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Improving Efficiency of Solar Panel Using Dual Axis with Mirror Reflection

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***Abstract*— Alternative energy sources are gaining popularity. Solar energy is quickly becoming recognized as a significant way to increase the availability of renewable sources of energy. To improve efficiency, a solar system should produce as much power as possible. Therefore, it is crucial that those working in engineering fields comprehend the technology related to this field. The solar tracker is an apparatus in which solar panels are mounted and which tracks the sun's path across the sky to make sure that the solar panels receive the most sunlight possible throughout the day. To ensure that the best sunlight is recognized, the tracker will attempt to navigate via the path after discovering the sunlight. To let a significant drive system follow the path of the sun through the sky, the design incorporates an efficient sensor array that can offer location information. This system differs from others that utilizes the sun as a guide rather than relying on the Earth as a reference point. Because the solar array can keep its alignment with the sun thanks to solar tracking, more electricity can be generated. Due to its accurate alignment with the sun's direction and improved ability to capture its movement, a dual axis tracking system with mirror reflection has significantly enhanced performance.**

Keywords—Servomotors, Dual-axis tracking system, Mirrors, Solar panel, Arduino.

I. INTRODUCTION

Pakistan has a significant energy problem despite the fact that power is a fundamental human need worldwide and a major driver of social, economic, and environmental advancement. The majority of Pakistanis, notably those in rural Sindh, reside in non-electricity-accessible rural areas. Oil, gas, coal, biomass, wind, and hydropower are just a few of the diverse energy sources available in Pakistan. The potential energy of solar is about 2900 Gigawatts (GW), the potential energy of wind is 346 GW, the potential energy of hydro is 6 GW, and the potential energy of biomass is 5 GW. Fortunately, Pakistan enjoys 365 days of the best sunlight, which generates an average of 5.45 kWh per day in Sindh. We are interested in solar projects as the solar system is expanding across Europe and South Asia now, and many are already underway or will be soon. Our nation's current demand for 25,000 megawatts (MW) will increase to 40,000 MW by 2030. The supply capacity of the nation is 37,402 megawatts. The tracking mechanism will work more effectively since the panel will turn automatically in the direction of the strongest sunlight. To maximize solar light absorption, these devices rotate in different orientations. It has the ability to move along single and dual axes if professionally designed. The only drawback is that it will increase installation and maintenance costs. The effectiveness of a solar system is influenced by the angle formed by photovoltaic (PV) panels and the sun. More direct sunlight results in better energy output from PV modules. As a result, tracking systems are employed to enhance the effectiveness of PV systems by following the path of the sun. Dynamic closed loop feedback control is the most effective technique, increasing two energy returns over fixed PV panels by up to 45% for dual axis and up to 25% for single axis. Depending on how well the equipment is fitted, the energy used by it is less than 5% of the total energy gathered. High installation costs may limit incentives to utilize this technology, however expanding the number of PV panels that can be installed in a Power plant would increase the tracking system's cost-effectiveness. As a result, these technologies work best in huge power plants, necessitating the need for more small-scale feasibility studies. A PV system's cost to energy ratio is reduced by 26.3 percent with single axis trackers and concentrators. Stationary PV with dual axes produces 30.79% more electricity than PV with a latitude tilt. Solar trackers can increase the amount of energy gathered by 10% to 100% when compared to a stationary system. The location has a considerable impact on solar tracking's effectiveness (or latitude). Furthermore, it was found that dual axis trackers performed 17.7-31.2 percent better than fixed panels and exceeded single axis trackers in terms of solar energy gain by a margin of 0.4-23.4 percent. The dual axis has the highest solar energy gain. The fact that tracking systems' financial advantages were significantly reliant on governmental tariff procedures serves as an illustration of the value Numerous case studies of these gadgets in various global locations.

II. RELATED WORK

Improving efficiency of solar panels using the dual axis tracking system has revolutionized the functionality of solar panels. The purpose of this literature review is to investigate the progress, advantages, limitations, and applications of solar panels. This will be accomplished by conducting an analysis of research papers. By examining the existing literature, to gain insights into the progress made in this field and understand the advantages and limitations of solar panels for various applications. This paper reviews on grid-connected, solar photovoltaic-based electric vehicle systems. The paper emphasizes the critical role of PVs and EVs in reducing global carbon emissions and promoting green energy. By integrating PVs into EV charging schemes, the dependency of EVs on the grid can be minimized, making the system more flexible. In addition, EVs can also be used as storage for both grid and PV systems to manage the intermittent nature of PVs. The paper discusses various modeling components for optimal EV charging scenarios. It concludes by suggesting future research directions such as projection of EV load demand, vehicle-to-grid (V2G) and vehicle-to-vehicle (V2V) power transactions, hosting capacity of PV-based charging stations, optimal charging control, and reliability of PV integrated charging stations [1]. This paper focuses on improving the efficiency of solar panels using a solar panel tracking system that aligns the panel perpendicularly with the sun. The system is embedded with a microcontroller, a Light Dependent Resistor sensor, and a DC motor to control its movements. The tracking system follows the sun's location throughout the day, ensuring maximum energy absorption from the sun. It is particularly beneficial for environments with high solar exposure, presenting potential for application in solar systems and power management systems. This research also suggests that this could be useful on an industrial scale in developing regions, such as Nigeria or Sub-Sahara Africa. Future recommendations include using more sensitive and efficient sensors for improved performance and cost-effectiveness [2]. This paper evaluates different photovoltaic prediction software tools using real data from Northern Spain. The study involves three facilities at various locations, subject to similar environmental conditions. The software tools evaluated are PV*SOL, Polysun, and System Advisor Model. These tools essentially simulate the output and performance of photovoltaic systems, providing data on aspects such as irradiance received, energy balance, and financial analysis, among others. Therefore, the goal of the paper is to analyze the accuracy of these software tools in predicting the performance of PV systems when applied to real-life data [3]. The study proposes a Detailed analysis of the Techno-economic renewable and sustainable energy reviews, and environmental characteristics of several solar tracking devices for home photovoltaic installations. With a range of 3.4 to 14.5 ton/kW, the single-axis tracker outperformed the fixed system at mitigating CO2 [4]. The paper proposes a as opposed to stationary PV systems, the electrical power used by single- and dual-axis solar tracking systems, when properly controlled, can increase by 22–56%. The most popular and effective control strategy is a combination of sensor- and microprocessor-based control systems. Because of inadequate control systems, electrical drives in active tracking systems that shift the axis can consume a lot of electricity [5]. This study presents a case study, Published In journal of Sustainable Energy Management and Planning. examines the effects of one- and two-axis solar tracking on the technological and economic viability of on grid PV systems. PV stations with single axis and dual axis solar trackers could reduce CO 2 emissions progressively more, according to the finding [6]. This paper focuses on a resource within the energy sector. By conducting a review of existing literature analyzing data and carefully examining key factors that impact investments in PV energy it aims to provide a comprehensive understanding of the field. The research equips decision makers with insights to navigate the landscape of government incentives, ever evolving technology, cost dynamics and environmental considerations. This facilitates informed investment decisions that contribute to a sustainable energy future. The findings of this study serve as a basis for shaping energy policies and promoting adoption of PV technology [7]. The focus of this paper is to optimize an integrated power system situated in Khorfakkan, United Arab Emirates. To generate electricity, combine photovoltaic (PV) tracking technology with a diesel generator. The primary goal of this study is to find the techno optimization, for the hybrid system. By using intermittent PV alongside a reliable but more expensive diesel generator, strike a balance between efficiency and cost effectiveness. When examining configurations researchers consider factors like system capacity tracking technology and operational strategies. Through an analysis of both economic aspects this paper offers valuable insights into designing efficient and affordable hybrid power systems in regions with abundant solar potential, like Khorfakkan [8]. The techno-economic study of stationary, dual-axis (2-axis) and single-axis (1-axis) tracking solar photovoltaic systems is the main topic of this article. In particular, poly-crystalline silicon (poly-c-Si) and cadmium telluride PV modules from the first and second generations are compared, and their performance in various tracking systems is examined. The weather of Mumbai is used to mimic a 76.8 kW grid-connected solar PV installation. According to the research, poly-c-Si modules show a little higher daily production in winter, while CdTe technology panels produced a slightly higher yield in the summer. For the poly-c-Si modules system, the average yearly performance ratio is 0.796, whereas for the CdTe modules system, it is 0.781. The study also accounts for factors like degradation rate, lifetime energy produced, and saved CO2 emissions. The final part presents an economic evaluation providing the lifecycle cost, unit cost of electricity, payback time, and total lifetime earning of these PV systems [9]. This study focuses on the third international conference on energy efficiency The results show that by employing single and dual axis solar trackers, the annual yield of the Quaid e-Azam solar power improves by 16.71 percent and 22.40 percent, respectively. Furthermore, using single and dual axis solar tracking, optimization typically results in additional reductions in GHG emissions of 17.8% and 24.65%, respectively [10]. This study focuses on Efficiency Analysis Relies on Photovoltaic Systems Axis Tracking, International Organ Science Research Journal, Engineering. In this suggested work, prefeasibility analysis of grid-connected PV systems using various modes of solar tracker systems is evaluated, and it is discovered that dual axis tracker mode produces more feasible output outcomes than fixes and single axis tracker mode [11]. This paper discusses that a microcontroller may be used to create a dual-axis tracker based on a close-loop algorithm that accomplishes optical tracking without raising system costs. The microcontroller uses the geographic location, time, and date to calculate the sun position using an algorithm and then sends commands to the motor driver. Since a microcontroller is being used, truly little extra hardware is required to calculate the sun position using the astronomical method [12]. This study explains the fundamental architecture, development, and history of the Solar PV system. Additionally, it introduces solar cell features, the effectiveness of different solar PV cell types, and a list of different solar cells along with their form factors and efficiencies [13]. This paper focuses on designing a universal solar tracker system to optimize the output of solar cells, increasing their efficiency by around 30-40%. This is accomplished by rotating the solar panels to remain perpendicular to the sun throughout the day, thus maximizing their exposure to sunlight. The system uses a microcontroller and a stepper motor to Observe how the sun moves and modify the panel's location as necessary. Unlike traditional systems that rely on light intensity (measured using a light-dependent resistor or LDR), this system is based on the position of the sun, making it effective regardless of the weather or geographic location. This implementation is particularly advantageous because it ensures that the system continues to receive sunlight even in cloudy or rainy weather, when the light intensity might be low, but the sun's position remains unchanged. The paper is part of a college project, and the proposed system is a miniature model of the main system [14]. This paper primarily discusses the concept of solar trackers, which are automated systems that track the sun's position to maximize the power yield from solar panels. The paper provides a critical analysis of various techniques used by researchers to enhance the efficiency of photovoltaic panels, which includes several types of tracking methods. Two specific examples of solar trackers are discussed: a novel passive solar tracker developed by Clifford et al. that is cost-efficient and suitable for equatorial regions, and a single-axis passive solar tracker created by Narendrasinh et al. implementing the Zomework principles with high volatile liquids. These solar trackers have been found to significantly increase the power output of PV modules. The paper also explores Bajpai et al.'s design of an automatic, two-axis solar tracker that uses a microcontroller and light-dependent resistors to sense sunlight, contributing to the efficiency gain of solar power generation [15]. This paper focuses on various maximum power point tracking (MPPT) algorithms used in photovoltaic (PV) arrays. This review aims to analyze and compare different MPPT techniques to enhance the overall performance and efficiency of PV systems. The authors begin by highlighting the importance of MPPT algorithms in PV systems, as they enable the extraction of maximum power from the solar panels under varying environmental conditions. They emphasize that the choice of MPPT algorithm plays a crucial role in optimizing the power output [16]. This paper discusses various methodologies that are used in Maximum Power Point Tracking techniques for solar photovoltaic systems. These techniques are important for maximizing the efficiency of solar panels, especially under various environmental conditions. The paper primarily covers Perturbation and Observation technique, which has several sub-techniques, Incremental Conductance technique, intelligent MPPT techniques including Fuzzy Logic Control, Neural network and ANFIS based MPPT, and some other MPPT techniques which are not specified in the given excerpt. It includes the analysis and discussion of different optimization algorithms like DPSO, Dormant PSO, Su Do Ku puzzle based MPPT, Cuckoo search, flashing firefly's colony, and Artificial Bee Colony, and how they enhance the effectiveness of MPPT systems [17].

III. METHODOLOGY

The two-axis solar panel prototype was built by our team. A tracker will maintain the solar panel in an orthogonal position to the sun regardless of where the sun is in the sky. The model is split into two parts, with the top half moving down a horizontal axis and the bottom half moving along a vertical axis. Each axis has two servo motors since each part functions separately. Four sensors and a microprocessor equipped with the necessary circuits are also part of the design. These components allow the motor's motion and direction, and consequently the panel's tilt toward the sun, to be controlled. Using the differences in voltage that the sensors send back, the microprocessor then tells the servo motor to move in the desired direction.

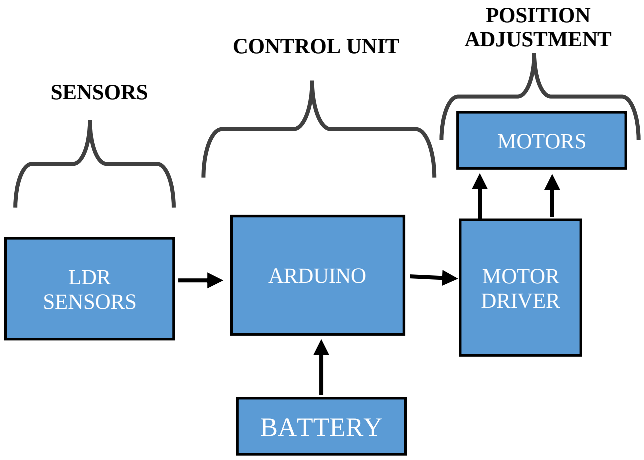

Figure1: Solar tracking system

Figure1 shows the four Light Dependent Resistors (LDRs) placed with a panel, on a single plate. These LDRs are exposed to amounts of light from a source causing their resistance values to vary. This occurs due to photoconductivity, a characteristic of LDRs that leads to a decrease in resistance as the intensity of incident light increases. Each LDR sends a signal to the Microcontroller, which is programmed with the logic representing its resistance value. One specific LDR value serves as a reference point for comparing the values. A mechanical connection has been made between one of the two DC servo motors and the other's driving axle to allow the former to move in tandem with the latter's rotating axle. Solar panel driving is done using the axle of the previous servo motor. The configuration of these two servo motors allows for both X- and Y-axis movement of the solar panel. Using the input signals obtained from the LDRs, the microcontroller directs the servo motors in the proper manner. The x-axis is tracked using one servo motor, while the y-axis is tracked using the other servo motor. The design of the solar tracking system is done in this manner.

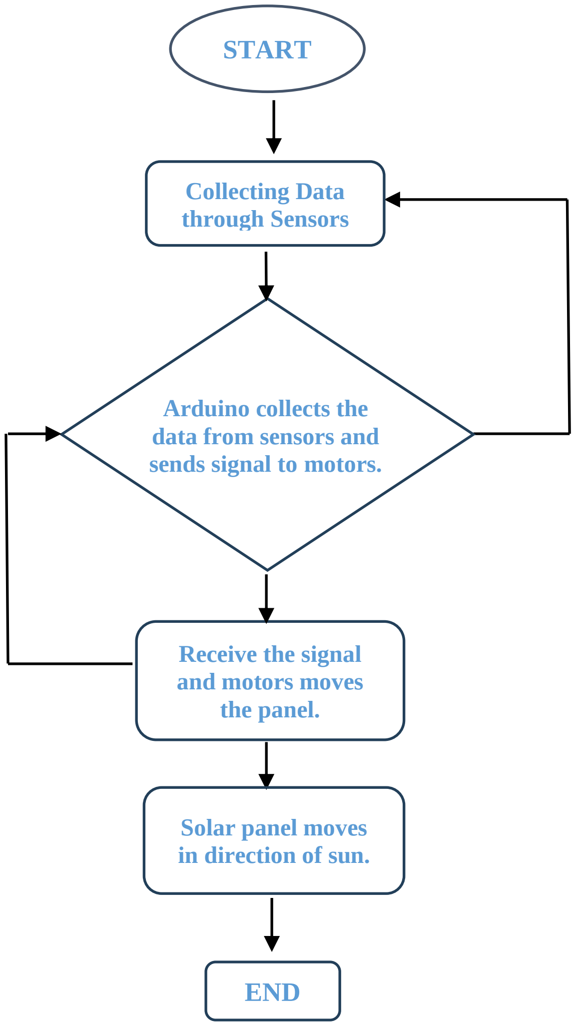

Figure2: Flow chart of Solar Tracking system

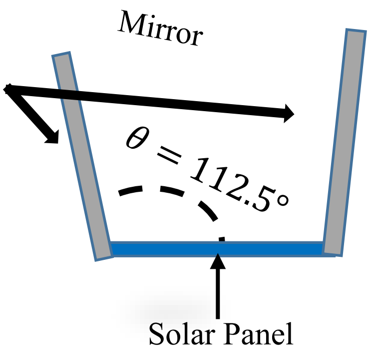

Figure3: Mirror reflection and Angle

Figure3 shows the angle of reflection where at which angle the mirror should be fixed to reflect the rays of sun to solar panel and increase the number of photons to produce more power through panels.

- CALCULATION FOR MIRROR ANGLE θ

$$Angle, \theta = \frac{135° - 90°}{2} + 90°$$

$$Angle, \theta = 22.5° + 90°$$

$$Angle, \theta = 112.5°$$

IV. DISCUSSION AND ANALYSIS

- PROTEUS SIMULATION:

Proteus is a set of exclusive software tools mostly utilized for electrical design automation. The application is used by technicians and professionals in electronic design to produce electronic prints and schematics for printed circuit boards. The microcontroller section of the design is subjected to the microcontroller simulation features of Proteus using a hex file or a debug file. Then it is combined with the corresponding analogue and digital electronics in simulation

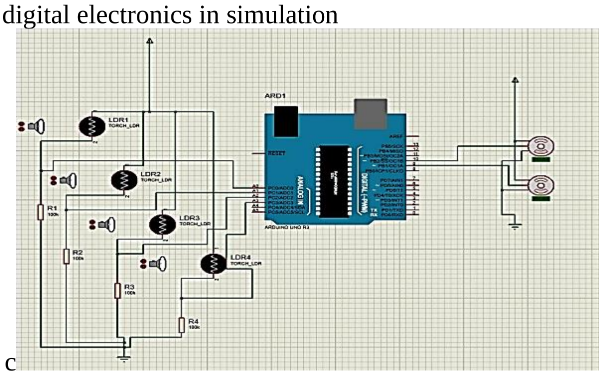

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Figure4: Proteus Simulation

Figure4 shows that the servo motors in the circuit are linked to pins 9 and 10, while the LDR pins are connected to analogue pins A0-A3. The sun's location in an east-west direction is indicated by the first two LDRs, while its location in a north-south direction is shown by the second pair of LDRs. The state of the LDR has also been used to determine which way the servo motors rotate.

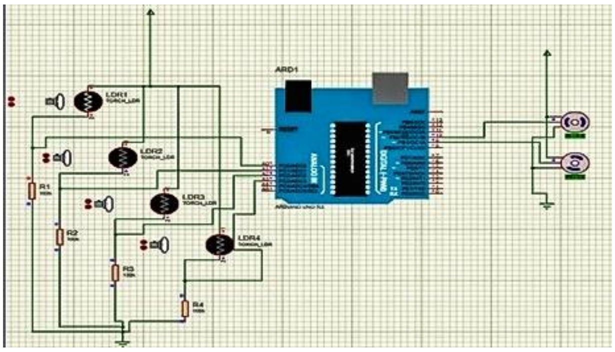

Figure5: Output1 Fisrt LDR value changed

Figure5 shows that The second servo motor, which corresponds to vertical alignment, began rotating in a clockwise way when the value of the first LDR was altered.

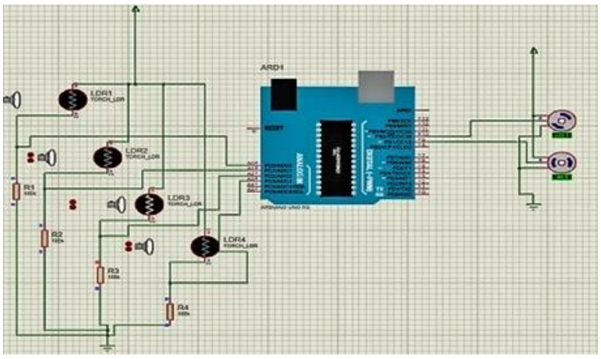

Figure6: Output2: value of First LDR has altered

Figure6 show that the value of the first LDR had altered, the second servo motor in the horizontal alignment position began to spin in a clockwise way. Consequently, the solar tracker has been created.

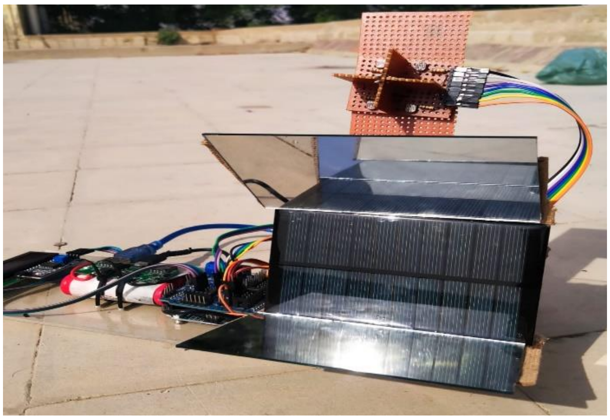

Figure7: Hardare Module

Figure7 shows that the LDR sensor's circuitry is designed to act as a voltage divider. The divider output voltage varies in direct proportion to the fluctuation in light intensity. The output of the voltage divider is linked to an analogue input (such as A0 for the microcontroller) at a voltage of 5 volts above ground and 0 volts below it. The analogue value received by A0 is then converted into a digital number between 0 and 1023 by the microcontroller's Analog to Digital Converter (ADC), which is coded in 10 bits. Using this value, the amount of light may be determined. Resistors used in voltage dividers have a value of 330 ohm. Once the solar tracker is perpendicular to the sun, no further control is applied. For controller stabilization, this range is used. In contrast, if the right LDRs detects light, the solar tracker moves until the difference is contained within the ranges and then travels in that way via the servomotor. Similar design principles apply to how the elevation axis is built. Additionally, measure the average radiation between all LDR sensors. Take further action (a value that has been changed and analyzed and is returned when the irradiation is zero) if this number is below a predetermined threshold. The solar tracker needs to return to the location of the sun's rising. For instance, if the position of the sun may be attained by setting the left-right servomotor 30 degrees, and the up-down servomotor, degrees. The C function "servo" makes this simple to accomplish. Provided by the Arduino IDE is "Write(angle)." Solar Panel and Load Side Circuit: The load relates to buck converter so that the maximum source could take advantage in our case by charging our battery. The buck converter was the solution settled on since our solar panel could hardly generate source full current, necessitating an increase in output power from the buck converter to charge the battery quickly and efficiently.

- RESULTS:

The experiment was performed on the sun radiation throughout the day with different timings to compare stationary panel with Dual axis Tracking system.

For Stationary Panel

1. **Time 10:00 am**

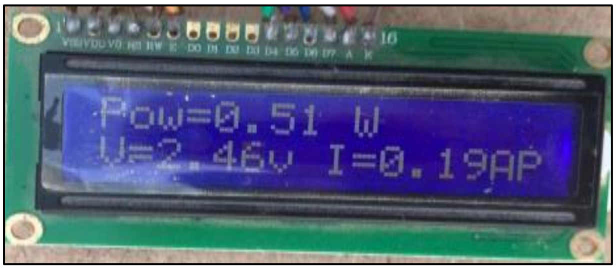

Figure8: LCD displaying of Stationary panel at 10:00am

2. **Time 12:00 pm**

Figure9: LCD displaying of Stationary panel at 12:00pm

For Dual Axis Tracking system with Mirror Reflection

1. **Time 10:00 am**

Figure10: LCD displaying of Dual Axis Tracking at 10:00am

2. **Time 12:00 pm**

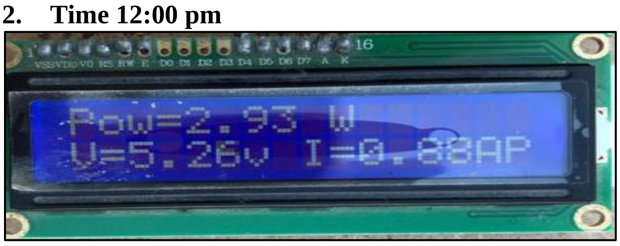

Figure11: LCD displaying of Dual Axis Tracking at 12:00pm

Results:

The stationary panel compared with Dual-axis tracking system with mirror reflection, so in results Dual-axis tracking System using mirror reflection improves the Efficiency.

Calculation Tables:

Table1 for Stationary Solar Panel

Time	Voltage(v)	Current(I)	Power(w)
8:00 am	0.97	0.02	0.0197
10:00 am	2.46	0.04	0.08
12:00 pm	2.79	0.12	1.50
2:00 pm	5.26	0.49	4.074
4:00 pm	4.41	0.30	3.44
5:00 pm	4.20	0.26	3.02
6:00 pm	3.46	0.21	2.14

Table2 for Dual-axis tracking system with mirror reflection

Time	Voltage(v)	Current(I)	Power(w)
8:00 am	2.21	0.06	0.1912
10:00 am	3.09	0.15	0.230
12:00 pm	3.89	0.21	2.43
2:00 pm	6.76	2.48	4.799
4:00 pm	5.27	0.38	3.979
5:00 pm	4.89	0.31	3.67
6:00 pm	4.41	0.26	2.897

Table 1 shows the results of a stationary panel, whereas Table 2 shows the results of a dual-axis solar tracking system with mirror reflection. From sunrise at 8:00 am until sunset at 6:00 pm, all power metrics are recorded. The testing findings show that the dual axis solar tracking system produces a lot of energy than a fixed solar panel. It demonstrates that solar panels can produce more electricity when they face the sun directly and when there is light shining on them. The effectiveness of solar panels is increased by this technique.

CONCLUSION

The planning and installation of a dual axis solar tracking system are briefly summarized. In comparison to stationary panels, it is more efficient and sustainable, which results in higher output. To capture solar energy in every direction, a simple, functional dual axis solar tracker has been built. This means that throughout the day and year, the sun's energy can be captured to the greatest extent feasible and turned into electrical power. The performance of a dual axis tracker has significantly improved as it precisely aligns with the direction of the sun, records its movement better, and does both. Comparing the power efficiency of single axis solar tracking system and Dual axis solar tracking system with mirror reflection it is improved by 36% during the mid-day time.

The novel integration of mirror reflection and dual axis tracking for solar panel optimization sets this research apart from other investigations. The innovation is in how these two technologies work together to produce a notable increase in solar panel efficiency. To emphasize the originality and improvements achieved by the proposed method, a comparison with the works of other researchers.

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