Comparison of Dual-Axis Solar Tracker with Static Solar Plate

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Abstract

Solar power is an important component of renewable energy for a long time. Solar power provides various benefits to residential consumers. This paper presents an automatic solar tracking system which aligns solar panels in the direction of solar rays in order to obtain maximum solar power. The tracking system automatically changes the direction depending on the light intensity. A comparison of the automatic solar tracking system has been made with the static solar plate and it is found that dual-axis solar tracker is more efficient as compared to the static solar plate system. The automatic solar tracking system reduces the number of solar panel arrays in comparison with the conventional system. The automatic solar tracking system is tested in a simulation environment and electrical parameters like voltage, current and power have been observed at different times during the day. An IoT monitoring system is also used to monitor the parameters from the static solar plate and dual-axis solar tracker systems. With the help of an automatic tracking system, the annual output has increased approximately by 38%.

Keywords: *photo module, solar energy, microcontroller, tracking system*

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I. Introduction

Solar energy from the sun is an important part of renewable energy. Solar energy has been obtained with the help of solar panels and these solar panels convert solar radiation into electrical energy. The conversion of solar energy into electrical energy is known as the photoelectric effect. The solar panels are made up of silicon and once solar radiation falls on solar panels, electrical energy is obtained with the help of photoemission. The maximum solar radiation falls on the surface when solar panels are aligned in the direction of solar radiation [1]. The solar radiation should fall in the perpendicular direction on the surface of solar panels. The conversion of solar energy into electrical energy is not maximum when solar panels are fixed. Normally, solar panels are mounted in a slanted position on rooftops. In order to obtain the maximum amount of solar energy, various tracking methods have been employed.

The single-axis trackers are normally used in solar power generation where the main objective is to track the direction of the sun by tracking the tilt angle along a single axis. The altitude angle is continuously tracked for optimal solar power. A single motor is used for the movement of the system in the direction of the sun. The motor operates depending on the voltage drop measured by two LDRs which are situated on opposite sides of the panel [2, 3].

The azimuth angle and tilt angle are continuously monitored for tracking the movements of the sun during the daytime in a dual-axis tracking system. In this automatic system, two motors are employed which operate on the commands given by four LDRs which are located on the four sides of the solar panel

[4-7]. This tracking ensures the alignment of solar panels at right angles with solar radiation [8].

Active and passive solar tracking is also employed in solar power generation. The light-dependent resistors are used in active solar tracking and these LDRs continuously monitor the movement of the position of the sun. The solar panels are adjusted with the help of drive actuators and motors. Passive solar tracking uses an imbalance in gas pressure which gets created by solar heat.

In order to cater to increasing power demand, a need for better tracking systems arises. The rotation of the earth needs to be properly studied for constructing an efficient and effective tracking system. As an automatic tracker follows the movement of solar radiations, therefore there is a great necessity to understand the revolutions of Earth.

Solar energy is considered an unlimited source of energy and it is vital in providing electrical energy to end-users. The position of the sun is not constant and it is continuously varying with respect to any fixed equipment [9,10]. The heliostat is a movable mirror which reflects the solar radiation onto a fixed location. The mirrors are used nowadays in order to increase the amount of radiation falling on the solar panels. The efficiency of solar panels increased due to the introduction of movable mirrors [11]. The objective is to obtain the maximum efficiency from a solar array and therefore latest technologies need to be introduced in solar power generation. This paper presents the conversion of solar energy into electrical energy with the help of an automatic solar power tracking system. An automatic solar tracking system is designed and linear actuators or motors are incorporated to align solar panels in the direction of direct solar radiation. A comparison is also made with a fixed tracking system in order to justify the effectiveness of an automatic tracking system. The proposed system also provides an uninterrupted power supply in case of any power failure incident.

II. Proposed Methodology of Dual Axis Solar Tracker

The proposed methodology incorporates a dual-axis solar tracker which is used to track the movement of solar energy for transmission of maximum solar energy into the solar system. An automatic tracking system is embedded into the solar panels for the purpose of tracking.

A. *Block Diagram of Proposed system*

The block diagram of the proposed system is shown in Fig.1. In this block diagram, the dual-axis solar tracker is incorporated into the solar system.

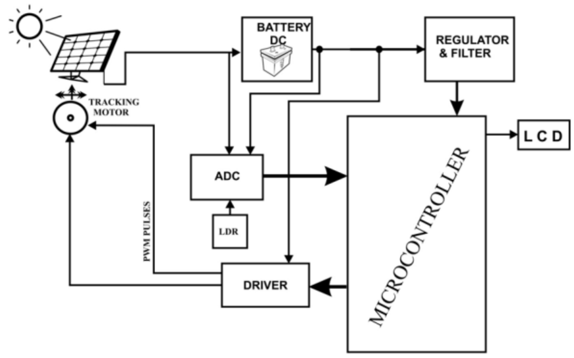

Fig. 1. Block diagram of the proposed solar system

It comprises solar panels, a tracking system, a controller, and a voltage regulation system. The tracking system is included to maximize the solar radiation falling onto the solar panel. The tracking system rotates the tracking motor depending on the intensity of radiation measured by four different LDRs. Two LDRs are used for single-axis trackers whereas four LDRs are used for dual-axis solar trackers. The solar intensity measured by LDRs is given to ADC which converts solar radiation into corresponding digital signals and then they are fed to the microcontroller. The microcontroller is used for controlling purposes and signals are generated to rotate the tracking motor. The status of the controller can also be seen using LCD. For constant supply to a load, a battery is used along with a regulator.

The microcontroller produces pulses that are given to the driver which in turn increases the strength of pulses. The strength of PWM pulses is enhanced to rotate the motor in the direction of solar radiation. LDRs are embedded according to the direction. They are placed in the direction of north, south, east, and west. Depending upon the intensity of solar radiation, a dual-axis motor rotates the solar panel in the direction of maximum solar radiation.

B. *Flowchart of dual-axis solar tracker*

The flowchart of the dual-axis solar tracker is shown in Fig. 2. The operation of the tracking system started with a change in the intensity of solar radiation detected by LDRs. The voltage difference between east side LDR and west side LDR is measured and similarly, a voltage difference is calculated between north side LDR and south side LDR. The difference in voltages is compared with threshold values. If the difference, V_E-V_W is higher than the threshold value, then the motor is rotated in the east direction, otherwise, it is rotated in the west direction. After rotating the motor on one axis, the difference in intensity of solar radiation is also calculated.

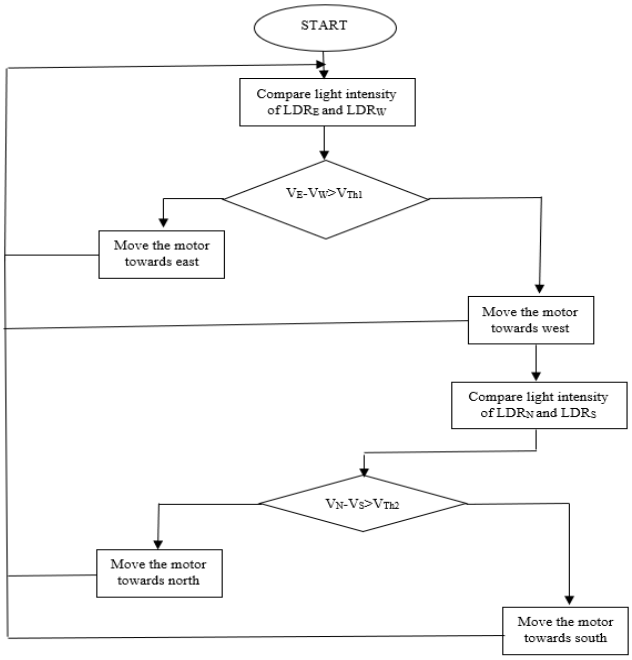

Fig. 2. Flowchart of dual-axis solar tracker

Again, the difference, V_N-V_S is compared with a threshold value. If it is higher than a threshold value, then the motor is rotated in the north direction and if not, then it is rotated in the south direction. In this way, the motor is rotated in two axes and the maximum intensity of solar radiation is extracted by using a dual-axis solar tracker. This process continues throughout the day. If the intensity of solar radiation is equal on the east side and on the west side, then there is no voltage difference between the two LDRs and due to that, the solar panel don't rotate in any direction. The solar panel don't rotate at night as there is no intensity of light for creating any voltage difference. The solar panel becomes stable when the light intensity sensed by LDR is equal. When there is a voltage difference, the solar panel starts its rotation and it continues to rotate till the intensity of solar radiation on two LDRs becomes equal.

III. Simulation In Proteus Environment

The simulation of the single-axis and dual-axis solar tracker is shown in Fig. 3. The single-axis and dual-axis solar tracker is tested in a proteus environment. Two LDRs are used for a single-axis tracking system and four LDRs are employed in dual axis tracking system. For simplicity, two LDRs are used which demonstrate the rotation of the motor from the left side to the right side. The microcontroller is used in a simulation environment for reading the intensity of light and the microcontroller reads the intensity of solar radiation with the help of left-side LDR and right-side LDR. The stepper motor is used in the proteus environment for the rotation of solar panels. If the intensity of solar radiation is equal for both the LDRs, then solar panels remain stable and the stepper motor doesn't start.

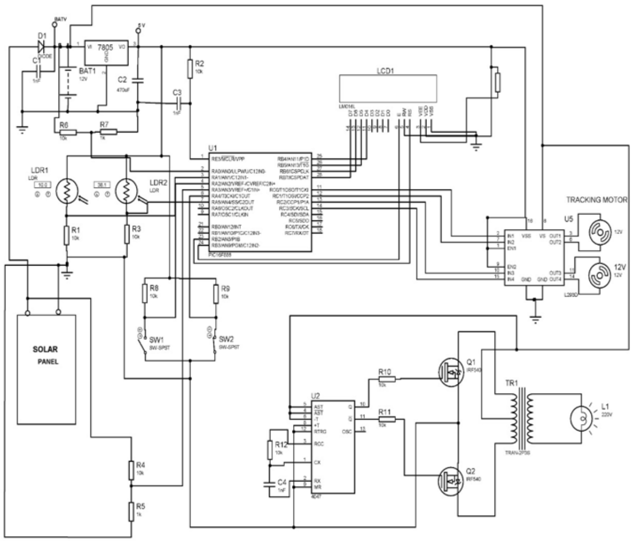

Fig. 3. Flowchart of dual-axis solar tracker

The same stability of solar panels is observed during night-time as there is no light at night. In the morning time, the stepper motor starts rotation of the solar panel when the left light sensor is turned on. The rotation of solar panels depends upon the difference in the intensity of solar radiation between two LDRs. The solar panel continues to rotate till the difference in the intensity of solar radiation becomes zero. This process of rotation continues in opposite direction after 12 noon and in the evening, the solar panel becomes stable when the light radiation measured by two LDRs is equal.

The inverter circuit is also used in the simulation in order to supply the power to load. The dc fed to the inverter is obtained from the solar panels after tracking the intensity of solar radiation using a dual-axis solar tracker. Due to solar radiation tracking, the maximum voltage is obtained from solar panels and this maximum voltage is fed to an inverter which provides power to the load. The 12V AC can be stepped up to 230V AC with the help of a step-up transformer.

IV. Experimental Results From Ubidot Dashboard

A. *Results from Ubidot Dashboard*

Fig.4 shows the Ubidot dashboard and the shown dashboard has an assigned gauge for each output parameter. These parameters are important for the proper monitoring of solar panels. The display of temperature and humidity is also shown in Ubidot dashboard.

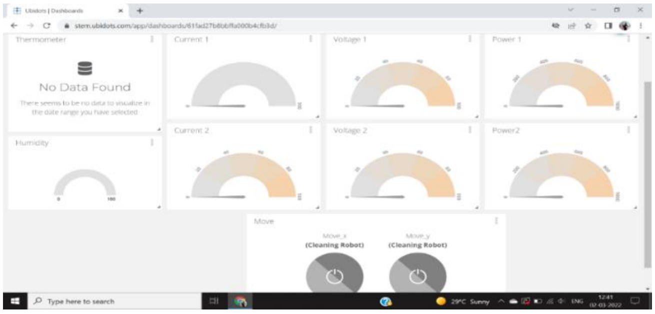

Fig. 4. Ubidot Dashboard

The outdoor experiment has been conducted on 25th May 2022 and this experiment started at 8:00 am and continued till 6:00 pm. The voltage, current and power have been obtained after performing an experiment on a solar panel. These parameters can be monitored with the help of a serial monitor of Arduino UNO IDE. The data stream is created after some seconds and it has been saved in Ubidot platform. Fig. 5 shows the sample of the data streams in Ubidot platform. The data has been collected and it is shown with the help of pointers in Ubidot platform.

Fig. 5. Dashboard with data from solar panels

B. *Results from experiments performed at an outdoor application*

An IoT monitoring system has been used to record the results of static solar plates and dual-axis solar tracker systems. The parameters of the dual-axis solar tracker are recorded from 8:00 am to 6:00 pm. The graph of voltage vs time is plotted and it is shown in Fig. 6. It is found that voltage increases to 20.1 V at 2 PM which indicates maximum voltage output from a solar panel. The graphs of current vs time and power vs time are also shown in Fig.7 and Fig.8 respectively.

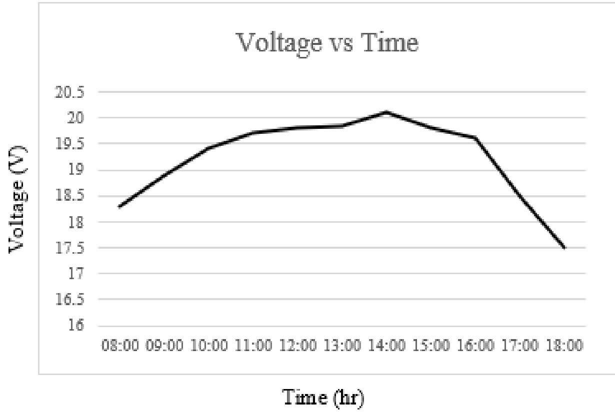

Fig. 6. Results of Voltage vs time

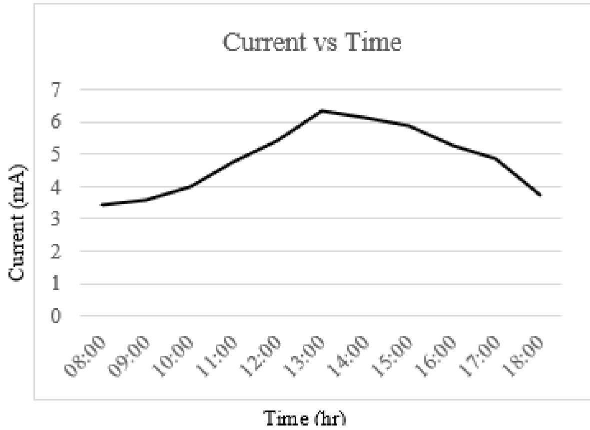

Fig. 7. Results of Current vs time

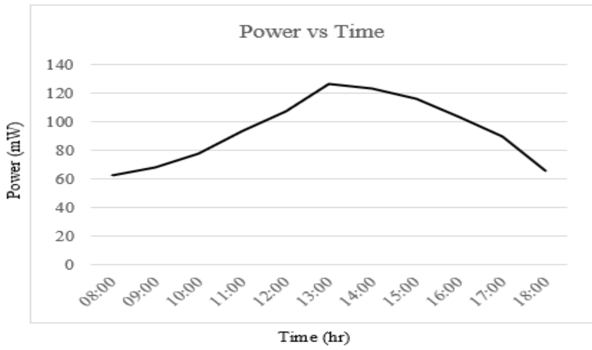

Fig. 8. Results of Power vs time

The maximum value of current and power recorded by the IoT monitoring system are recorded at 2 PM. At this time, the solar panel receives maximum sunlight from sunray. From Fig. 7 and Fig.8, it is concluded that solar panel extracts maximum solar radiation with the help of dual sensors attached to them.

C. *Comparison of dual-axis solar tracker with a static solar plate*

TABLE I. COMPARISON BETWEEN STATIC SOLAR PLATE AND DUAL AXIS SOLAR TRACKER

	Static Solar Plate			Dual-axis solar tracker				
Hour (24hr clock)	Voltage (V)	Current (mA)	Power (mW)	Voltage (V)	Current (mA)	Power (mW)	Gain (%)	% Gain is more in dual-axis solar tracker as compared to static solar plate
08:00	16.8	1.23	33.6	18.3	3.41	62.4	85.71	
09:00	17.0	2.34	39.8	18.9	3.57	67.6	69.85	
10:00	17.6	2.51	44.2	19.4	3.98	77.2	74.67	
11:00	19.4	3.64	70.6	19.7	4.76	93.8	32.86	
12:00	19.6	4.45	87.2	19.8	5.40	106.92	22.61	
13:00	19.7	5.12	100.9	19.85	6.35	126.04	24.92	
14:00	19.8	5.94	117.6	20.1	6.11	122.81	4.43	
15:00	19.4	5.43	105.3	19.8	5.87	116.23	10.38	
16:00	17.2	5.01	86.2	19.6	5.26	103.1	19.60	
17:00	16.5	4.28	70.6	18.5	4.86	89.9	27.34	
18:00	16.2	2.87	46.5	17.5	3.75	65.7	41.29	

A comparison has been made between static solar plates and dual-axis solar trackers. Table I lists the various power obtained at various hours by static solar plate and dual axis tracker. The experimental verification has been completed successfully and it is found that the dual-axis solar tracker is more efficient as compared to the static solar plate. The output power obtained from solar panels is on the higher side in comparison with single-axis solar tracker ad static solar plates. There is a significant rise in output power after employing a dual-axis tracking system. After experimental verification, it is found that a single-axis solar tracker increases annual output by approximately 30% whereas a dual-axis solar tracker increases output further by 8%. Therefore, there is a total 38% hike in solar panel output which is appreciable.

The comparison is also shown with the data recorded by the IoT monitoring system. The power values at different instants are recorded for static solar plate and dual-axis solar tracker systems. The graphs are plotted for power values of static solar plate and dual-axis solar tracker system. From Fig.9, it is clearly visible that the dual-axis solar tracker system produces more output as compared to the static solar plate. From Table 1, it is found that there is a 38% rise in the power level of solar panels when dual-axis solar tracker system is employed with solar panels.

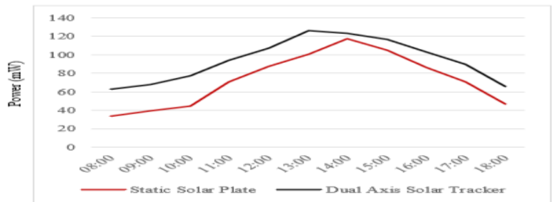

Fig. 9. Comparsion between static solar plate and dual-axis solar tracker

V. CONCLUSION

The dual-axis solar tracker is tested in a simulation environment and experimental results have also been obtained. The experimental results show an appreciable rise in solar panel output after the introduction of a dual-axis tracking system. A total of 38% hike is noted when a dual-axis tracking system is employed for extracting the maximum power from solar radiation. The tracking system incorporates four LDRs, a controller for controlling the tracking, stepper motor. This tracking system eliminates the number of solar PV arrays to obtain solar power. The efficiency is evaluated for different readings obtained at different times of day and it is experimentally verified that the efficiency of dual axis solar tracker is more as compared to a static solar plate. An IoT monitoring system is also used along with a dual-axis solar tracking system to monitor the parameters of solar panels. The parameters can be accessed with the help of a Wi-Fi module and data streams are transferred to the IoT monitoring system.

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