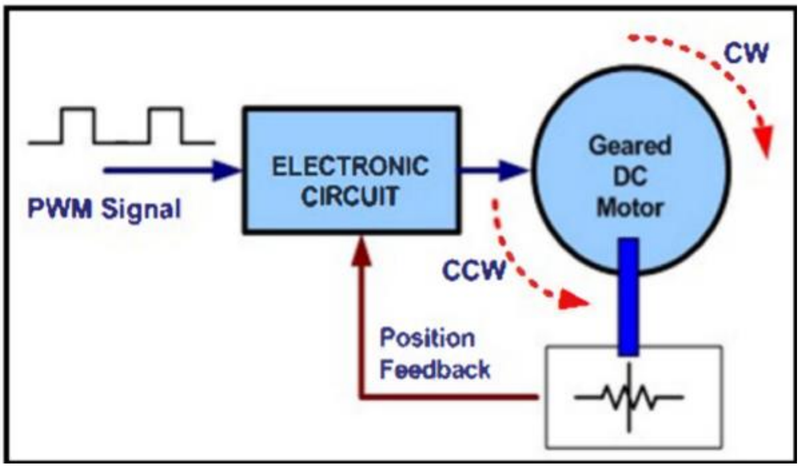

Fig 2.1 PWM analog signal is converted to digital signal to control the servos

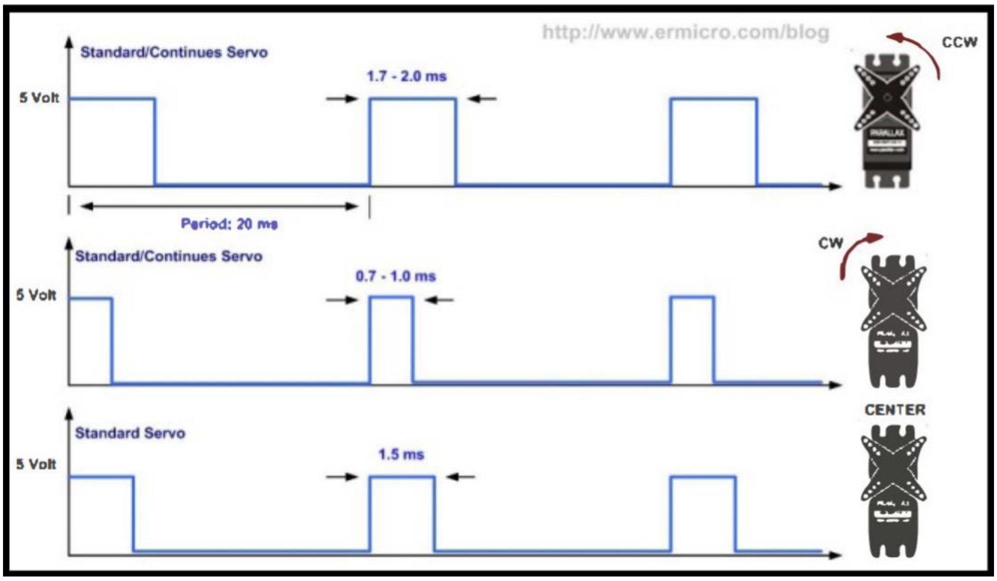

Fig 2.2 Servo motor PWM timing diagram.

4) **Solar Panel:**

Fig 2.3 solar panel

Solar panels are devices that convert light into electricity. They are called "solar" panels because the most powerful source of light available is the sun. A solar panel is a packaged, connected assembly of photovoltaic cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. Fig. 1.10 shows the model of mono crystalline solar panel used in the project. Several types of solar cells available in the market are:

- Monocrystalline silicon (mono-silicon or single silicon)
- Polycrystalline silicon (multicrystalline, multisilicon, ribbon)

Software implementation

In this chapter, the design and development of algorithm of program logic is discussed. The flowchart to develop the program logic with the program implementation is also being discussed.

The sun tracking system is based on the Light Dependant Resistor theory (LDR). As illustrated in Fig 2.4, Four LDR are linked to Arduino analogue pin A0 to A4, which serves as the system's input. LDR's analogue value will be converted to digital using the built-in Analog-to-Digital Converter (Pulse Width Modulation). The servos are moved using the PWM pulse values. The servo motor will move the solar panel to the position of the LDR that was set-up in the programming based on the greatest light intensity obtained by one of the LDRs input.

There are three motor rotation points: 0, 90, and I80.

The pseudo code is explained below

Pseudo Code:

Step 1: Start

Step 2:Initialize LDR 1,2,3,4

Step 3:Checks the Value Difference of LDR

Step 4: Check the condition

If LDR1 is greater than LDR 2,3,4 then the Servo motor turns Right

Step 5: Checks the condition

If LDR2 is greater than LDR 1,3,4 then the Servo motor turns Left

Step 6:Checks the condition

If LDR3 is greater than LDR 1,2,4 then the Servo motor go up

Step 7:Checks the condition

If LDR4 is greater than LDR 1,2,3 the the Servo motor turns Right

Step 8:if It is Dark

Then goto step 3

Step 9:END

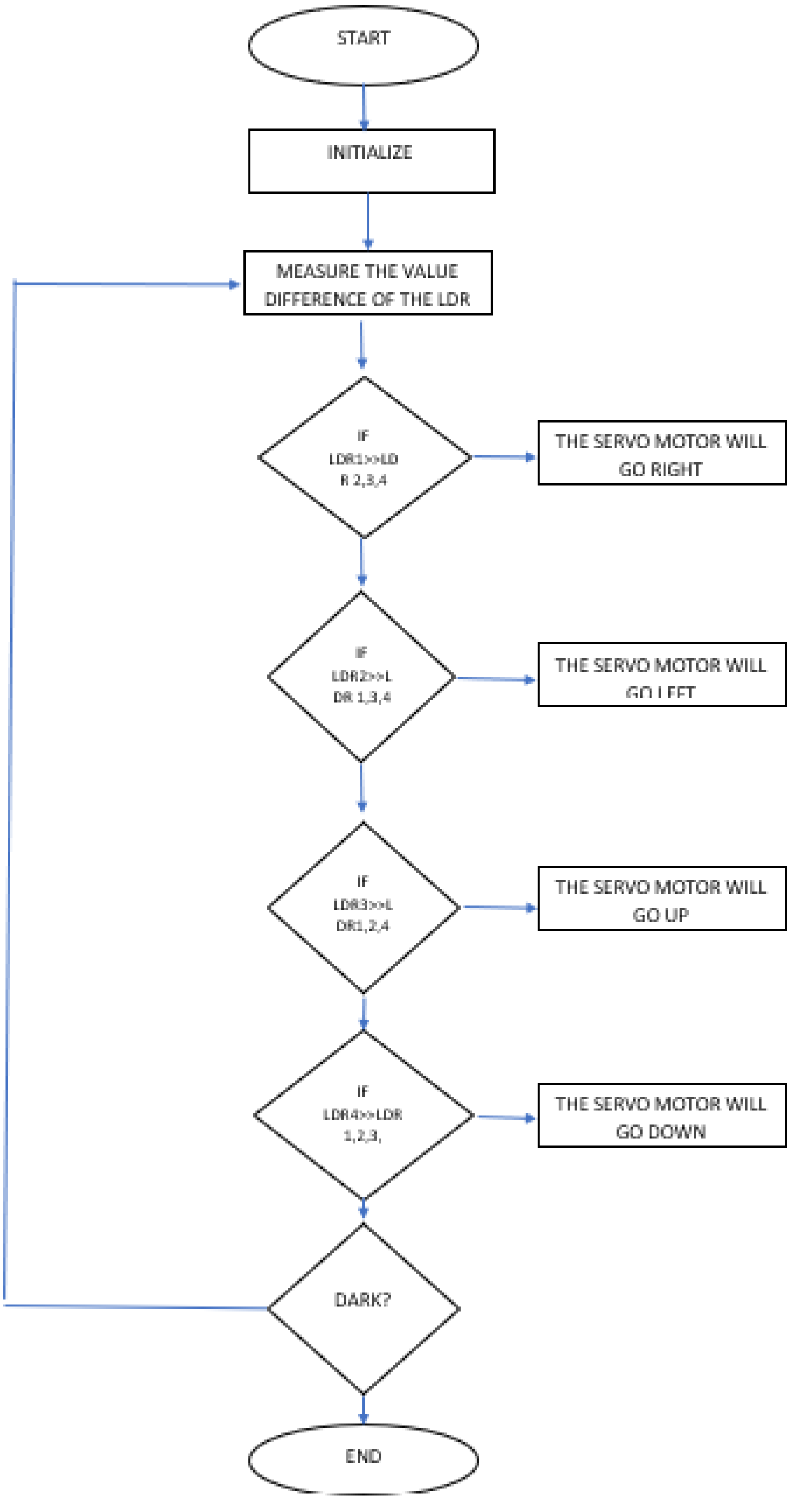

Fig 2.4 :Flowchart for the overall process

5. Results

It is observed that the location for the solar panel is one of the important things in collecting the output voltage. Solar panel will perform best when facing south as this will help to get the most exposure from the sun as it moves from East to West. For most areas, the peak performance hours of the day will be between 9 a.m. till 12 p.m. This is when the sun is at its peak illumination.

The measurements of the data are taken from a wide area whereby there is no obstruction that would prevent the tracker from maximum sunlight. The measurement of output voltages are taken in 3 straight days between 9 a.m until 6.00 p.m. The largest output voltage for the solar panel is 7 V. The average of output voltages is used to draw up the graphs. There are 2 conditions of output voltage being measured. The conditions are:

- Static solar panel with 15 degree of angle facing south
- Solar panel with tracking system facing south.

By pursuing these 2 conditions, the highest and lowest output voltages at the peak performance of sunlight can be measured. The highest output voltage that the author measured for solar tracking condition is 6.67 V at 1.20 p.m. while the lowest output voltage is 5.94 V at 6.00 p.m. hours while the highest voltage for static panel is 6.65 V and the lowest is 5.89 V. The sun position is one of the main factors that caused instability measurement output voltage. The position of sun is considered to be unpredictable hence causing the surroundings to be dimmed at certain times. The solar panel will not be able to achieve a maximum illumination from the sun.

6. Project Costing

The costing for the proposed system is given in table 3 .

Items	**No's**	**Cost (INR)**
Arduino MEGA development board	1	975
LDR	4	30
Boost converter	1	180
Servo motor	2	315
Breadboard	1	100
Resistors	4	40
Voltage regulator	1	20
potentiometer	2	80
Solar panels	4	800
Miscellaneous		3000
Total		**5540**

Table 3 Project Costing

7. Conclusions and Suggestions for Future Work

Sun tracking operation combined with sensors, actuators, and motors to govern the power output of a solar PV tree helps to overcome its disadvantages. It can be implemented using a microcontroller and other suitable integrated circuits after its design has been provided. It has the potential to improve the efficiency of solar PV systems.

Advantages of the system are

- The invention of Solar Tracking System helps us improve the performance of PV solar system in a simple way
- Used relative method of sunlight strength.
- Established a model of automatic tracking system to keep vertical contact between solar panels and sunlight.
- Improved the utilization rate of solar energy and efficiency of photovoltaic power generation system.

One of the key recommendations is to utilise a more powerful solar panel with a higher output voltage and wattage. It is suggested that the LCD display be used to improve the hardware part. Time, voltage, and current will be displayed, among other things. Aside from that, by incorporating the Global System for Mobile Communications, the solar tracking system may be monitored from a far (GSM).

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Appendix

```
#include <Servo.h>
Servo horizontal; // horizontal servo
int servoh = 180;
int servohLimitHigh = 175;
int servohLimitLow = 5;
// 65 degrees MAX`

Servo vertical; // vertical servo
int servov = 90;
int servovLimitHigh = 135;
int servovLimitLow = 45;

// LDR pin connections
// name = analogpin;
int ldrlt = A0; //LDR top left - BOTTOM LEFT
int ldrrt = A2; //LDR top rigt - BOTTOM RIGHT
int ldrld = A1; //LDR down left - TOP LEFT
int ldrrd = A3; //ldr down rigt - TOP RIGHT

void setup(){
horizontal.attach(9);
vertical.attach(10);
horizontal.write(180);
vertical.write(90);
delay(2500);
}
```

```
void loop() {
int lt = analogRead(ldrlt); // top left
int rt = analogRead(ldrrt); // top right
int ld = analogRead(ldrld); // down left
int rd = analogRead(ldrrd); // down right
int dtime = 10; int tol = 90; // dtime=diffirence time, tol=toleransi
int avt = (lt + rt) / 2; // average value top
int avd = (ld + rd) / 2; // average value down
int avl = (lt + ld) / 2; // average value left
int avr = (rt + rd) / 2; // average value right
int dvert = avt - avd; // check the diffirence of up and down
int dhoriz = avl - avr;// check the diffirence og left and rigt

if (-1*tol > dvert || dvert > tol)
 {
 if (avt > avd)
 {
 servov = ++servov;
 if (servov > servovLimitHigh)
 {servov = servovLimitHigh;}
 }
 else if (avt < avd)
 {servov= --servov;
 if (servov < servovLimitLow)
 { servov = servovLimitLow;}
 }
 vertical.write(servov);
 }
```

```
if (-1*tol > dhoriz || dhoriz > tol) // check if the diffirence is in the tolerance else change
horizontal angle
{
if (avl > avr)
{
servoh = --servoh;
if (servoh < servohLimitLow)
{
servoh = servohLimitLow;
}
}
else if (avl < avr)
{
servoh = ++servoh;
if (servoh > servohLimitHigh)
{
servoh = servohLimitHigh;
}
}
else if (avl = avr)
{
delay(5000);
}
horizontal.write(servoh);
}

delay(dtime);
```

```
}
```