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Comparative Analysis of Dual Axis Automated Solar Tracking System

Abhishek Shivdeo[1], Pavan Dumbre[2], Nimish Ladkat[3], M. V. Walame[4]

Dept. of Mechanical Engineering, Vishwakarma Institute of Technology, Pune, India

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Abstract - The Earth receives more energy from the sun in an hour than is used in the entire world in one year .Every day 120,000 terawatts of power from the Sun flows through to the Earth – 10,000 times more that flows through our industrial civilization at any given time. One kW of power generated from solar panels prevents: 150lbs of coal from being mined, 300 lbs. of CO2 from being emitted and 105 gallons of water from being consumed. A 5kW solar panel system is large enough to produce the electricity requirements of an average 4 person household. Thus in order to harvest this energy with the maximum possible efficiency, the dual axis sun tracking system has been used , This system tracks the sun by moving the panel in order to balance the intensity imbalance detected by light dependent resistors. The inspiration for this project was derived from the sunflower which moves its own face analogous with the position of the sun, thus keeping the intensity of sunlight constant and maximizing the efficiency of the panels.

Key Words: **sunflower, biomimicry, solar energy, dual-axis solar tracking system, zenith angle, azimuth angle, light dependent resistors.**

1. INTRODUCTION

The development of human race has a fair share of help from energy sources. And as the rate of development has increased , the energy demand has rapidly increased .[1] To meet these demands humans have explored and discovered various sources of energies , these sources have evolved from simple fire , using wind for sail to present day sources such as thermal , nuclear power plants and various other modern day sources .[1]But as we started using these sources , we faced the fact that most of them are present in limited amounts on earth and most of them cause pollution and harm the environment as well as are harmful for the humans and so we realized the needs for non-conventional sources of energy , these include wind energy , hydropower , tidal energy , geothermal energy , solar energy. [2]Among these, solar energy has gained popularity in modern age .India being blessed with 9 months of clear skies, utilization of solar energy can be done at a greater extent, currently solar energy extraction is not that affordable due to high initial cost and low efficiency thus the efficiency of energy extraction could be increased so that the high initial cost can be recovered at a faster rate.

The idea to harness the energy of sun to generate electrical energy was based on the photovoltaic effect. This effect was observed in 1839 by Alexandre Edmond Becquerel, and it was not until late 1800's that first solar cell was developed with less than 1% efficiency. Over a period of time, the solar cells were developed to have greater efficiency. Till now, the greatest efficiency recorded is 46%.

The variation in availability occurs daily because of the day and night cycle and because of the Earth's revolution around the sun, thus to increase the efficiency even more, various methods have been introduced in this area. One of these is by using a solar tracking system. In essence there are three ways to boost up the efficiency of a solar harvester system: increase the efficiency of the photovoltaic cells, amplify the output of the energy conversion system using control algorithms or by increasing the solar input overall. This paper discusses a specific example of the last method, known as *dual-axis solar tracking system*.

Main objectives of this research are:

- Comparative study for the increase in output of the system by comparing the average voltage output between stationary solar extraction system and dual axis solar tracking system.
- Prototyping of a dual axis tracking system for small and making working model for the same.

1.1 Theory

- A solar tracker is a device that orients an object toward the sun. In any solar application, the conversion efficiency is improved when the modules are continually adjusted to the optimum angle as the sun traverses across the sky.
- The inspiration for this project was derived from the *sunflower* which moves its own face analogous with the position of the sun. And the idea was inspired by biomimicry of sunflower.

Key Factors Influencing Solar Panel Performance

- ➢ Temperature of solar panel
- ➢ Shading
- ➢ Soiling
- ➢ Irradiance

From these factors, **Irradiance** has greater effect on the performance of solar panel.

Irradiance is the measure of the amount of sunlight falling on a given surface. *Higher* the irradiance of the solar cell, *greater* is the amount of energy the cell produces. The irradiance on the solar panels varies throughout the day as a result the energy produced also varies. This issue can be resolved with the use of Dual Axis Solar Tracker.

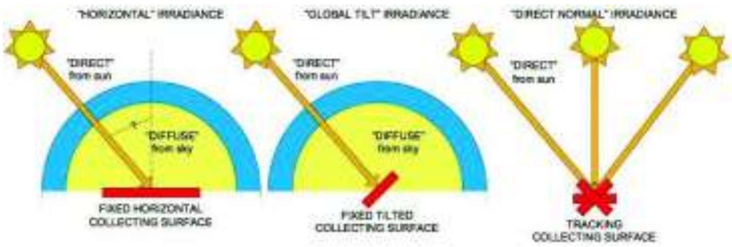


Figure 1 Perpendicular Irradiance

The Solar panel tracks the sun, by changing its angles of zenith and azimuth.

- The zenith angle (ϴz) is the angle between the sun's direction and the axis perpendicular to the desired area and upward.
- The azimuth angle (ϴA) is the angle between the North Pole and the direction of the sun's projection on the earth in the clockwise direction.

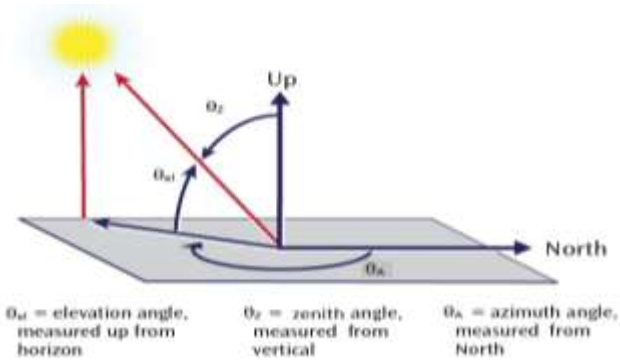


Figure 2 Sun's Position

There are mainly three types of solar tracking systems:

- *Open Loop Trackers*: This system uses no sensors but instead determine the position of the sun through pre-recorded data for a particular site and hard code the tracker's movement to match the movement of the sun in that area.
- *Closed loop or Active Trackers*: This system uses sensors and input data to continuously give feedback to the subsystem responsible for the movement of the solar panel. This way the solar tracker can actively keep track of the sun and give live and continuous signals for the movement.

Efficiency of the solar panel:

$$\eta max \% = \frac{Pmax}{E*Ac} \times 100$$

Where,

Pmax = Maximum Power Output (in W).

E = Incident Radiation flux (in W/m2).

Ac= Area of Collector (in m2).

2. EXPERIMENTATION

2.1 Algorithm

It uses sun as a reference and a guiding source to keep the panel surface perpendicular to the sun.

The tracker makes the use of 4 LDRs get variable inputs according to the varying intensity of sunlight falling on them, hence it is a closed loop solar tracking system.

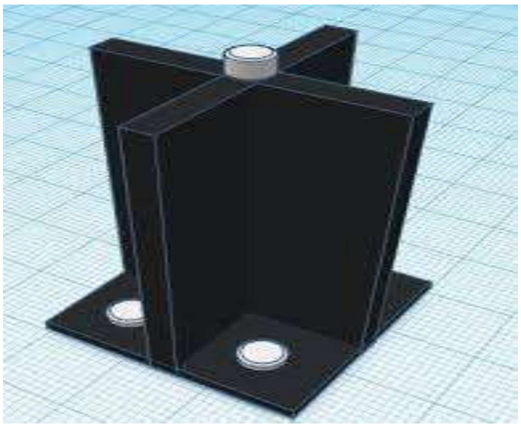


Figure 3 Separator of LDRs

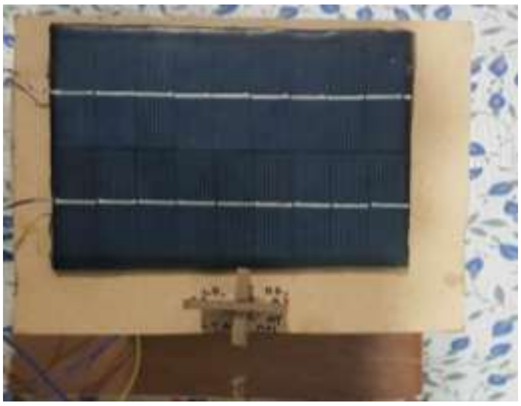


Figure 4 Top View, 4 LDRs

The main objective of the Solar Tracker Algorithm is to quickly determine to the best angle of exposure of light from the sun. This is done by the use of 4 Light Dependent Resistors and 2 servo motor. These Light Dependent Resistors provides input to the program with the fed logic. Their analogue inputs vary according to the intensity of the light falling on them. According to the logic, all the inputs from the Light Dependent Resistors will be compared and the program will give instructions to the two servo motors accordingly, such that the motors will move the shaft on which the panel is mounted in the direction where the light intensity is maximum or we can say in the direction where the panel will always be perpendicular to the sun.

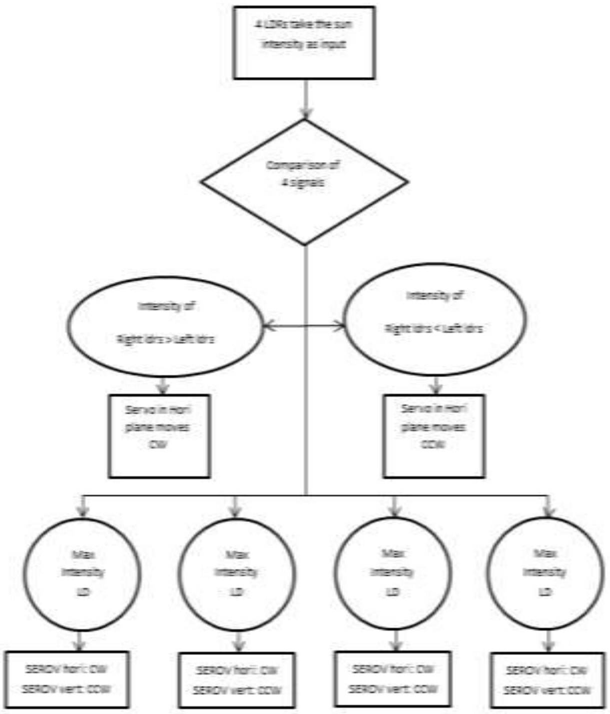


Figure 5 Process Flow

2.2 Circuitry

The main components used in the circuit are:

- 4- Light Dependent Resistors
- 4- 100k Ohm resistors
- 2 Servo Motors, 4.1kg torque
- Arduino Uno board

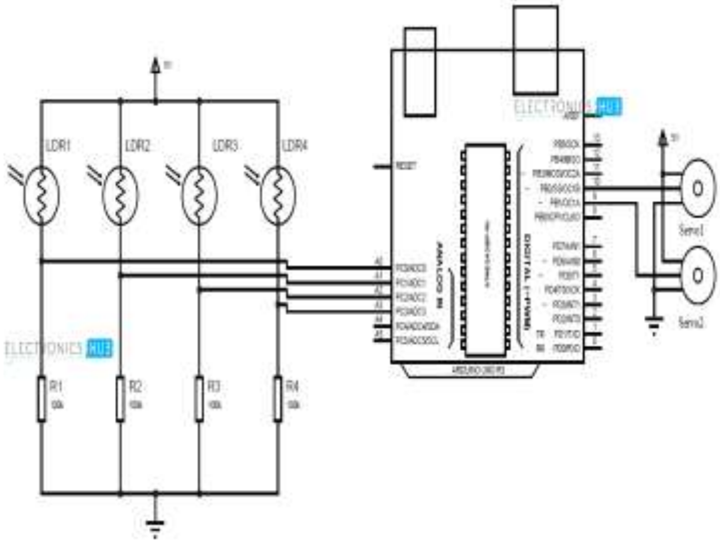


Figure 6 Circuit

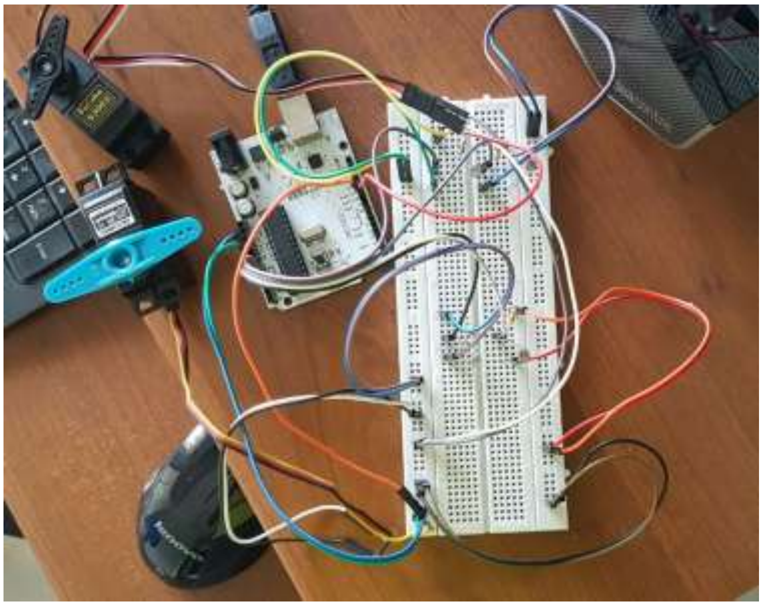


Figure 7 Preliminary Testing Circuit

2.3 Designing and Manufacturing

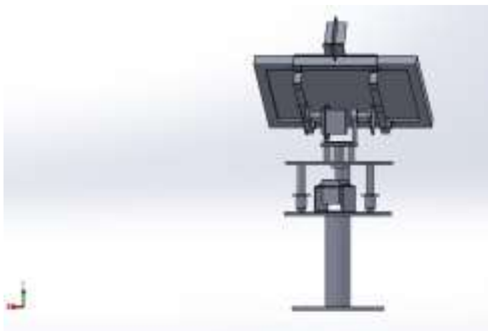


Figure 8 Prototype Back View

Figure 9 Prototype Top View

Figure 10 Prototype Side View

These are the images of the futuristic prototype that can be used for practical uses in the field.

It contains a top platform to hold the solar panel. With a separator attached to its head to bifurcate the 4 LDRs. The tripod with ball bearings on the horizontal plane helps the vertical servo to move the horizontal servo as well as the whole platform above it to move freely without any friction.

In the end it is given a solid base that can be hinged to the ground with the help of screws for which the slots are provided.

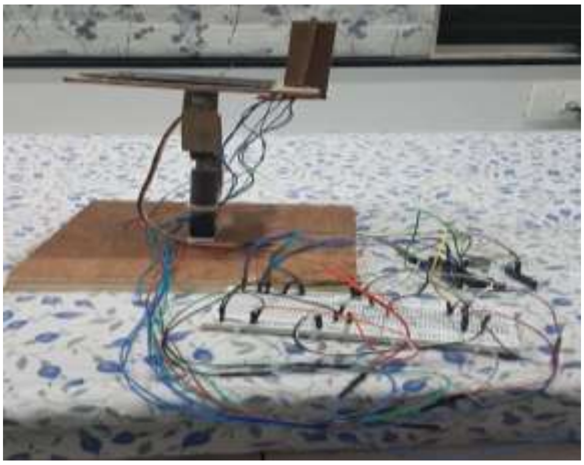


Figure 11 Working Model Side View

Figure 12 Working Model Top View

Figure 13 Working Model Front View

2.4 Procedure

- The experimentation involved the implementation of both: the simple solar energy extraction system without any tracking system in it that is stationary solar energy extraction system and that of solar energy extraction system that makes the use of Dual Axis Solar Tracker.
- Both the setups were kept on the rooftop for the whole day starting from 10am till 5pm.
- The voltage readings for the solar panel were measured every half an hour for both the systems.
- V vs Time graphs were plotted for both and were compared.
- The average voltage for both the systems was calculated and the percent increase in average voltage was calculated.

3. RESULTS AND CONCLUSIONS

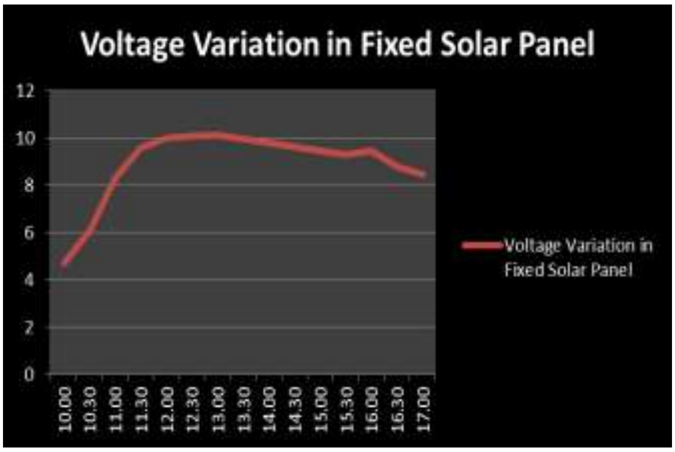
Table 1 Voltage Generated by Fixed Solar Panel

Sr. No.	Time (24 HRS)	Voltage (V)
1	10.00	4.7
2	10.30	6.1
3	11.00	8.3
4	11.30	9.6
5	12.00	10.01
6	12.30	10.11
7	13.00	10.15
8	13.30	9.97
9	14.00	9.78
10	14.30	9.63
11	15.00	9.48
12	15.30	9.29
13	16.00	9.45
14	16.30	8.78
15	17.00	8.47
	Average V_1 =	8.92133333

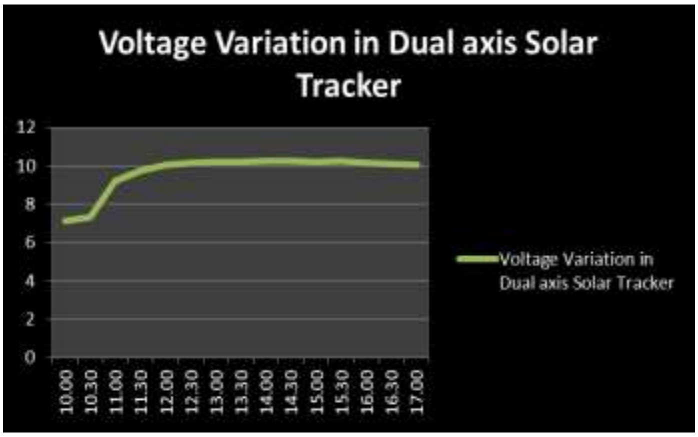
Table 2 Voltage Generated by Dual Axis Solar Tracker

Sr. No.	Time (24 HRS)	Voltage (V)
1	10.00	7.12
2	10.30	7.32
3	11.00	9.23
4	11.30	9.78
5	12.00	10.03
6	12.30	10.15
7	13.00	10.22
8	13.30	10.21
9	14.00	10.24
10	14.30	10.26
11	15.00	10.22
12	15.30	10.27
13	16.00	10.17
14	16.30	10.09
15	17.00	10.03
	Average V_2 =	9.68933333

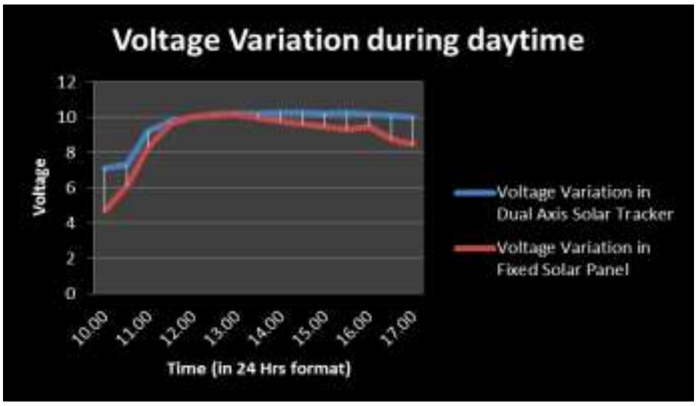
Graph 1: V vs Time for fixed Solar Panel



Graph 2: V vs Time for Dual Axis Solar Tracker



Graph 3 Comparison of Voltage vs Time for Fixed and Solar Tracker



The calculation of average voltage tells us that there is a significant increase when the solar tracker was installed.

$$\text{Percent increase in Average Voltage} = \frac{\text{Average } V_2 - \text{Average } V_1}{\text{Average } V_1}$$

$$= \frac{9.68933333 - 8.92133333}{8.92133333}$$

∴ Percent increase in Average Voltage = ***8.61 %***

By the assistance of Dual Axis Solar Tracker system we were able to boost the average voltage by 8.61%.

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