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Performance Analysis of Designed and Implementation Dual-Axis Solar Tracker with Monitoring System

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***Abstract:** Renewable energy has been the prime focus in recent times for mitigating the ever-rising energy demand. Because renewable energy doesn't emit carbon into the environment, it is considered the cleanest form of energy source. Solar energy has always been the most popular renewable energy source in our country for its geological advantages. Solar cells need to use sunshine as effectively as possible. The continuous change in the relative angle of the sun concerning the earth reduces the watts delivered by the solar panel. At present, fixed arrangement of solar panels is used to harvest solar energy from the sun, which only receives few amount of its effectiveness from the sun because it encounters the sun for a limited period of time per day. In this context, the solar tracking system is the best alternative to increase the efficiency of the photovoltaic (PV) panel. Solar trackers move the payload toward the sun throughout the day. In this paper, we suggested a Light Dependent Resistor (LDR) based dual-axis solar tracking system to increase tracking movements as well as PV energy production by leveraging the benefits of sun radiation.*

***Keywords:** Renewable Energy, PV Panel, LDR, Dual-Axis Solar Tracker.*

1. INTRODUCTION

The energy problem that has been caused by the depletion of fossil fuel supplies may be remedied by harnessing the sun's kinetic energy as an alternative source of power. Solar energy is completely unlimited and available everywhere. Since the price of solar photovoltaic energy continues to fall, it has become the most competitive option among the renewable energy sources and is being employed in a variety of country [1]. Solar power is one of the renewable energy domains or sources that sees the most widespread use of the several alternative pathways. From the beginning of this decade, both the worldwide demand for photovoltaic modules and their production have been growing at an exponential rate, with Europe accounting for the highest proportion of new installations and developments, followed by the Asia-Pacific area [2]. The large-scale PV installations, which draw many study interests and financiers, also impose challenges and risks on the system even though PV technology provides a number of ancillary enhancements in conventional power systems [3]. The supply of solar energy is very unpredictable, which presents a challenge for those who want to make use of it. The day-night cycle causes daily fluctuations in availability, while the earth's orbit around the sun causes seasonal shifts in availability. Both of these factors contribute to the varying degrees of availability. In order to solve the issues, the solar panel should be designed in such a manner that it consistently gets the highest possible light intensity. From the beginning, it has been seen that the efficiency of the solar panel is somewhere between 10 and 15 percent, which does not match the load requirements that are intended. So, there is a need for increasing the panel's efficiency in a manner that is cost-effective [4].

Many studies are being conducted with the goal of creating and improving solar power systems that are both efficient and dependable. A solar tracking system and control have emerged as one of the most essential components of a solar power sys-tem [5], with the goal of maximizing the efficiency with which solar energy is absorbed and enhancing its overall effectiveness. Many different types of study have introduced open-loop and closed-loop based tools to regulate the axis of movement for a monitoring device [6]. Solar tracking systems may be divided into two primary categories, single axis systems and dual axis systems, according to the way in which they are built. As compared to a system that uses stationary solar panels, a solar tracking mechanism with a single axis may increase the efficiency of solar energy absorption by as much as 32% [7]. It also gives a structure that is less difficult and less costly, making it possible for it to be utilized in a broad variety of applications. Recent research has centred on perfecting open-loop, sensor-free sun monitoring devices. For their presentation of a single-axis solar tracking structure, Zhu et al. [8] used a tracking method based on the sun-earth geometry connections and the fore-cast of solar energy to carry out a numerical construction. A similar open-loop control tracking schedule-based single-axis sun tracking device was suggested by Kuttybay et al. [9].

It is necessary to have a technique that is able to estimate and localize the location of the sun in relation to the solar panel system in order to be able to monitor the position of the sun. There are generally two primary kinds of solar tracking methods that are used to estimate the location of the sun [10]. The first technique is a sun tracking system that is based on astronomical calculations. This system performs an astronomical calculation with the input of the precise location of the plant on the earth, and then calculates the periodical solar position with respect to the time [11]. The result of this calculation is an approximation of the movement of the sun with regard to the earth. The fact that this system is resistant to perturbations from the outside, such as variations in the weather, is the primary benefit of using this method. One other possibility is a solar tracking system that is based on sensors [12]. This method makes advantage of sensor perception to immediately estimate and localize the location of the sun based on the information received in real time. This technology is able to make accurate estimates of the sun's location when the sensor can detect the sun with complete accuracy. Nonetheless, the quality of perception is of critical importance to the

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operation of this system. On the other hand, the majority of tracking systems that are based on these sensors do not have the capacity to differentiate between the absence and presence of the sun. Because of this, the technique often results in false detection and an erroneous calculation of the location of the sun, particularly in conditions when the weather is poor. Several researchers have been working on a study and inquiry on the usage of camera for detecting and localizing sun position, using image processing technique [13]. This is being done in order to address the problem that has been identified. Minor et al. [14] described the construction of a high-precision sun-tracking system that utilized a digital camera. The system had an accuracy of up to 0.1 degrees and was not affected by the weather in any way.
Based on a review of the latest research, we found it hard to make a low-cost solar tracking system with a clearly accurate tracking approach. The main contribution of this paper is the design, and development of a dual-axis solar tracking system. In this work, the tracking strategy employs the simplicity of LDRs participation for tracking the sun's trajectory. The proposed tracking system would simply rotate in a daily rotation around the north-south and east-west axes, with a simple mounting system but good stability. In this work, different types of sensor data are studied.

The remainder of the project is structured as follows: Section II explains the system model of the project, Section III demonstrates the methods, Section IV presents the circuit diagram, Section V provides results and discussion, and Section VI wraps up the work.

System Design

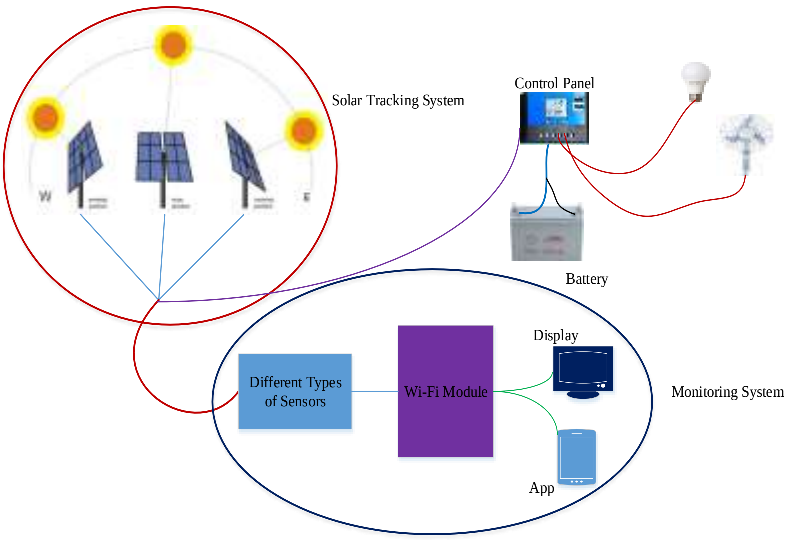

Fig.1 System Model of Dual-Axis Solar Tracker with Monitoring System

The system model shown in Fig. 1 will serve as the foundation for this chapter's discussion, and it is essential that we have a solid understanding of the concept that underpins it. When we take a look at the diagram, we can see that there are two significant factors: the first of which is the monitoring system, and the second of which is solar tracking of the sun. Solar panels having two axes of rotation are utilized here so that they may follow the sun. The movement of the solar panels is essentially determined by the amount of sunlight that is hitting them. In the morning, solar panels are typically angled toward the east; around noon,

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they are at their most acute angle, and in the afternoon, they pivot to face the west. There are different types of sensors attached to the solar tracker, such as a temperature sensor, a current sensor, and a voltage divider, which collect data from the solar cell and send it to the Wi-Fi module, which then sends it to the display and app. When looking at Fig. 1, it is clear that the monitoring system includes a control panel that, in the most basic sense, manages the battery as well as the load.

2. METHODOGY

Dual Axis Solar Tracker

All Fig. 2 shows the block diagram of the solar tracking system of the project. It is clear from looking at Fig. 2 that there are four LDRs being utilized in this scenario. In this case, LDR are utilized to essentially revolve the solar cell along the X and Y axes. If we take a look at Fig. 2, we will notice that there is also an LM358 IC and an L293D. In this case, the LM358 is utilized for receiving the negative voltage, and the L293D is utilized for assisting the gear drive in rotating the solar cell. In this case, a buck converter is used to provide DC 5 volts from the solar panel. When sun-light hits LDR-1, a negative voltage will flow through LDR-2 and into the LM358 integrated circuit. A trigger is input into the L293D integrated circuit, which causes the gear motor that is used in the X-axis to revolve to the left. When LDR-2 is exposed to light, a negative voltage will enter LM358 IC because this voltage path goes through LDR-2. In this manner, a trigger will be entered into the LM358 IC, and this will cause the gear motor that is used in the X-Axis to revolve to the right. If LDR-1 and LDR-2 are both activated by the L293D IC at the same time, or even if they are not, the motor that is used in the X-Axis will be in halt mode. In the event that LDR-3 is exposed to light, a negative voltage will travel through it and into the LM358 IC. The L293D integrated circuit will be triggered, which will cause the gear motor that is used in the Y-Axis Upward to revolve. When LDR-2 detects the presence of light, a negative voltage will be introduced into the LM358 Circuit via LDR-4. Through this method, a trigger will be supplied to L293D IC through LM358 IC. This will cause the gear motor that is used in the Y-Axis to revolve downward. If LDR-3 and LDR-4 are both initiated by the L293D IC at the same time, or if neither of them are, then the halt mode will be activated for the motor that is used in the Y-axis.

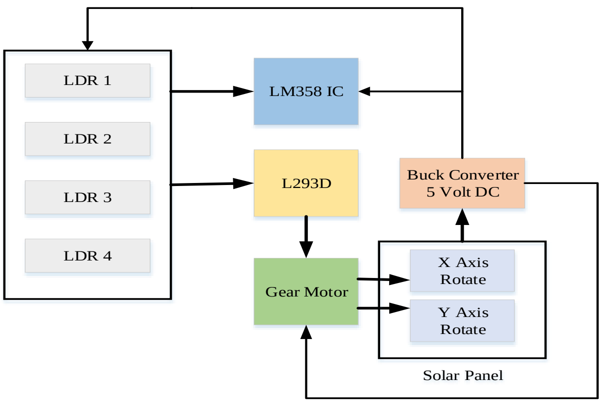

Fig.2 Block Diagram Dual Axis Solar Tracking System

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Monitoring System

All functions of this system are managed by the Wi-Fi Module, which is shown in Fig. 3. The Wi-Fi module turns on when it receives 5 volts from the buck converter. There are three sensors used in the monitoring system, such as the current sensor, voltage divider, and temperature sensor, which are shown in Fig. 3. Here, a voltage divider sensor is attached to the solar panel, which is used to measure the output voltage of the solar panel. The Wi-Fi module collects data from the sensor after measuring the voltage and sends it to the display and SD card. For measuring the total current of the system, we used a current sensor, which is attached to the charge controller. After getting current from the system, the Wi-Fi module collects it and sends it to the display and SD card. Here, a temperature sensor is used to measure the temperature of the solar panel. It's attached to the solar panel, which is shown in Fig. 3. Basically, the Wi-Fi module collects data from the sensor and sends it to the display and SD card. The temperature sensor turns on after receiving 5 volts. If we look at Fig. 3, it can be seen that the display and SD card need 5 volts to turn on. With the help of the display, anyone can see the voltage, current, and temperature easily. SD cards are used to store all of the data collected from the sensors in this case.

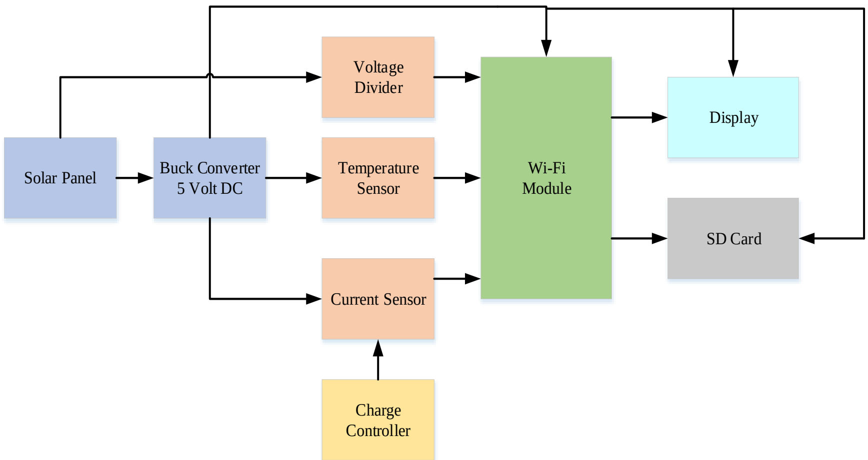

Fig.3 Block Diagram Monitoring System

Circuit Diagram

Dual Axis Solar Tracker

The full circuit schematic of the tracking system can be seen in Fig. 4, which was created with the help of the software program AutoCAD. If we take a look at the circuit diagram, we can see that the buck converter, LDR, L293D IC, LM358 IC, and timer IC are all components that are utilized here. Here, a buck converter is used to step down the voltage, and that is connected with all the circuit components. In this case, the LDR-1, LDR-2, LDR-3, and LDR-4 both are connected with the LM358 IC and the L293D IC correspondingly for the purpose of moving the solar panel from left to right and from down to up. In this device, 4Nos NC-type limit switches are used. The first two switches are used along the X-Axis and the next two switches along the Y-Axis will move the panel to a limit during dual-axis movement and stop its operation there. The NC contact will change to NO contact after the solar panel moves up to a certain limit in either direction. After the contact of one switch changes from NC to NO contact, the next switch automatically waits for the instruction of the

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LDR to move the solar panel in the opposite direction through the motor. Thus the motor will move the solar panel Left-Right along the X-Axis. Similarly, another motor along the Y-Axis will move the solar panel Up-Down and control it through two NC contact switches.
After the contact of one switch changes from NC to NO contact, the next switch automatically waits for the instruction of the LDR to move the solar panel in the opposite direction through the motor.

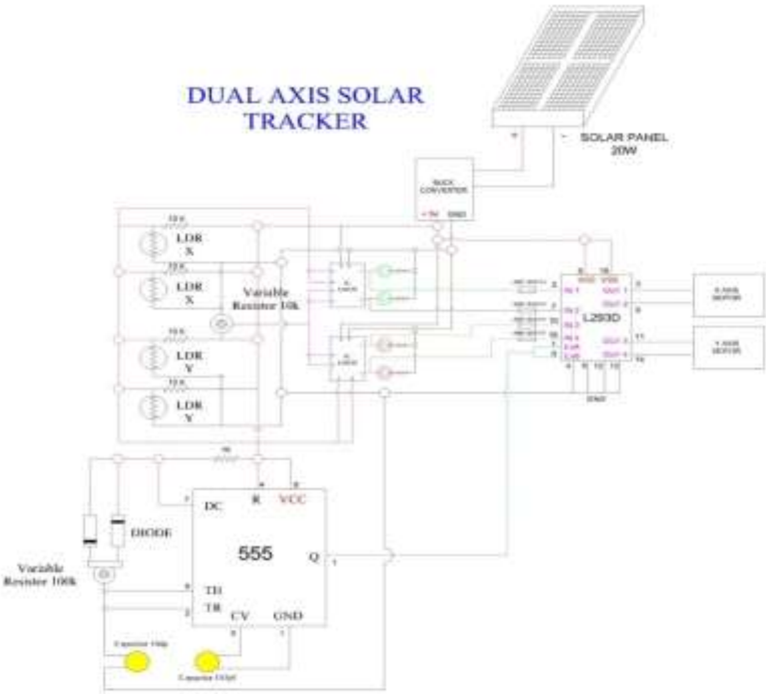

Fig.4 Circuit Diagram of Dual Axis Solar Tracking System

Monitoring System
Different types of sensors are used at the input of the device, which respectively will help the device efficiently provide different data. A current sensor data input is provided at input pin D-32 of the device, which will help to get the value of the current used by the solar panel. A 40kΩ and a 06kΩ resistor are input across pin D-34 for voltage measurement, which will give the value of the voltage obtained from the solar panel. A thermal sensor is used here for temperature measurement which will provide the output data on the D-26 pin of ESP-32. Through the data obtained from this sensor, the surrounding temperature and humidity of the solar panel can be known. A dis-play is used for human and machine interface which is connected to the D-21 and D-22 pins of ESP-32. Voltage, current, temperature, and humidity can be monitored through this display. Finally, a micro SD card adapter is connected to pins D-5, D-18, D-19, and D-23 of the ESP-32. This will store the entire system data in a memory card.

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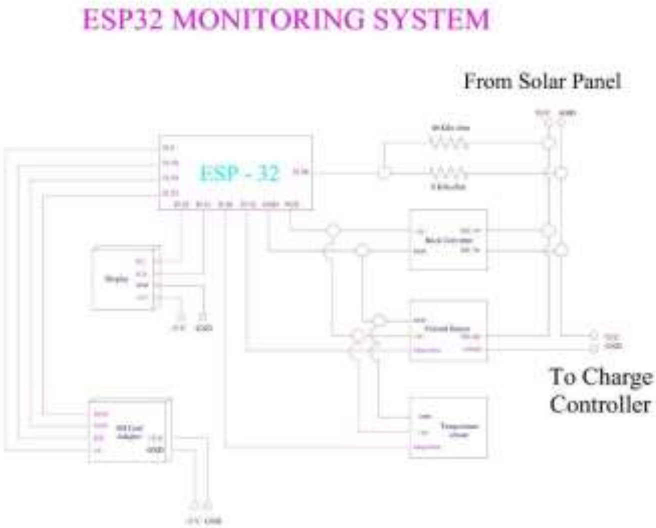

Fig.5 Circuit Diagram of Monitoring System

3. RESULTS AND DISCUSSION

Measurements of energy, current, voltage, temperature, and humidity were obtained from the solar tracking panels at various points throughout the day, starting at 1:05 p.m. and ending at 1:24 p.m., respectively, and are presented in Table 1. From the table, it is seen that at 1:05 p.m., the current, voltage, temperature, humidity, and energy are respectively 22.18 V, 13.06 mA, 25 0C, 75%, and 0.05 W. The solar panel will begin to accumulate more current and energy as time passes once it has begun to track the sun. In contrast, the fluctuation in voltage is not as great as the variation in current because voltage does not have a direct correlation with the amount of light coming from the sun, which is shown in below table. According to Table 1, the energy at 1: 18 p.m. is 228 W, which is the highest because the sun is very well set on the solar panel at this time. If we look at the table, it can be seen that the temperature and humidity is always constant.

Table 1. Different Types of Data from Wi-Fi Module

Time & Date	**Voltage (V)**	**Current (mA)**	**Temperature (Â°C)**	**Humidity (%)**	**Energy (Ws)**
Thursday, January 05 2023 01:05:49 PM	22.18	13.06	25	75	0.05
Thursday, January 05 2023 01:06:49 PM	22.52	13.56	25	75	18.54
Thursday, January 05 2023 01:07:49 PM	22.51	12.98	25	75	36.21
Thursday, January 05 2023 01:08:50	22.44	12.98	25	75	53.77

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PM					
Thursday, January 05 2023 01:09:50 PM	22.49	12.99	25	75	71.44
Thursday, January 05 2023 01:10:50 PM	22.34	13.2	25	75	89.2
Thursday, January 05 2023 01:11:52 PM	22.24	12.99	25	75	107.06
Thursday, January 05 2023 01:12:53 PM	21.17	12.83	25	75	123.43
Thursday, January 05 2023 01:13:53 PM	22.11	13.07	25	75	140.98
Thursday, January 05 2023 01:14:54 PM	22.17	13.02	25	75	158.38
Thursday, January 05 2023 01:15:54 PM	22.32	13.15	25	75	176.14
Thursday, January 05 2023 01:16:54 PM	20.69	13.08	25	75	192.45
Thursday, January 05 2023 01:17:55 PM	22.33	13.19	25	75	210.28
Thursday, January 05 2023 01:18:55 PM	22.39	13.23	25	75	228.13

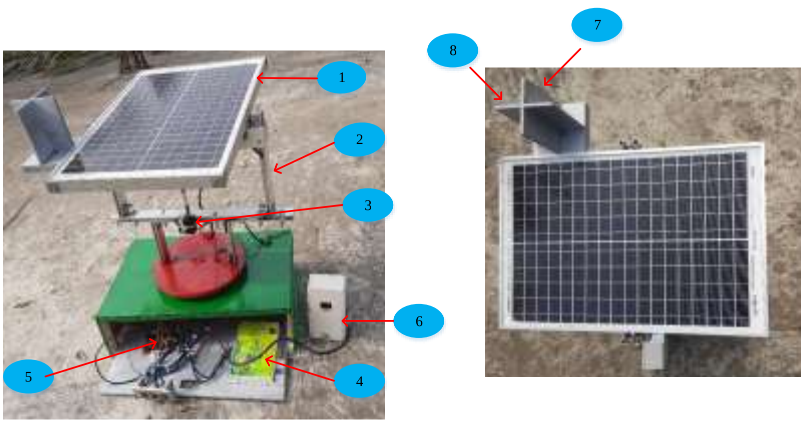

Fig.6 Final Prototype of the Project

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The completed version of the prototype is depicted in Fig. 6. As shown by the number 1 in Fig. 6, the Solar cell is attached to the structure in the appropriate position. The revolving platform, identified here as number 2, is primarily employed for the purpose of rotating the solar panels, and it is used to hold the solar panel. The motor controller is located at the revolving stand, as indicated by the number 3 in Fig. 6. This stand is also used to revolve the rotating stand. Number 4 shows the charge controller which is attached with the base of the solar panel. The ESP8266 NodeMCU board and all the sensors are placed at number 5 in Fig. 6. The display is represented by the number 6 in Fig. 6. In essence, numbers 7 and 8 relate to 4 LDR. In essence, they are mounted on the solar panel's top, two on each side.

4. CONCLUSIONS

In this paper, the use of a dual-axis solar tracker system in the deployment of photovoltaic technology results in significant increases in energy efficiency and overall power output, as compared to fixed systems. The ability to continuously adjust the position of the solar panels to align with the sun's trajectory enables the capturing of more sunlight, and thus greater energy production. The purpose of this technique is to optimize the effectiveness of the dual axis solar power plant system in collecting solar energy. Furthermore, this technology has shown to be cost-effective in the long-run, and as such, its implementation should be seriously considered as a viable option in the development of renewable energy systems. It is possible to bring about a drastic change in the energy sector by generating additional solar energy using dual-axis solar tracker. Bangladesh still has many remote settlements where electricity has not yet reached. In Riverine and island areas, where electricity is impossible to reach, by using this technology it is possible to deliver electricity to every house by producing more energy. Even in the case of rural electrification, it is possible to deliver electricity to the doorsteps of multiple consumers by using this technology to produce more energy. By making this technology available, it is possible to encourage people to use "Green Energy".

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