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Analysis and Testing of Dual Axis Solar Tracker for Standalone PV Systems using Worm Gear

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ABSTRACT

When solving the world's most significant energy problems, among the most current innovations is to use solar energy. Maximizing solar energy selection for direct conversion into energy remains a considerable challenge. We require a significant amount of power to maintain life on Earth. Our bodies get it from the food we eat, but machines and equipment need the energy to function. Because non - renewable sources are finite, we are increasingly turning to renewable energy sources. The Sun is one of the most important renewable energy sources. This basic concept evaluates and tests a dual-axis solar tracking system in two ways. The first is a timer-based tracker, and the second is an LDR-based tracker. This project consists of a worm gear mechanized system for rotating the panel in the direction of the Sun along with a few sunlight sensors. The mechanized system is controlled by a microcontroller-based control system that detects sunlight. The project's primary device that converts is a PIC Microcontroller connected to LDRs and a geared D.C. motor with a panel set up on its shaft. According to the research, the motor will move the solar array in response to the Sun's light intensity. The short definition of this system is to compare two types of systems with the study of existing literature in terms of developing a prototype of mechanically based dual axis solar array that actively tracks the Sun so that maximum power is gained by the arrangement at all points of time of the day.

Keywords: Dual Axis system, P.V cell, Solar tracking system, PIC Microcontroller, LDR

1.INTRODUCTION

Energy demand will skyrocket in the coming years, while conventional energy reserves will rapidly deplete. Non-conventional / renewable energy must be harnessed to meet the rising energy demand. Solar energy is the most abundant and uniformly distributed of all non-conventional energy sources available. However, solar energy capture technology is being researched and developed. For human life to progress, energy is required. The amount of energy consumed reflects a country's economic development. Due to the rapid depletion of traditional energy sources such as coal and petroleum, most countries are attempting to focus on nonrenewable energy sources such as wind, solar, and geothermal. Etc.

Because nonrenewable energy sources are generally location-based, wind energy is abundant in coastal areas in India. Still, solar energy is available all over the country due to India's proximity to the equator. We can maximize solar energy production by using a dual-axis solar tracker in India because sunny days are consistent throughout the year. We use a tracking system in our project, which allows us to track loads of daylight in real-time by rotating solar panels in multiple axes. We can follow the Sun in four directions with a dual-axis system, resulting in a significant amount of energy from the solar panel. We'll be able to put more sun rays behind bars because of this development. The dual-axis in service is nearly as good as a single axis. Still, it captures solar energy more efficiently by rotating the horizontal axis at intervals and the vertical axis. Our tracking system consists of two LDR sensors, a motorized mechanism, and a PIC microcontroller. This system runs nonstop. This system includes a cleaning setup with a SERVO motor to clean the solar panel and a select switch to choose whether the system is timer or LDR based. In addition, the voltage values of the solar panel will be displayed on an LCD in various modes. The time of the RTC is set using a keypad in this system. A real-time system clock is like a watch in that it is powered by a battery and monitor and assesses even when the power is turned off.

The idea of just using devices to measure solar irradiation came from studies. It enables accurate tracking of the Sun's position in various weather conditions. If clouds obscure the Sun, it can also relocate it. It has a 0.1-degree accuracy and is unaffected by temperature changes. It also adds to the project or investment and bulkiness. We use real-time tracking with a programmable Arduino in our project, which can easily take data on sun rotation for a specific location and control it accordingly. This curriculum can be altered depending on the spot, lowering the cost of the sensing material. Here in this paper, we are using a dual-axis tracker with Arduino programmed control box.

Worm gear mechanism: Worm gear is a gear made up of a spiral threaded shaft that engages and drives a toothed wheel. The rotational movement changes by 90 degrees due to the worm's role on the worm wheel, as is the plane of motion. Friction is created when lubricated gears are turned. Heat is produced because of friction. Worm gears are used as speed removers because they have low and high torque levels, making them suitable for various applications. Worm gears are commonly used because they provide high torque multiplication and high-speed reduction. If the coefficient of friction between the gear and the worm is more significant than the tangent of the worm lead angle, the worm gear is considered self-locking and will not back drive. Worm gears resemble screws in appearance. The gear, wheel, or worm wheel is usually made up of a worm gear and a spur gear or helical gear. Worm and gear pairs are a small and simple way to achieve high torque, low-speed gear ratio. Helical gears, for example, typically have gear ratios of less than 10:1, whereas worm and gear sets have ratios ranging from 10:1 to 500:1. The possibility of significant sliding action, resulting in low efficiency, is a disadvantage.

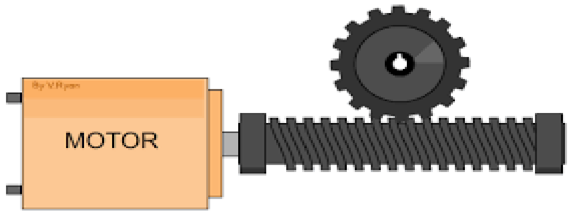

Fig:1. Worm Gear Mechanism

2. LITERATURE SURVEY

Ghassoul (2001) demonstrated a positional tracking system using a Siemens micro–PLC S216. The scheme had never been used before, and the testing specifications had never been made public. In (Sungur 2008) proposed a dual-axis tracking system that used the method to calculate the Sun's azimuth and solar altitude angles over one year. The dual-axis tracking system, which a PLC controlled, had been designed and installed. In the two-axis sun tracking system, 42.6 percent more energy was obtained. The system used no unusual amounts of energy. (YOUSIF 2012) introduced an industrial automation tracking system based on four sensors mounted on the solar panel frame to track the position of the Sun. An ATmega16L microcontroller controlled the system. The power output gain for the solar tracking panel with two axes was 31.5 percent higher than the fixed solar panel. (Wang and Lu, 2013) proposed a simple response to the requirements of a hold Sun tracker using a single dual-axis A.C. motor to follow the Sun. With only a single tracking motor, V Sundaram Siva Kumar and S Suryanarayana suggested a dual-axis tracking system to implement and develop a simple and effective control method. Their primary goal is to increase power gain by precisely solar tracking. This paper successfully developed, built, and tested a dual-axis sun tracking system and got the highest result.

They concluded that this tracking system is easy to use, precise, and cheap.

3. THE OBJECTIVE OF THE STUDY

- Given that the Sun moves at 15 degrees per hour and that the tracker would make position changes, the main goal of the dual-axis tracker is to follow the position of the Sun for maximum energy efficiency.
- It should be a more reliable and efficient dual-axis solar tracking system, making electricity available in remote areas. Collect data from both solar tracking systems and compare the data for both methods to determine which form provides the highest percent efficiency in the solar tracker.
- Cleaning system for solar panels uses servo motors to extract more power from the boards.
- It uses a worm gear mechanism to adjust the face of the solar panel or reflective surfaces to align the Sun as it moves across the sky. The system completes one rotation per day.

4. THEORETICAL ANALYSIS:

The Earth rotates once around in an imaginary axis every day. This axis goes through two poles, the north, and south poles. The equator is the line perpendicular to this imaginary axis. The Earth tilts about 23.50 degrees from the plane of its orbit, and it takes 365 days to complete its rotation around the Sun. The figure depicts the Earth's various axes.

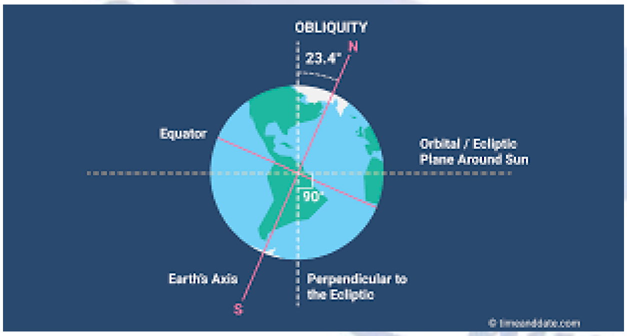

Fig: 2. Various Axis of Earth

a. Latitude and longitude: The Earth's surface is defined as the angle founded by the equatorial region and the single sentence passing through at that point and through the Earth's core. Lines and areas of similar latitude detect groups on the Earth's crust concurrent to the equator and one another. The angle created by a compared meridian and another meridian intersecting with a point on Earth's surface. All connections are large ellipses that intersect at the north and south poles.

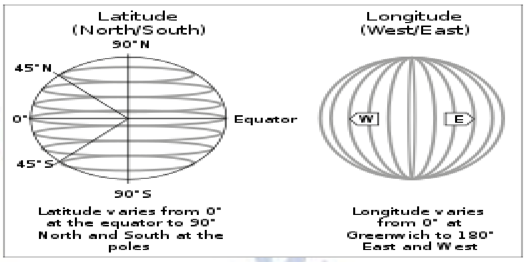

Fig: 3. Latitudinal and Longitudinal axis

b. Solar zenith angle:

The solar zenith angle is the angle founded by the sunrays and the lateral orientation. It is linked to the photo-voltaic altitude angle, established by the Sun's rays and the horizontal distance.

c. Solar azimuth angle:

The solar azimuth angle is the azimuth angle of the Sun. The Sun's position along the local horizon is specified by the horizontal coordinates, while the solar zenith angle stipulates the Sun's maximum height in the sky.

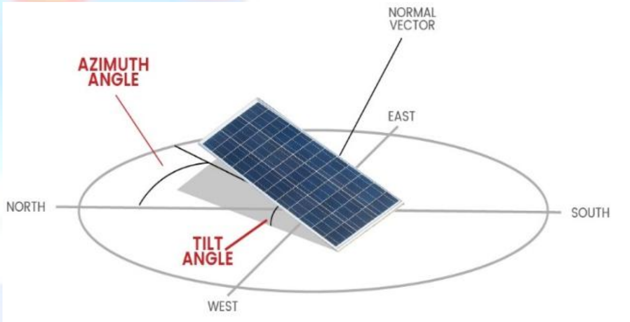

Fig:4. Solar Azimuth Angle

5. FIXED AXIS AND DUAL-AXIS

Fixed tilt arrays are solar panel arrays placed at a fixed angle, usually the optimum tilt. Solar panels must be pointed in the direction that captures the most sunlight to be as efficient as possible. Because fixed-tilt arrays are immobile, they are simple to build, design, and maintain. Fixed systems are resilient and require little maintenance because they have no moving parts.

Dual-axis trackers have two degrees of freedom that serve as rotation axes. These axes are usually orthogonal to one another. A primary axis is an axis that is fixed concerning the ground. A secondary axis is an axis that is referenced to the primary axis. Dual-axis trackers are commonly used in a variety of ways. There are several standard dual-axis tracker implementations. They are classified by the orientation of their primary axes concerning the ground.

6. EXPERIMENTAL SET-UP AND WORKING:

The entire setup is used to construct the solar system's framework. The platform's structure comprises solar cells plates, stands, gears, motors, an electrical circuit, and other accessories. The figure depicts the method of the two ways. The figure shows the technique of the two-axis system. It can be rotated in two axes, one perpendicular to the Earth and the other parallel to the Earth, as shown in the plan, and the full sub-assemblies with the circuit. Dual Axis Solar Tracking Systems are available in several configurations. As even the building shows, the panel has two types of motion, so and during the day, this will track the Sun premised on the sensing and save power to the battery, and it will also shut it down in the evening. Then after reversing the panel, it will save power to the battery.

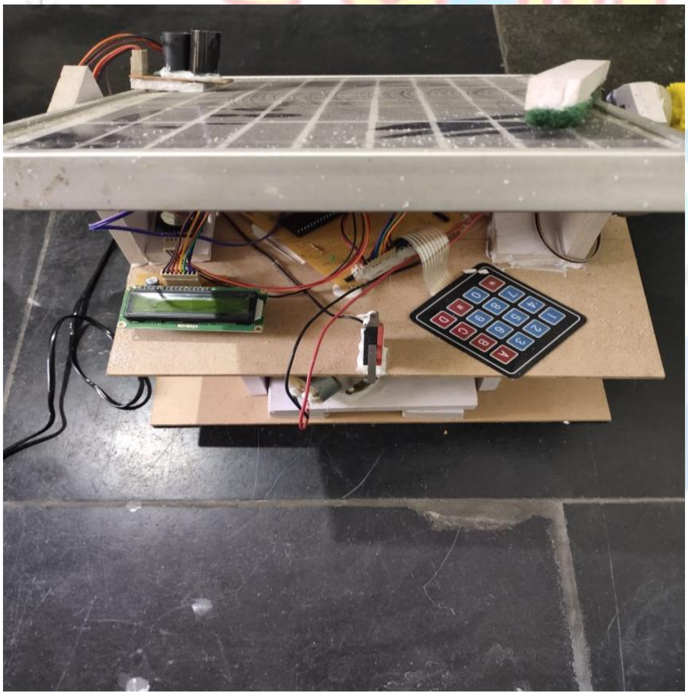

Fig:5. Complete Set up of Solar Tracking system

The circuit detects the access code depending on the quantity of solar radiation detected by the LDR sensors and begins and runs the motors as the LDR sensors detect the amount of solar radiation. The design is done here based on the power and setup requirements. This system was designed with the setup requirements and the height and material availability in mind. The improvement has made the most significant impact on the design. The details are edited, and the project is low-cost. Saving money is also an essential benefit of using this method.

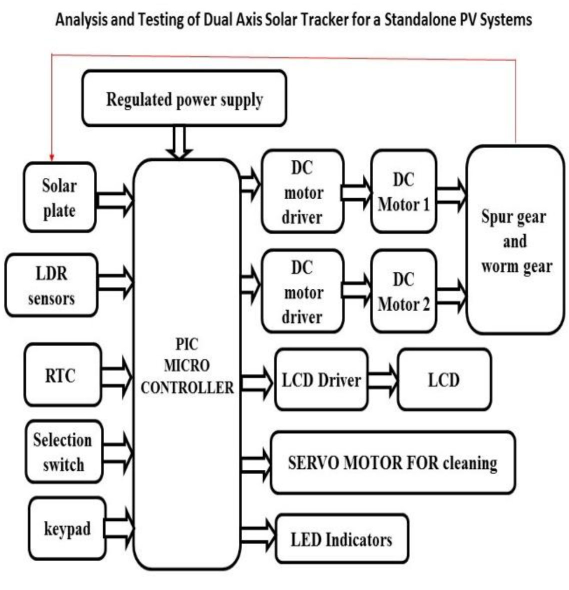

Fig: 6. Block Diagram of Analysis and Testing of Dual Axis Solar Tracker for a Standalone P.V. Systems

This device tracks the Sun in two ways. The first is a tracker based on a timer, and the second is a tracking system based on an LDR. A microcontroller is a whole device that converts the system, toward which LDRs and a geared D.C. motor with a review panel set - up to its shaft are attached. There is, in fact, a switch that allows the user to use either technique of tracking. The segments and sub receive input from LDR sensors about an angle of the Sun, which it processes and uses to control the motion of the solar array connected to the D.C. motor. The goal of solar tracking on both axes is thus met. Suppose the user chooses to monitor the counting down. RTC then enters the picture. It tracks events in real-time. A keyboard can be used to set the duration of the RTC. The RTC is powered by a communications battery and maintains time even when the switch is turned off. In both preceding cases, the viewer can eventually quantify the manual process by checking the voltage. If the solar panel's output is not within a predetermined voltage range during a specific time interval, it indicates that there is sand only on the solar panel. In that case, our system will clean the solar array once a day with a servo.

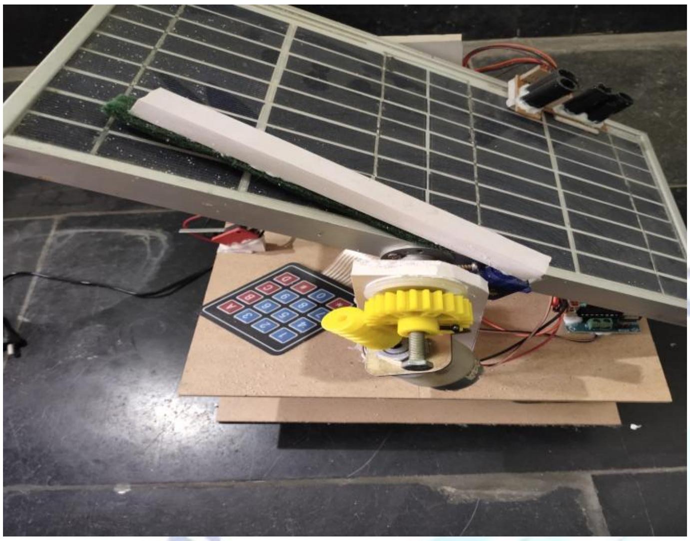

Fig: 7. Gear Mechanism of Solar Panel Setup

TABLE: 1. Day Wise Average of Fixed Axis of Solar Panel

JNTUA CEA CAMPUS ANANTHAPURAM			
laitude-14.6497∘N, longitude-77.6072∘E			
DATE	OUTPUT POWER (watt)	INPUT POWER (watt)	EFFICIENCY (%)
15/10/2021	2.069	17.245	12
16/10/2021	2.554	17.028	15
17/10/2021	2.526	14.032	18
18/10/2021	2.040	15.692	13
19/10/2021	2.510	14.765	17
20/10/2021	1.749	9.714	18
21/10/2021	1.735	11.563	15
22/10/2021	1.724	14.364	12
23/10/2021	2.442	15.264	16
24/10/2021	2.202	14.683	15
25/10/2021	1.382	7.272	19
26/10/2021	1.656	7.527	22
27/10/2021	2.448	12.883	19
28/10/2021	2.361	13.888	17
29/10/2021	2.402	13.347	18

TABLE: 2. Day Wise Average of Dual Axis of Solar Panel

JNTUA CEA CAMPUS ANANTHAPURAM			
laitude-14.6497∘N, longitude-77.6072∘E			
DATE	OUTPUT POWER (watt)	INPUT POWER (watt)	EFFICIENCY(%)
15/10/2021	2.782	19.871	14
16/10/2021	2.554	15.964	16
17/10/2021	1.744	7.928	22
18/10/2021	2.808	13.373	21
19/10/2021	2.624	10.094	26
20/10/2021	3.674	13.608	27
21/10/2021	2.754	9.834	28
22/10/2021	2.678	9.233	29
23/10/2021	2.711	9.683	28
24/10/2021	2.621	9.707	27
25/10/2021	2.602	10.006	26
26/10/2021	2.738	11.407	24
27/10/2021	2.587	11.760	22
28/10/2021	2.680	14.887	18
29/10/2021	2.776	16.330	17

7. RESULTS:

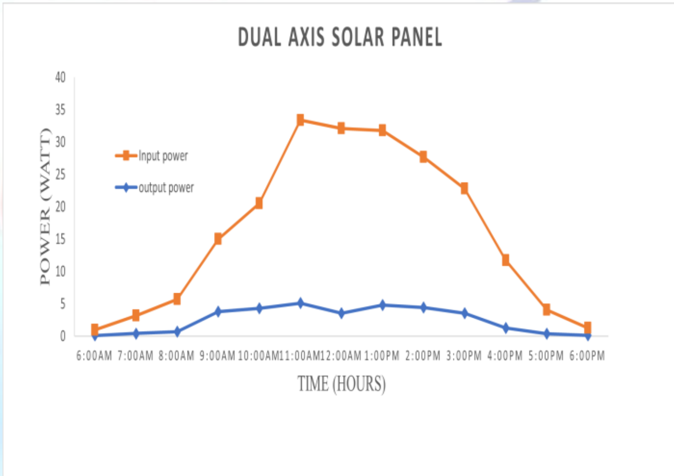

Fig: 8. Time Vs. Power of Dual Axis Solar Panel on October 19th

This section will look at a dual-axis solar panel's output and input power on October 19th, 2021. The solar irradiance valve was also collected using a dual-axis solar panel. The output increases at 10:00 a.m., with the maximum power gained between 12:00 a.m. and 1:00 p.m. At 6 a.m., the emphasis was at its lowest point.

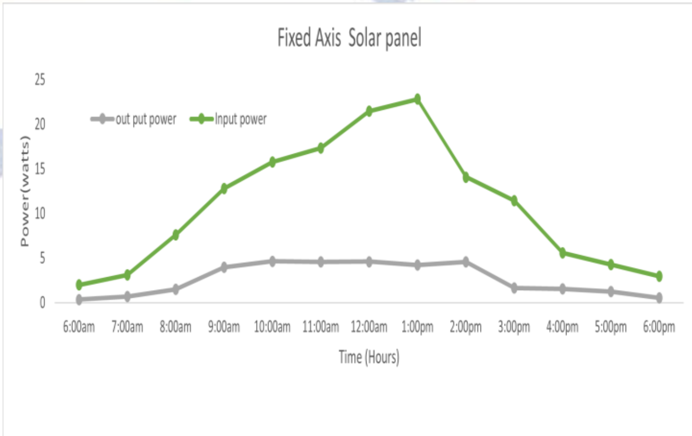

Fig:9. Time Vs. Power of Fixed Axis Solar Panel on October 19th

This section will define a fixed-axis solar panel's output and input power on October 19th, 2021. This section will calculate the efficiency based on the work and input power. The output increases from 9.00 a.m. to 1.00 p.m., with the maximum power gained between 12.00 a.m. and 1.00 p.m. At 6 a.m., the emphasis was at its lowest point.

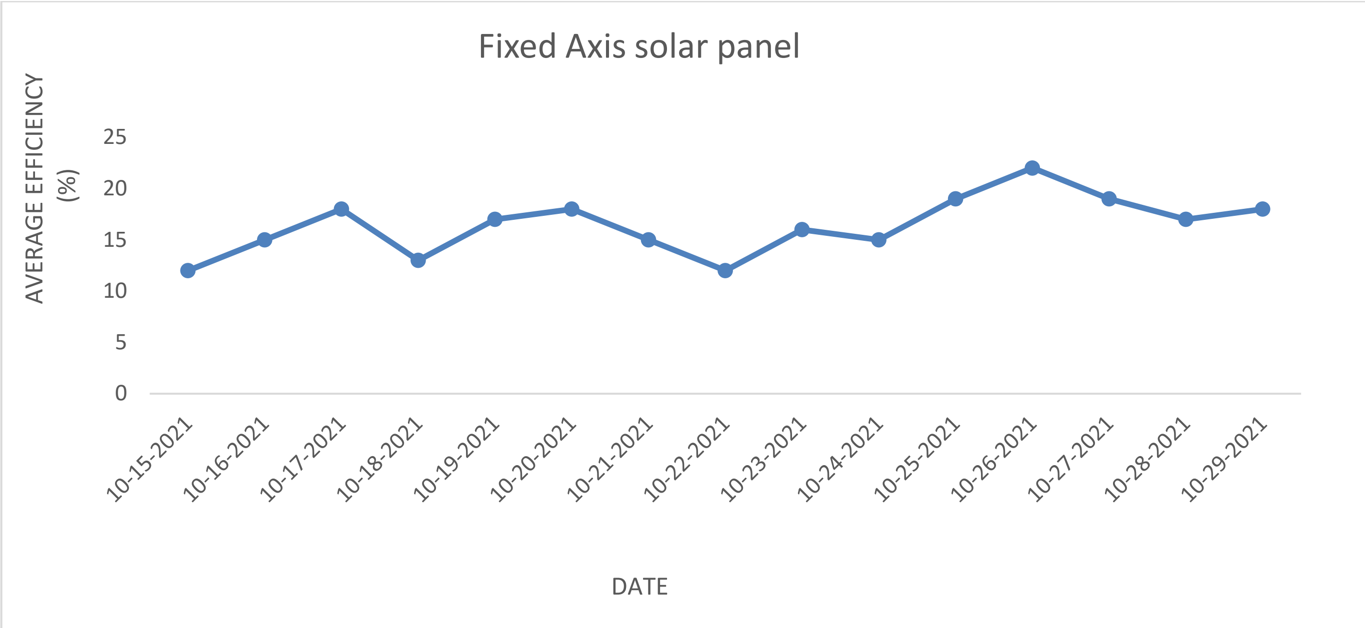

Fig:10. Date Vs. Average Efficiency of Solar Panel

The graph above depicts the average efficiency from October 15/10/21 to October 29/10/21. Maximum efficiency is at 26/10/21, with minimum efficiency at 15/10/21 and 23/10/21. Lower efficiency occurs on 15/10/21, gradually increases to 17/10/21, and decreases again.

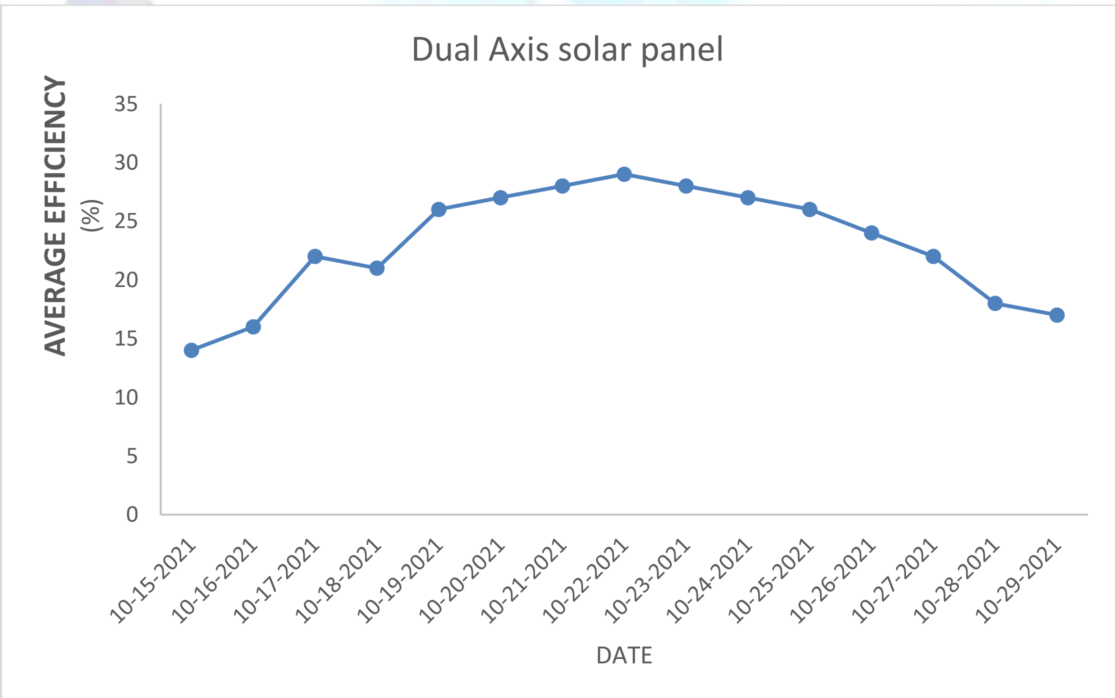

Fig:11. Date Vs. Average Efficiency of Dual Axis Solar Panel

This section will look at the average efficiency's values from October 15/10/21 to October 29/10/21. Here, we will calculate that the dual-axis solar panel remained at a low peak during the day on 15/10/21, with the highest power at 22/10/21.

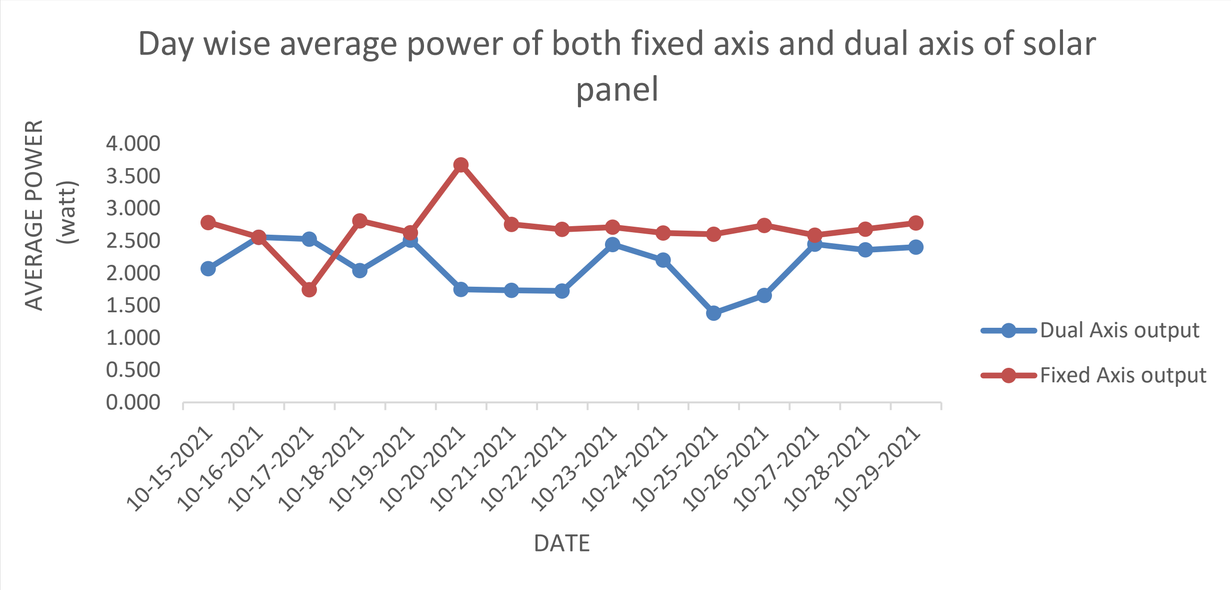

Fig:12. Date vs. Average Power of day-wise of fixed axis and dual axis of solar panel.

The graph above shows the average outpower from October 15/10/21 to October 29/10/21. Here, the maximum efficiency was on 20/10/21, and after that, it decreased slightly. On 15/10/21, efficiency is lower, then gradually increases at curves at 22/10/21. It gradually reduced after that. Fixed axis solar panel: The graph above shows that the output of set axis average valves was defined from Oct 15/10/21 to Oct 29/10/21. On 19/10/21, the power valve reached a peak and then gradually decreased.

8. CONCLUSION:

The existing model presents an Integrating feature of all the hardware components used and developed with PIC Microcontroller. The Presence of each module has been reasoned out and placed very carefully. Dual-axis tracker aligns with the sun route, tracks the sun movement cost-efficiently, and includes an excellent performance upgrade. The investigation outcomes clearly show that dual-axis tracking is good enough for the fixed-axis system. The proposed method is price effective collectively as an angle adjustment in fixed-axis hunter provided notable power increase among the system.

1. Using dual-axis solar tracking system, the net output energy gain was 7% - 9% over fixed axis panel output energy. Finally, we achieved 30% efficiency by using a dual-axis solar panel system.
2. The analysis of the results showed that the percentage of power gain was 84% during the morning, and during evening time, the rate of power gain was 100%. The space requirement for a solar park is reduced, and they keep the same output, and the return of the investment timeline is reduced.
3. Tracking the Sun from east in the morning to the west in the evening will increase the solar panel's efficiency by 15-20%, depending on whom you ask and where you are in the world.

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