Optimization of Solar Energy Tapping by an Automatic Solar Radiation Tracker

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Abstract— **"**If the entire solar energy is tapped for an hour, it is believed to be able to light up the earth for a year" said Dr. Simone Boehme while addressing CST students on April 25th, 2017. However, it is not possible to extract one hundred percent of the solar energy anywhere at any time of the day with the present technology. The only possible thing is to optimize the available solar energy and there are numerous ways to enhance the solar energy tapping. The solar panel that could sense the movement of the sun would be one of the best alternatives to tap optimum solar energy as the panel will receive direct sunlight for a longer duration. This paper explains how the LDRs is used to move the solar panel according to the movement of the sun.

Keywords*-Arduino, LDR, solar panel, motor, intensity of sunlight, efficiency.*

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I. INTRODUCTION

In the recent decade, there has been an increasing number of residences and institutes that used solar energy as a substitute power for lighting and heating. This is because solar energy is an unlimited energy resource, set to become epitome of renewable power source in the years to come. Sun's energy is tapped using solar cells which are fixed on the ground. However, the sun's position varies in the sky due to which the efficiency of the solar cell reduces. Going outside to a solar cell every hour to turn it towards the sun might be possible, however, keeping the solar cell facing the sun throughout the day manually is not a very efficient use of a person's time. The solar tracker is an automated solar panel that actually follows the sun enabling the solar panel to receive direct sunlight for a longer duration of time, which will then increase the power generation.

This paper is based on dual axis automated solar tracker which will enable the rotation of the solar panel in all directions. Many of the existing solar trackers are single axis which has some drawbacks in regard to the efficiencyof the solar panel, the dual axis will overcome some of these drawbacks.

II. WORKING PRINCIPLE OF AUTOMATIC SOLAR RADIATION TRACKER

The dual axis solar tracker has the advantages of being able to cover all the four directions, so this project has been designed to do the same. All the operations are controlled by microcontroller (Arduino). The four LDRs mounted on the solar panel at the four directions, will collect the sunlight/light intensity and send it to Arduino. The Arduino will provide instructions to the two motor drivers to rotate the two motors in clock wise or counter-clockwise direction according to the information sent by the LDRs. The tracking circuit is so designed that the rotation of the motor depends on the output voltage from the LDRs. If the voltage at LDR1 one is greater than LDR 2, then the motor will rotate in clockwise. Similarly, when the voltage at LDR 2 is greater than LDR 1 then it will rotate in anticlockwise. The block diagram below shows the tracking device in the prototype.

A. Block diagram

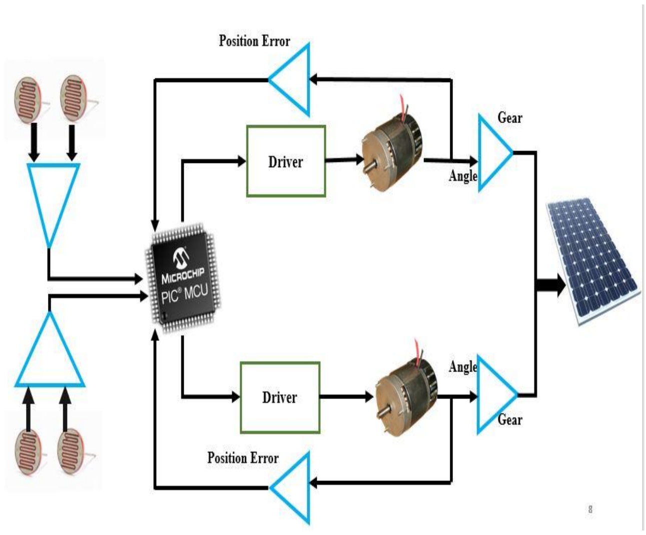


Figure 1 Block diagram of automatic solar tracker.

B. Schematic diagram of the project

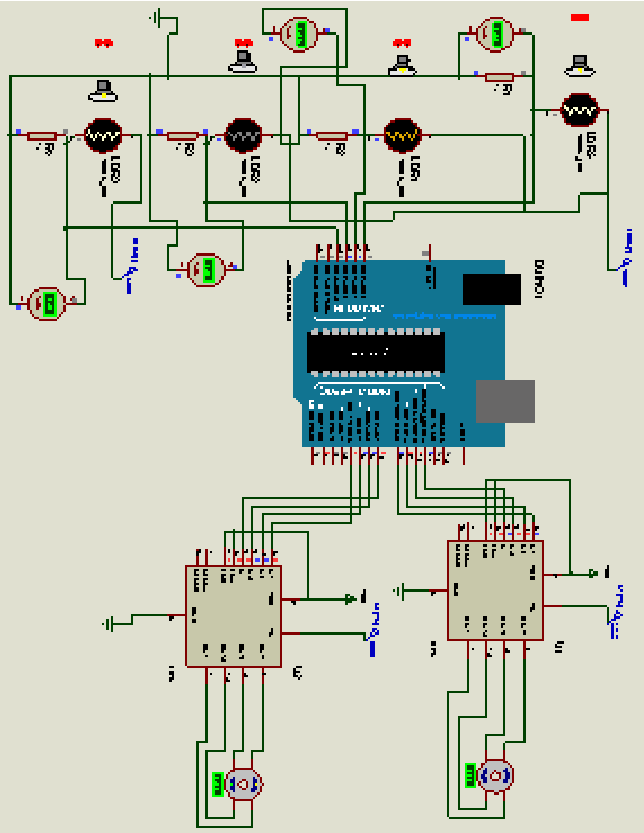


Figure 2 Semantic diagram of solar tracking system

III. AUTOMATIC SOLAR RADIATION TRACKER COMPONENTS

In this project, the main part of the electronic system is the Arduino (microcontroller). It will take in light intensity (data) from the four LDRs in the form of analog voltage and convert it to digital value for easy comparison. It will then send instructions to the motor driver to control the rotation of the stepper motors in the desired direction and align the solar panel according to the intensity of sunlight. Another component is the motor driver which is the interface between the Arduino and stepping motor. LDRs are placed at the four corners of the panel. LDRs sense the intensity of the sunlight and Arduino receives the output from LDRs. After calculating the difference between the LDRs, Arduino decides in which direction the motor should rotate to get maximum sunlight. Stepping motors are used in this project for the accurate and desired motion of the panel for this system, a stepper motor of 1.8 step angle is used. Since this is a dual axis system, two numbers of stepper motor are required. The resistor is used in parallel to the LDR, so the voltage across the resistor is taken as the input voltage to the microcontroller (Arduino) as shown in Figure 2.

IV. DESIGN ASPECT

A. Input voltage to the microcontroller

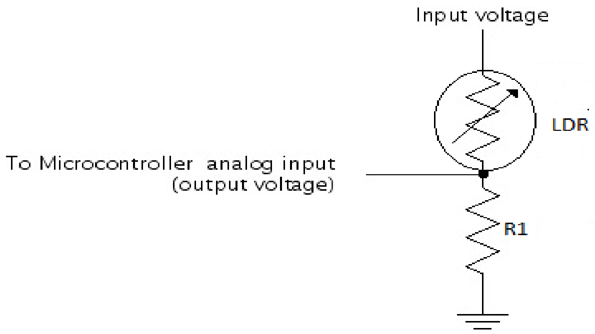


Figure 3 Input voltage to the microcontroller

In this project input for the Arduino is used as voltage from LDRs. The reason behind of using the voltage as input is Arduino has inbuilt code that convert input analog voltage into digital. It is very easy to compare the input from each LDRs and make motor to rotate in desire position according to the intensity of sun.

V(out)=$(5 * R1)/(R1 + LDR1)$

Value of LDR when;

In darkness= 5MΩ

Under light = 0Ω

I. When the torch light is given to the LDR

V(out)= $(5 * R1)/(R1 + LDR1)$

V(out)= $(5 * 1k\Omega)/(1k\Omega + 0)$

V(out)= 5V

II. When the light is not given to LDR

V(out)= $(5 * R1)/(R1 + LDR1)$

V(out)= $(5 * 1k\Omega)/(1k\Omega + 5M\Omega)$

V(out)= 99.99×10^{-4}V

B. Selection of stepping motor

The holding torque of the stepping motor (17PM-K044) is 270mNm. As per the design the average weight of 710g of stepping motor has been considered, which along with the panel the other motor need to hold and be able to take the load.

F = ma-------1

where,

F=force

m=mass of the object that motor need to hold.

a=acceleration due to gravity.

T = Fr---------2 where,

T=torque

r=radius of the rotor

Since the motor has,
m=710g
$g=9.8m/s^2$
$F = 0.71 \times 9.8$
$= 6.958Nm$
r=2cm
$T = Fr$
$= 6.958 \times 0.02$
$= 0.13926Nm$
T =139.926mNm

The required holding toque is *139.926mNm* as per the design. The 17PM-K044 motor has holding torque of *270mNm.*

V. Programming and Fabrication

As said earlier, Arduino is the heart of this system. It controls the entire functioning of the system. In order to achieve the desired movement of panel, it is crucial to understand the logic and bring about the idea in a form of flow chart and then code it.

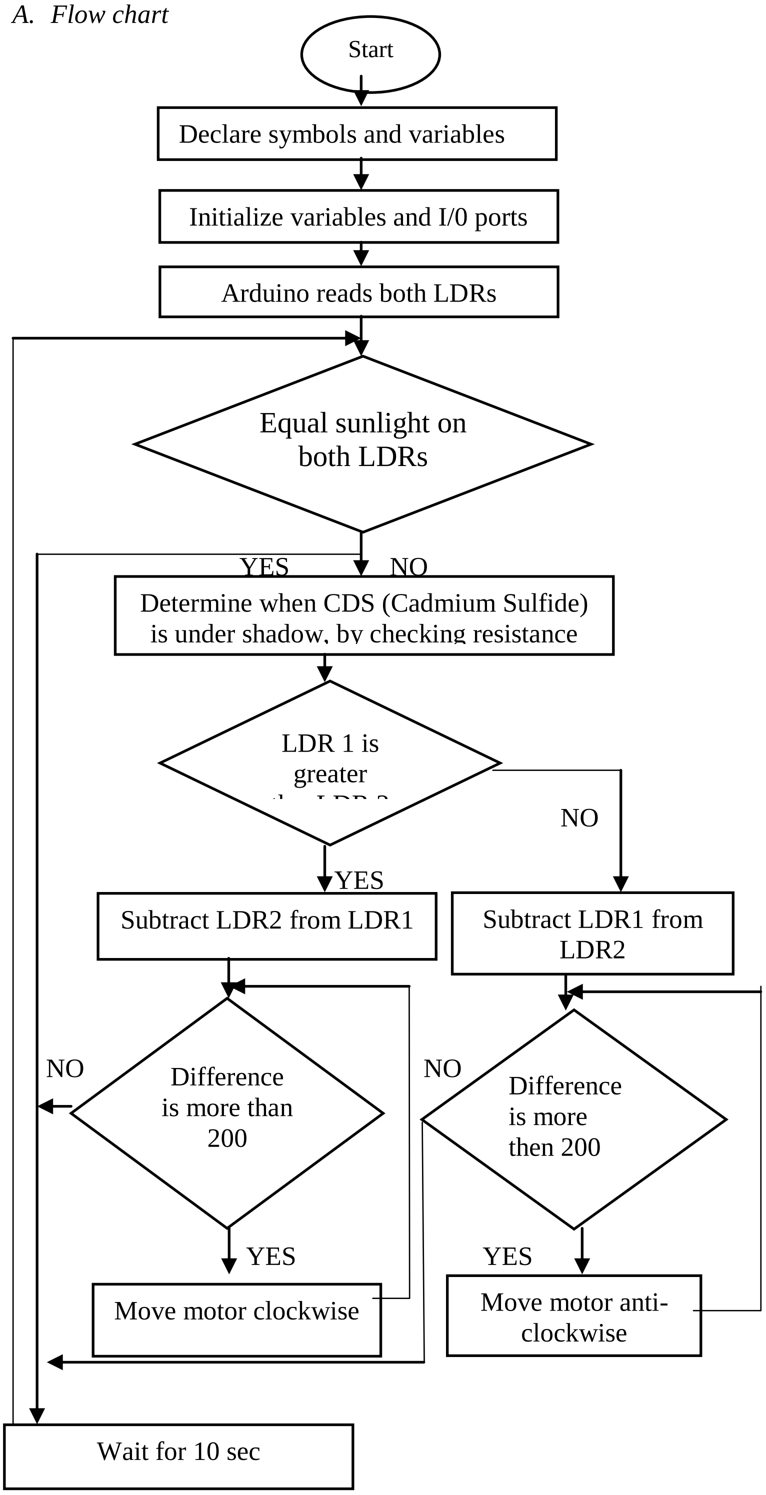
The Arduino will take in four analog voltage inputs from the four LDR sensors. LDR1 and LDR2 is responsible for the movement of the motor1 and similarly, LDR3 and LDR4 for the motor2. LDRs sense the difference in the intensity of lights at different points and depict this as potentials or voltages; higher the intensity of light, greater the voltage across the LDR. The Arduino has inbuilt program to convert analog voltage to the digital value. Firstly, Arduino will compare the inputs from LDR1 and LDR2. If there is a difference of 200 digital value between the two LDRs and if LDR1 is greater than LDR2, then the motor1 will rotate in clockwise direction, else in anticlockwise direction. Similarly, if LDR3 and LDR4 has a difference of 200 digital value and if LDR3 is greater than LDR4 then the motor2 will rotate in clockwise direction, else in anticlockwise direction.

The Arduino uses following formula to convert analog voltage value into digital value;

$$\text{Digital Voltage} = \frac{\text{Analog Voltage}}{5} \times 1023$$

This digital value is very important as this form the base of comparison among the four light intensities from the LDRs. When equal or no light is given to the LDRs, it will not sense any light and hence, will not send any data to the Arduino. Due to which there won't be any difference while comparing. Thus, themotor won't rotate in any of the directions and the panel will remain stationary.

A. *Flow chart*



ISSN: 2321-8169
886 – 892

B. *Prototype Design in AutoCAD*

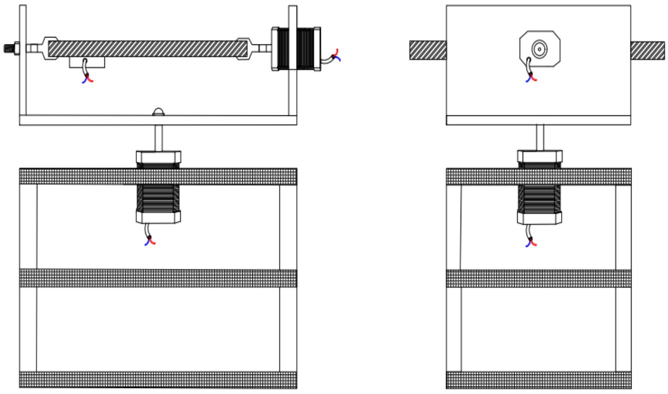


Figure 4 Front view and side view of the prototype

C. *Working Model Automatic Solar Tracker*

Before building the design from AutoCAD, the circuitry hardware needs to be fabricated onto a PCB board. Since, this is the most essential part of the design and also the terminals in the PCB are closely placed, precautions need to be taken to avoid wrong wiring. This model has all its circuit built in a single PCB board so that it is easy to manage and also looks very tidy.

Once the heart of the project was completed, the aesthetics of the project was taken into consideration which involved some carpentry work. Taking the measurements from the design, a cubical box is made. Inside the box, all the circuitry components are placed along with the drivers. On top of the box, one of the motors is fixed so that it will rotate a frame from left to right. The frame holds the solar panel and rotates it up and down with the help of the second motor which is mounted at the ends of the frame as shown in Figure 5.

Figure 5 Working model of automatic solar tracker

VI. Testing and Measurements

A. *Light Intensity Testing*

Couple of tests and experiments were carried out after building the prototype. All the tests were performed under normal conditions within a room using light intensity from torch light and tube light.

a) *Tube Light (osRAM L36W/880)*

When the source of light is at a distance of 2.4m

$$\text{Surface area } (SA) = 2\pi rh + 2\pi r^2$$

$$= (2\pi \times 2.4 \times 1.1 + 2\pi \times 2.4^2$$

$)m^2$

$$= 52.778m^2$$

$$\text{Intensity} = \frac{60\text{w}}{52.778\text{A}^2} = 1.136\frac{\text{W}}{\text{A}^2}$$

Output voltage from LDR1

Analog voltage=1.688V

$$\text{Digital voltage} = \frac{1.678}{5} \times 10^{23}$$

$$= 345.36\ V$$

With the source from tube light, the theoretical value of LDR1is 345.36V and the actual value of LDR1 obtained is show below;

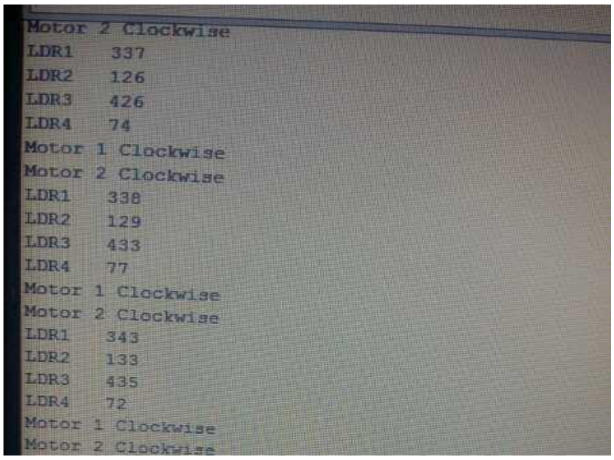


Figure 6 Serial monitor display from tube light source

b) *Samsung Grand Max (Flash Light)*

With the light source from Samsung Grand Max, the analog output from LDR is 4.08 V as shown in the figure below.

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886 – 892

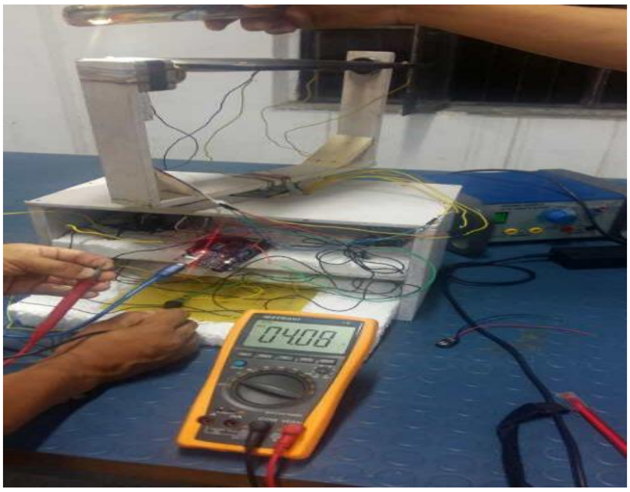


Figure 7 Output voltage with mobile light source

$$\text{Intensity} = 60\text{-}80 \text{ Lumen}$$
$$\text{Analog Output Voltage} = 4.08\text{V}$$
$$\text{Digital Output Voltage} = \frac{4.08}{5} 10^{23} \quad = 834.768\text{V}$$

When the light source is given from the mobile phone, the theoretical value obtained is 834.768. So, the difference among four LDRs should be near to this value for the motor to rotate. The obtained value is shown below;

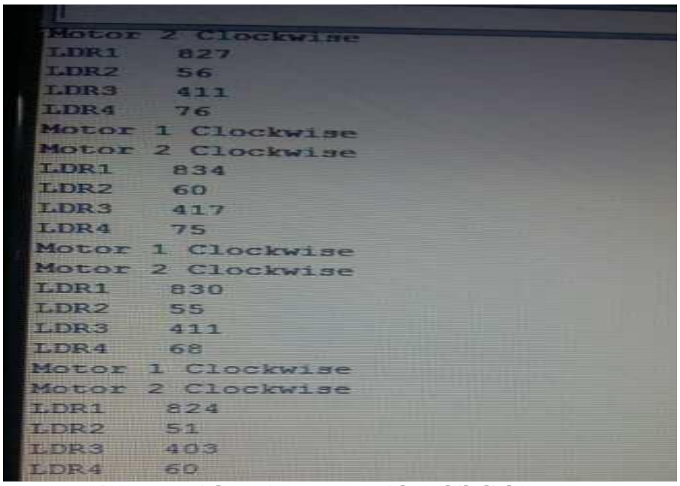


Figure 8 Serial monitor output with mobile light source

Table 2: Comparing the Monitor Display Reading and Theoretical Calculation

Sl. No	Light source	Readings from monitor display	Theoretical calculation	% error	Remarks
1	Tube Light (osRAM L36W/880)	337	345.36	2.42	The error is due to voltage drop across the circuit.
2	Samsung Grand Max (Flash Light)	827	334.768	0.93	Higher the intensity lesser the error

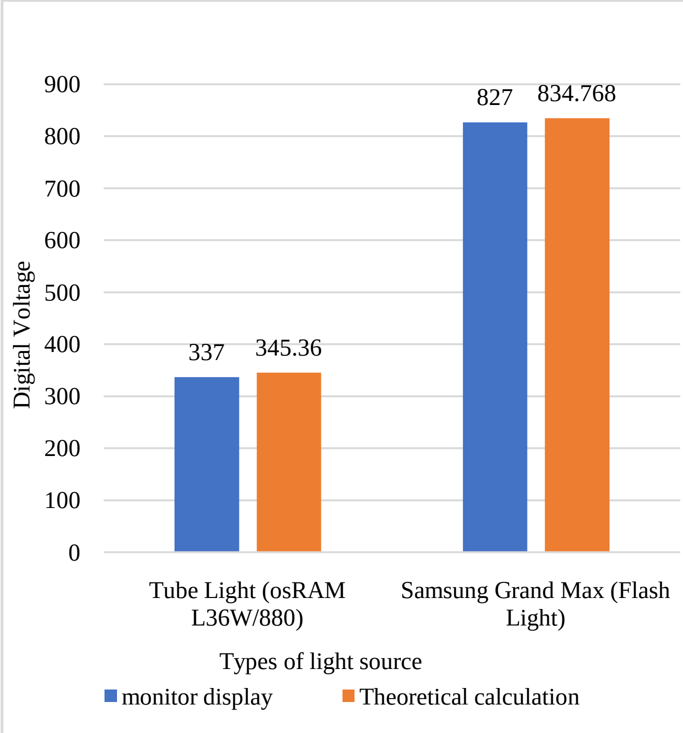


Figure 9 Comparison between two different sources of light

B. *Accuracy on Rotation*

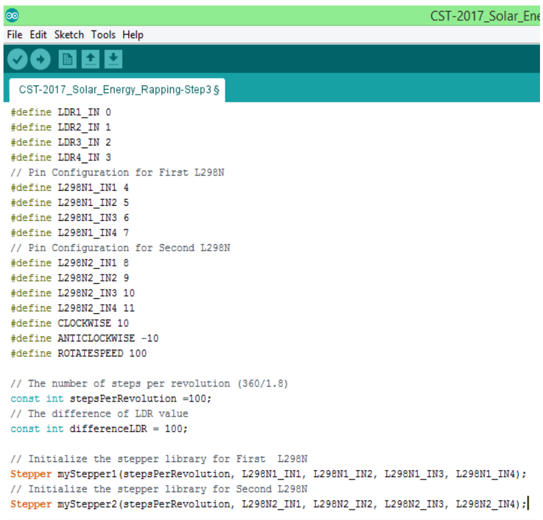
The rated step angle of the stepping motor is 1.8°, with the help of programming, the following tests are carried out for rotation.

a) *Angle is set at 3.6°*

The number of step per revolution is 200 (360/1.8) for the stepping motor. For testing, the step per revolution is set to 100 which is equivalent to 3.6°.

It can be calculated as follow:

$$1\text{step} = \frac{360}{1}$$
$$100\text{steps} = \left(\frac{360}{100}\right) = 3.6°$$




```
#define LDR1_IN 0
#define LDR2_IN 1
#define LDR3_IN 2
#define LDR4_IN 3
// Pin Configuration for First L298N
#define L298N1_IN1 4
#define L298N1_IN2 5
#define L298N1_IN3 6
#define L298N1_IN4 7
// Pin Configuration for Second L298N
#define L298N2_IN1 8
#define L298N2_IN2 9
#define L298N2_IN3 10
#define L298N2_IN4 11
#define CLOCKWISE 10
#define ANTICLOCKWISE -10
#define ROTATESPEED 100

// The number of steps per revolution (360/1.8)
const int stepsPerRevolution =100;
// The difference of LDR value
const int differenceLDR = 100;

// Initialize the stepper library for First  L298N
Stepper myStepper1(stepsPerRevolution, L298N1_IN1, L298N1_IN2, L298N1_IN3, L298N1_IN4);
// Initialize the stepper library for Second L298N
Stepper myStepper2(stepsPerRevolution, L298N2_IN1, L298N2_IN2, L298N2_IN3, L298N2_IN4);
```

Figure 10 Program codes for 3.6° step angle

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886 – 892

b) Testing on Prototype

The following figure gives the rotation of the panel at 3.6° step angle.

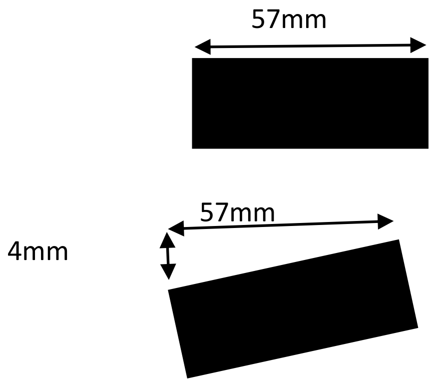

Figure 11 Panel rotation at 3.6° steps

Using the Pythagorean Trigonometric

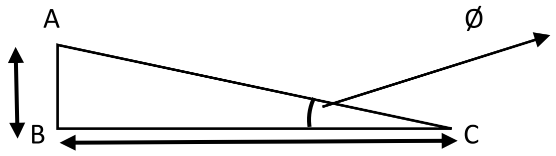

Figure 12 Panel rotation angle

AB=4mm
BC=57mm

$$tan Ø = \frac{AB}{BC}$$

$$tan Ø = \frac{4}{57}$$

$$tan Ø = 0.07017$$

$$Ø = \tan^{-1} 0.07017$$

$$Ø = 4.014°$$

$$\text{Accuracy \%} = \left(\frac{3.6}{4.014}\right) x100 = 89.68\%$$

Table 3: Showing the Comparison on Degree of Rotation

Sl No	Angle set (degree)	Practical output (angle in degree)
1	3.6	4.014
2	7.2	7.989
3	14.4	15.769

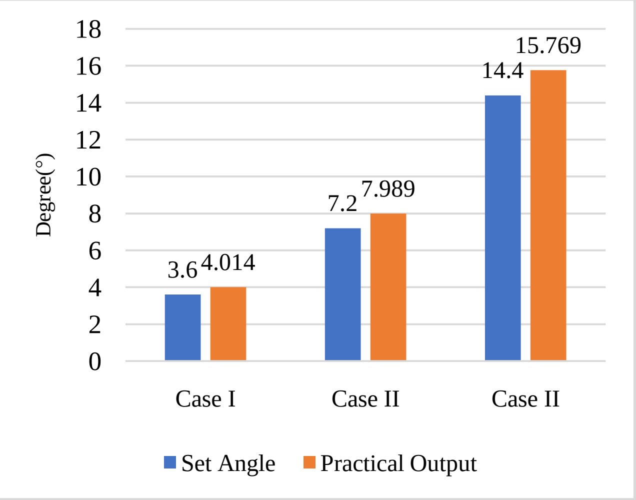

Figure 13 Comparison between set angle and the practical output angle

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VIII. CONCLUSION

In this project, the Arduino microcontroller was used for the solar tracking system. The controller circuit used to implement this system has been designed with minimal number of components which brings down the cost of the project without compromising with its efficiency. The entire circuitry has been integrated onto a single PCB for a simple and easy assembly. The usage of the stepper motor which has 1.8° step angle enables accurate tracking of the sun while keeping track of the panel's current position in relation to its initial position.

After examining the information obtained while testing, it can be said that the proposed automatic solar tracking system is a feasible method of maximizing the energy received from the solar radiation. It has been shown that the sun tracking systems can collect about 8% more energy than what a fixed panel system collects and thus high efficiency is achieved through this tracker[1, 2]. It improves the efficiency of the solar power generation system in terms of solar energy extraction and overall power generation. According to the test results of this project which gave 89.68% accuracy of panel movement, the dual axis solar tracking system is an efficient device to move the solar panel towards the direct sunlight for a maximum period of time in a day.

This system has a great potential to be further explored and improvised as the demand for renewable energy (solar) has been drastically increasing in all parts of the world. Moreover, CST campus has its own solar power generation unit which, as

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of now is fixed, so with the help of this system it will enhance its power generation capability making CST self-sufficient in regard to power supply.

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