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Optimization of Solar Panel Output Power Using Dual Axis Solar Tracker

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Abstract: The huge demand of electrical energy is growing day by day. Conventional energy source which is produced by fossil fuel is not sufficient to fulfil the current demand of electrical energy and this is also exhaustive in nature. Now it is serious issue for energy researchers to find any alternate energy option. Solar energy is one of the most expanding renewable Energy. The performance of solar cells depends upon solar irradiance and its angle of incidence of light on PV panel. When the temperature varies, its power and effectiveness also vary. The aim of researchers is to find power and effectiveness should be optimum. Continuous incident of light at optimum angle of PV panel can be made possible by dual axis solar tracker. In this type of tracking system, there are two servo-motor used to move the panel vertical and horizontal axis. LDR is used to sense the light intensity and send the analog signal to the microcontroller and according to the signal, microcontroller move the solar panel using servo motor. This design provides the comparative study between the fixed axis solar panel and dual axis solar tracker implementation on the Tinkercad free web application. As an experimental result show that the electricity generated by the proposed tracking system is total increase of about 8% to 22% over fixed-angle solar system.

Keywords: PV Panel, Arduino UNO, Analog Signal, LDR, Servomotor etc.

I. INTRODUCTION

Solar energy is a form of energy derived from the heat and energy of the sun's rays. It is a renewable and therefore environmentally friendly energy source. Solar energy has emerged as a renewable energy source for 20 to 30 years. This solar energy is converted into electrical energy using solar panels according to the principle of the photovoltaic effect. Among renewable energy sources, solar energy is widely used. Because it is simple and easy to manage.

Currently, there are two main types of solar trackers: the single axis solar tracker and dual axis solar tracker. In this study we have developed that implement optimum output of dual axis solar tracker [1,2]. A solar tracker is a device used to rotate solar panels around the earth's axis. For fixed solar panels, there is no panel movement. However, the position of the sun changes with sunrise and sunset (the sun rises in the east and sets in the west).

For this reason, single-axis solar trackers have been developed that rotate solar panels in an east-west direction. However, because of the Earth's rotation and, we cannot always receive the same amount of sunlight. Accordingly, a dual-axis solar tracker for efficient and economical solar energy utilization by rotating the panel vertically was proposed. The main ideal of binary solar trackers is to increase the efficiency of solar panels by 10-25% compared to static and single-axis solar trackers [3]. Solar position tracker, the mechanism consisted of Arduino, DC motor, light sensor, and encoder. According to Feedback signals from encoders and sensors, microcontroller DC motor drive for control the angle of the solar panel is such that the panel is always Keep it perpendicular to sunlight [4].

To track the sun's movement accurately dual axis tracking system is necessary. The active/continuous tracking system tracks the sun for light intensity variation with precision. Hence, the power gain from this system is very high [5].The growth in RE is dominated by wind and solar power (approximately 90% of the world's newly added RE capacity), which is underpinned by the continuous reductions in development costs. Although the use of RE is increasing rapidly, the COVID-19 pandemic has impacted RE deployment and temporarily constrained RE growth [6,7].

The literature check easily shows the different styles of solar tracking for maximum application of solar power.[8] proposed a binary axis tracking system to apply and develop a simple and effective control scheme with only single tracking motor. Their main motive is to ameliorate the power gain by accurate tracking of the sun. In this paper they

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successfully designed, erected and examined a binary axis sun tracking system and entered stylish result. They concluded saying that this tracking technology is very simple in design, precise in tracking and affordable. In the present world, solar energy systems including photovoltaics and solar concentrating systems have been [9] considered as the most applicable solution in terms of industrial and domestic applications.

The Maximum Power Point Tracking (MPPT) is a technique for maximizing the generation of power from solar [10,11] panels by maintaining the working of P-V solar panels which is maintained in the methodology. Dual axis solar tracking system works well even if it is cloudy season as compared to the single axis solar tracking system [12]. It is appropriate for equatorial nations where there are little seasonal differences in the sun's position. The benefit of the single axis is that it only needs a single actuator, which is lighter and easier to control. However, it needs to be installed [13] correctly so that the mechanism can track the movements of the sun.

[14] presented a smart binary axis solar tracker. They used Arduino uno for the development of their proposed model. After the trial, they observed that maximum voltage was tracked about 25 to 30 and the generating power increased by 30 compared to static system. [15] over looked the cause of a binary axis solar tracking with development of power energy compared to a fixed PV panel in Sanliurfa, Turkey. They set up that everyday power gain is 29.3 in solar radiation and 34.6 in power generation for a particular day in the month of July. In 2017, [16] enforced a microcontroller grounded binary axis model working on a solar panel. Through this model, they observed that the solar panel except maximum power if the solar panel is aligned with the intensity of light entering from the sun. It improves the power affair and also palladium necessary for the system from rain and wind.

[17] proposed binary axis system with a concerted system of an Astronomical algorithm and camera grounded feedback processing for localizing and tracking light intensity to increase the effectiveness in achieving power energy. They also designed an emulsion algorithm system to combine approximation data of the sun acquired from astronomical grounded and visual grounded feedback. After simulation, it redounded that the azimuth and elevation sum squared crimes from the proposed algorithm are 0.3688 and 0.3874 degree, and the astronomical algorithm are 1.0997 and 1.2877 degree. [18] describes the development of solar tracking system grounded on solar charts using microcontroller, which can read the real sensible position of the sun by latitude's position for maximizing the effectiveness of energy position. Their main motive of this design was to work with minimum driver commerce in the insulated areas where there's lack network content. with PV panels facing the sun at all times, it ensures maximum solar energy being converted into electrical energy during the course of the day. Hence, substantial gain can be obtained by using dual axis solar tracker compared to static solar tracker [19].

II. METHODOLOGY

A. Working Principle of Solar Tracking System

Single-axis solar trackers track the Sun from east to west, rotating over a single point, either panel row wise or section wise. Binary- axis trackers rotate on both the X and Y axes, making panels track the sun directly. The solar tracking system follows the line of the Sun using three-point motion for azimuthal tracking with a clockwise open-circle control system that operates from 9:30 to 17:00 each day as illustrated in Figure 1. shown from, and a direct selector is used to track degradation over time.

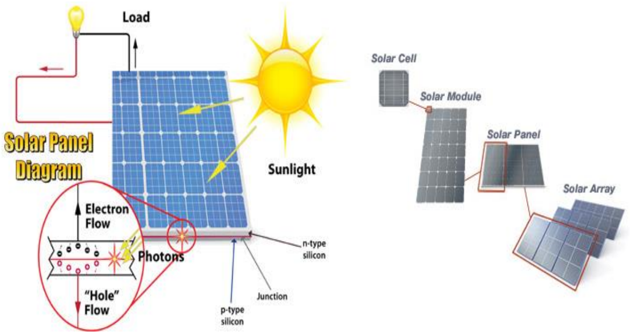

Fig. 1: Schematic Diagram of Solar Tracker [20]

In our design we will use solar panel to convert the light energy into the electrical energy. The Sun change its position throughout the day that's why we can't suitable to use the whole light energy so we've made a tracking system in which solar panel can be rotate as per the sun changes its position. We'll use the four LDR Sensor to sense the light and if the sun changes its position also separate LDR Sensor sense the light an induce the high voltage signal and this high voltage signal fed to the microcontroller or Arduino UNO as well as remaining detectors also give its generated voltage position to the microcontroller. All voltage signal of the each LDR detector that are fed to the microcontroller. Microcontroller

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signal fed to the microcontroller or Arduino UNO as well as remaining detectors also give its generated voltage position to the microcontroller. All voltage signal of the each LDR detector that are fed to the microcontroller. Microcontroller admit the voltage signal from the any input/output pin of the microcontroller and compares the each LDR output signal to with each LDR sensor output. When the controller find the highest voltage position of any LDR detector gives the instruction to the motor through the motor driver circuit to rotate the solar panel on the axis in the direction of the LDR detector which are generating high voltage. so, the battery can charge through the Solar panel. By using external two servo motors and by making connection in parallel we can move the solar panel in any direction. As by rotating the solar panel in the direction of the sun we use the maximum energy of the sun. The working principle of solar tracking system developed in this study is demonstrated by the following block diagram in fig 2.

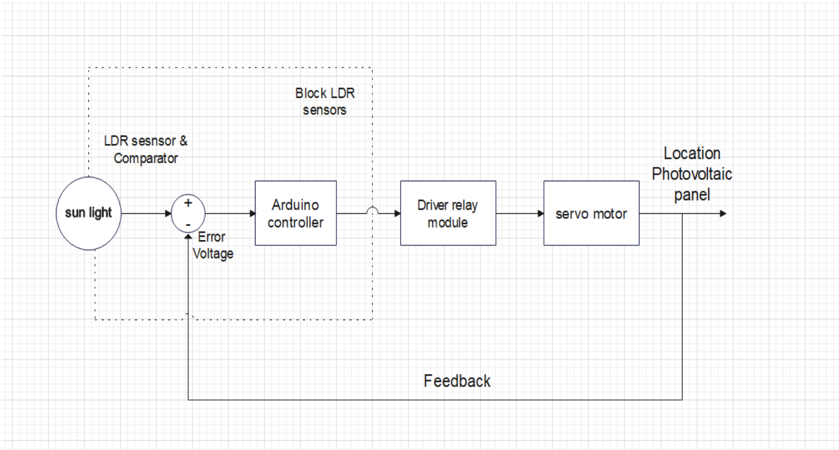

Fig.2 Block Diagram for Solar Tracker Using Servo Motor.

B Incidence Angle

To quickly track the position of the sun the control program must first calculate the theoretical value. Elevation and azimuth with coarse adjustment An automatic tracking mechanism using the following equations [21,22].

$\theta z = \text{Cos}{-1}[\text{Sin}\ \delta.\ \text{Sin}\ \varphi + \text{Cos}\omega.\text{Cos}\delta.\text{Cos}\varphi]$ (1)

$\alpha = 90 - \theta z$ (2)

$A = \text{Cos}{-1}[(\text{Sin}\ \alpha\ \text{Sin}\ \varphi - \text{Sin}\ \delta) / (\text{Cos}\ \alpha.\ \text{Cos}\ \varphi)]$ (3)

Where,

z: incidence angle	δ: declination
α: altitude angle	φ: local latitude
φ: hour angle	A: Azimuth angle

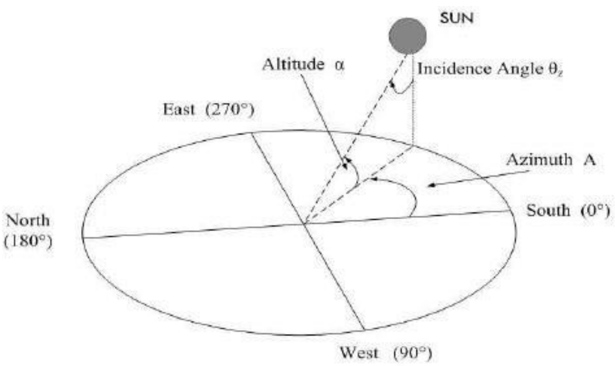

Fig.3 Angle of Incidence [23]

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C Flowchart of Algorithm

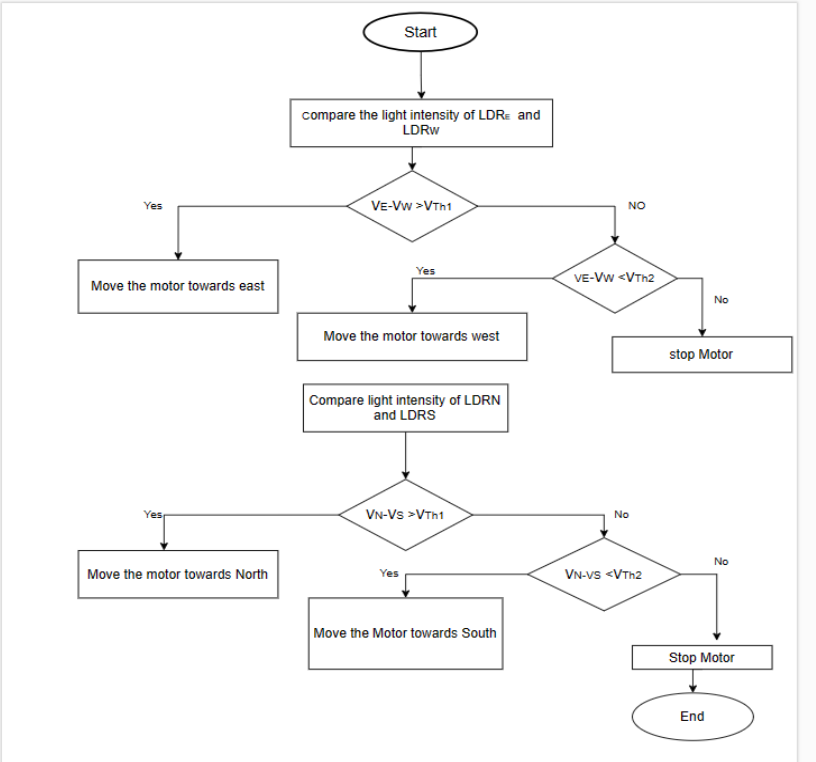

Fig.4 Flow Chart for Dual-Tracker Sun Tracking System

C Problem Statement

There are many issues that happened within the former type of stationary solar system. The main issue is that the solar panel is installed in fixed manner due to this reason power generated by it was very low. The other problem can be considered as the high cost of installation of PV system for domestic use. Stationary solar panel cannot move in any other direction so that its effectiveness is low. This is the main reason to design solar tracker. The solar tracker follows sunlight for extra power. On the other hand, purpose of this design to reduce the cost of purchasing additional solar panels. The objective of the system is to reposition the solar panels relative to the sun so that light falls in perpendicular way.

III. COMPONENTS AND THEIR FUNCTIONS

A Arduino UNO

As shown in the figure 5, The Arduino UNO is the best board to get started with electronics and coding. The Arduino Uno is a microcontroller board based on the ATmega328, an 8-bit microcontroller with [24] 32KB of Flash memory and 2KB of RAM, which is the most used and documented board of the whole Arduino family. It is easy to work with Arduino and it does not need an operational system. It is a free open-source electronics component used for building electronics projects. It is programmed in C language using dedicated IDE software (Integrated Development Environment) that runs on PC computer or laptop. The board is programming directly via USB standard cable and internal Arduino IDE – a programmer unit is not required. Because of the ease of use, Arduino UNO has been considered the ideal controller for the prototype.

Fig.6 Arduino UNO [25]

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B *LDR*

A light dependent resistor (fig. 6) is a passive electronic element that changes its resistance according to the intensity of light that falls on its surface. LDRs are also known as photoresistors, photocells, or photoconductors. They are made of semiconductor materials that have high resistance in the dark and low resistance in the light. LDRs are widely used as light sensors in various applications, such as street lighting, alarm clocks, burglar alarms, and light intensity meters. In this project, we are using 4 LDRs to detect the sunlight. And when they send signal to the Arduino, two servo motors will be guide to better angle for the solar panel to maximize its efficiency [26].

Fig.6 Light Dependent Resistor [27]

C Servo Motor

A servo motor which can be operated with power supply from 4.8V to 6V. Normally voltage of 5V with operating frequency, f0 = 40Hz is used. Servo motor is used to give accurate angle control such as 45 degrees, 90 degrees. The angle can be hold continuously. It can rotate from 0 degree to 180 degrees when the pulse duty gyration changed [28].
A servo motor consists of three main components:

1-Motor
2- Sensor
3-Controller

Motor:- Motor can be either a Dc Motor or an AC motor depending on the power source and the application requirements. The motor gives the mechanical power output to rotate or move the shaft shown in figure 7.
Sensor:- Sensor can be either a potentiometer an encoder, a resolver, or another device that measures the position, speed, or torque of the output shaft and sends feedback signals to the controller.
Controller:- Controller can be either an analog or a digital circuit that compares the feedback signals from the sensor with the desired setpoint signals from an external source (such as a computer) and generates control signals to adjust the motor's voltage or current accordingly.

Fig.7.Servo Motor. [29]

D Solar Panel

Solar panel use sunlight as a source of energy to generate direct current electricity. A solar cell or photo-voltaic cell is an electrical device that converts the energy of light from the sun into electricity by the photo- voltaic effect, which is a physical and chemical phenomenon. Solar cell is a device whose electrical characteristics similar as current, voltage and resistance vary when exposed to the sun [30]. A collection of PV modules is called a PV panel Poly-crystalline solar cells as shown in Figure 8 is used in this research. A Solar panel is the main point of the project. It involves solar panel to get the voltage output. This is renewable energy that needs to convert into voltage. This photo voltaic panel will be managed by using software to switch on the circuit that will be converted the output and stabilize the voltage that be used in the project. According to a US tech report, solar tracking is particularly effective in summer when the increase in energy output can be 50% or more, and 20% or more in the fall, depending on the technology used.

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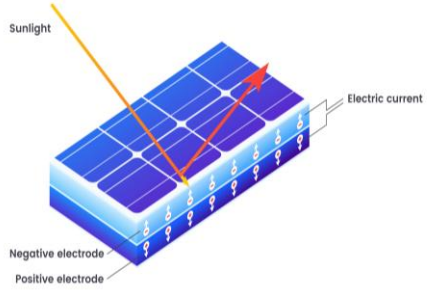

Fig.8.Solar Panel [31]

E Software Design

This section explained the circuit design of light dependent resistor controlling the rotation of the servo motor by using Tinker Cad software. This circuit consists of an Arduino UNO, an LCD Display, two servo motor, four units of light dependent resistor (LDR), four units of 10kΩ resistor. Figure 9 shows the Tinker CAD graphical user interface designed to study the dual axis solar tracker's performance.

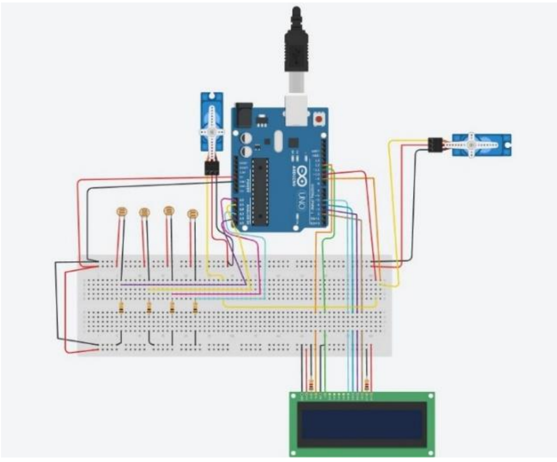
Fig.9. Dual Axis Solar Tracker Circuit by Using Tinker CAD

E Hardware Design

This section discusses the idea on hardware design for Dual axis solar tracker.

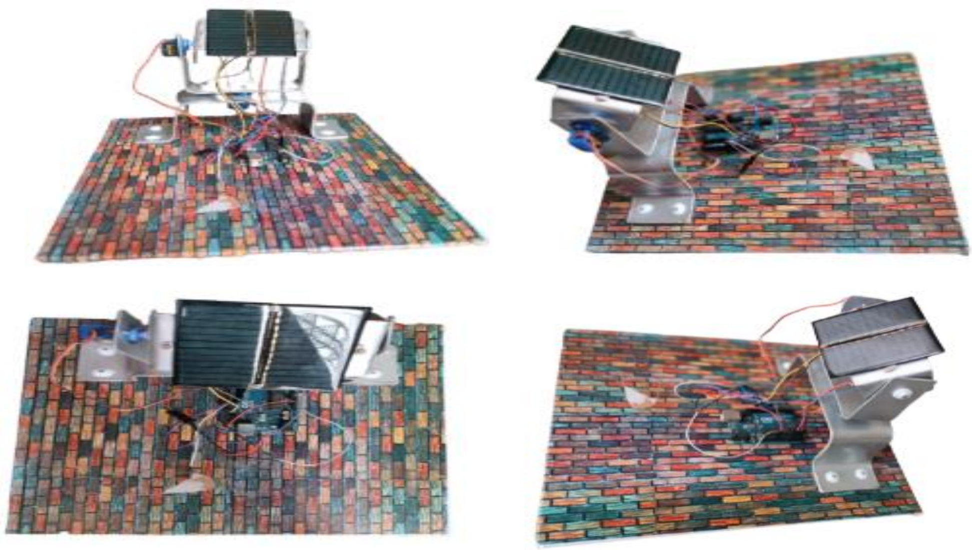
FIG.10. HARDWARE DESIGNED MODEL

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IV. OBSERVATIONS

The testing has been done on 12-07-2023 as shown in above Figure 10. The data of output value from the solar panel has been recorded and tabulated in the Table 1.

Table 1. Comparison of PV Panel Output Values between
Fixed Solar Panel and Dual Axis Solar Tracker System with No Load.

Time (Hours)	**Solar panel Output values With fixed Angle (45 degree)**				**Solar Tracker Panel Output Values with variable Angles (Dual-Axis)**			
	A(°)	V(V)	I(A)	P(W)	A(°)	V(V)	I(A)	P(W)
9.30 am	45	12.55	0.12	1.50	30	12.80	0.14	1.80
10.00 am	45	13.11	0.13	1.70	30	13.20	0.15	2.04
10.30 am	45	13.38	0.14	1.87	45	13.86	0.16	2.24
11.00 am	45	13.43	0.28	3.76	60	14.55	0.30	4.51
11.30 am	45	13.60	0.29	3.94	120	15.50	0.31	4.72
12.00 pm	45	13.72	0.32	4.39	135	16.00	0.33	5.26
12.30 pm	45	13.81	0.38	5.25	180	16.15	0.39	6.30
1.00 pm	45	13.86	0.40	5.54	150	16.19	0.41	6.64
1.30 pm	45	13.88	0.41	5.69	135	16.23	0.42	6.82
2.00 pm	45	13.67	0.30	4.10	120	15.87	0.31	4.92
2.30 pm	45	13.56	0.29	3.93	90	15.70	0.30	4.71
3.00 pm	45	13.30	0.14	1.86	60	15.25	0.15	2.23
3.30 pm	45	13.27	0.13	1.72	45	14.28	0.14	2.06
4.00 pm	45	12.85	0.11	1.41	30	14.00	0.13	1.69
4.30 pm	45	12.45	0.08	0.99	15	13.89	0.09	1.18
5.00 pm	45	11.84	0.04	0.47	0	13.00	0.04	0.56

V. RESULT AND ANALYSIS

In this study System performance was plotted, two solar panels used and were compared with the output generated from the fixed-axis solar panel with the same structure and characteristics and the dual-axis tracking system were performed. Dual axis solar panel output is more than single axis trackers and stationary systems in terms of electrical energy output. This article presents a curious and easy-to-implement dual-axis solar tracker using LDR with ARDUINO UNO. This technology helps to fully control solar radiation by monitoring dual axis sensors. This is possible because the solar panels are still properly aligned with the incoming sunlight. This fits well with the idea of solar trackers managing more energy than fixed solar panels. This is the development of a simple and inexpensive tracking system.

Over the past few years, solar trackers have played a major role in improving the performance of solar panels, which has proven to be the ultimate technological revolution. With global warming constantly affecting the world in several ways, it is essential we began taking care of nature in whatever way possible and modern-day technologies on being clean and green. It can be used in stand-alone application and street light systems. This paper concludes that solar tracking system provides more effective method to track the solar panel and provide economic consistency for generation of electric power. The electricity generated as a result of the experiment is the proposed tracking system increases the total about 17% to 22% higher than fixed-angle solar systems in sunny days and about 8% to 11% cloudy.

Further analysis has been done on the comparison of output value: power, voltage and current between the fixed solar panel and dual axis solar tracker system. The result of the comparison of output value with no load is shown in the Figure 11.

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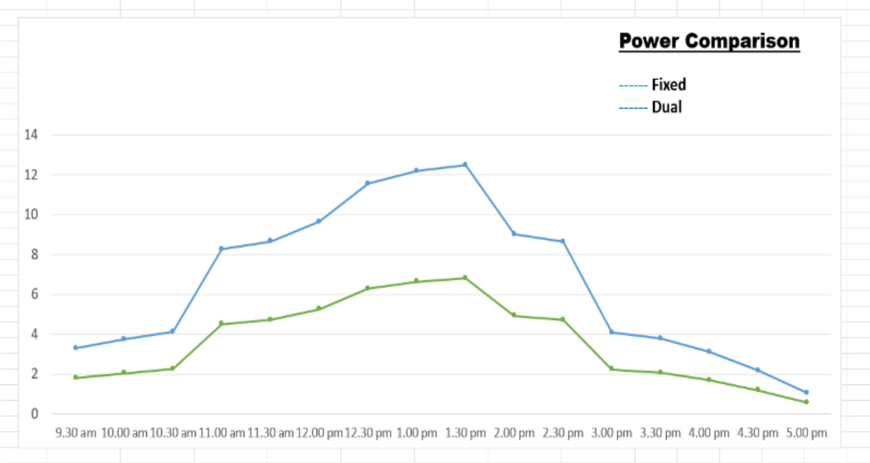

Fig.11 Power Graph Between Dual Axis Solar and Fixed Axis Solar

VI. CONCLUSION

This research paper develops and implemented dual-axis solar tracking system with minimal effort and cost. From table of comparison it can be conclude that dual axis solar trackers are more efficient than single axis trackers and stationary systems in terms of electrical energy output. Dual-axis tracking increases each panel's power output about 20%, allowing to use fewer panels, frames, and other components to produce the same amount of power. Lowers a project's beginning costs. The circuit is designed with a minimum number of Components that Minimize and Simplify Costs

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