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Performance Analysis of Dual Axis Solar Tracker

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Abstract: Solar tracking systems have been demonstrated to increase the efficiency of standard PhotoVoltaic (PV) energy generation systems by researchers in the recent past. The current paper deals with the design, implementation and testing of a scaled-down dual-axis solar tracking PV system. The system performance is evaluated in terms of the data obtained by testing the prototype and a basic trend analysis of the data obtained is also carried out. This analysis helps in evaluating the performance of the system throughout a day.

Keywords: PV, Solar Tracker, Dual-Axis, Performance, Analysis

I. INTRODUCTION

A portable and efficient solar PV (photovoltaic) module can effectively serve power needs of diverse types, ranging from civilian usage to military applications. It is also critical for such systems to be as efficient as possible; hence, incorporation of solar tracking mechanisms in the design and implementation of such systems can appreciably increase system efficiency[1]. Initially, single-axis solar trackers were designed by researchers, but in recent years, design of dual axis solar trackers has further increased system efficiency.

II. SYSTEM

The fabrication of dual-axis solar tracking PV modules is especially relevant in the present day, due to the increasing requirements of clean renewable alternative energy sources [1][2]. Solar trackers help to maximize the absorption of energy from incident solar radiation [2]. The setup of such systems is usually carried out with an initial study of horizontal irradiance at the installation sites, to estimate the power output available from the systems post-installation. Another important factor is cell temperature, which is inversely related to power output from the solar cell. Thus in-plane irradiance and cell temperature play an important part in estimation of system output prior to installation [3]. A brief classification of solar-tracking PV systems is illustrated in Figure 1 below.

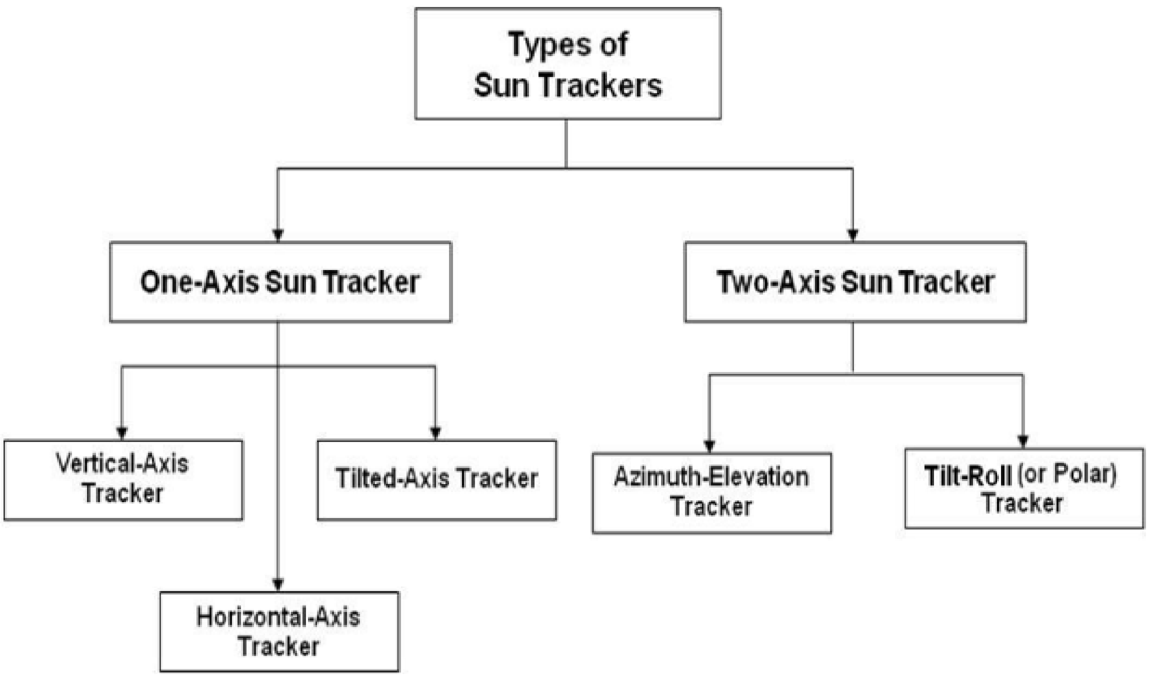

Fig. 1 Types of solar trackers

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The current paper deals with the design and implementation of an azimuth-elevation type two-axis solar tracking PV system equipped with LDR (Light Dependent Resistor) sensors to track the location of panel relative to the Sun with the aid of an ATmega328 microcontroller in an Arduino Uno board, along with necessary Op-Amps, diodes and resistors. Two permanent magnet-type DC stepper motors are used to move the panel along each of the axes. The circuit for sun tracking is shown in Figure 2 as follows.

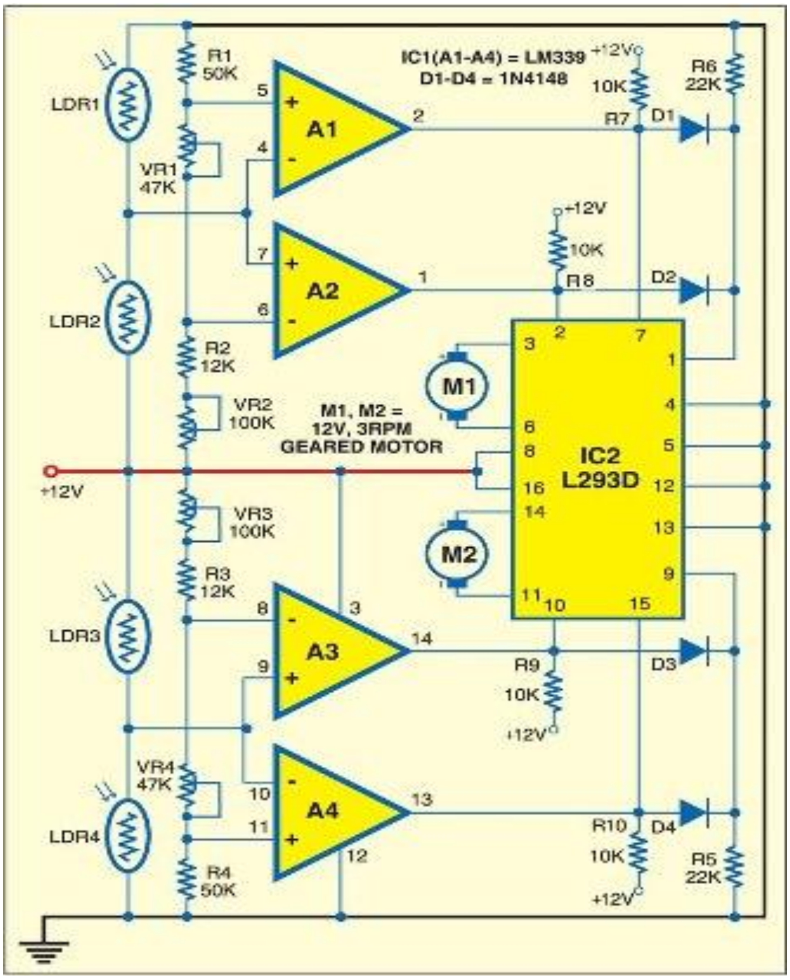

Fig. 2 Sun Tracking Circuit

Comparative studies have also been made between the performance of stationary, single-axis and dual-axis solar tracking PV systems [4][5]. There have also been studies on different control strategies for improvement of system performance. As mentioned earlier, the in-plane irradiance is a critical factor in estimation of system performance as well as control, for which the tilt angle of the system is also relevant to the control scheme proposed [6]. The current paper compares between the stationary and sun-tracking performances of the two-axis solar tracking system. The equation for determination of relative performance in terms of a parameter ε, with P_T being the output power obtained while tracking, P_S being the power obtained while stationary and P_C representing the power used for tracking, is shown below.

$$\varepsilon = (P_T - P_C)/P_S \qquad \ldots(1)$$

This equation is used to calculate the relative efficiency of the system in terms of the experimental results obtained. Hence, using this particular equation, we can determine the degree to which the designed system exceeds the un-optimized system performance in terms of obtained output.

III. EXPERIMENTAL RESULTS

The solar panel is tested by keeping it static as well as using the dual-axis tracking circuit to dynamically adjust the orientation of the panel. The specifications of the solar panel and the motors are shown in Table 1 below.

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Table 1. Specifications of motors and solar panel

Component	Specifications	Quantity
Solar Panel	100 mA, 6V	1
Micro Servo Motors	a. 3 pole ferrite, all nylon gear b. Top ball bearing c. Operating Voltage: 4.8V~6.0V d. Operating speed: 0.12sec/60 degree e. Output torque: 1.6kg/cm at 4.8V f. Dimension: 21.5*11.8*22.7mm g. Weight: 9g each	2

The results of the experiments outlined above are displayed in Table 2 which follows.

Table 2. Variation of output power obtained from PV array with time

Time of Day	Net Output Power (Watt)		ε
	Static Panel	Panel with Two-Axis Tracking	
10 AM	0.18	0.11	0.61
11 AM	0.3	0.17	0.57
12 NOON	0.52	0.52	1
1 PM	0.31	0.45	1.45
2 PM	0.19	0.36	1.89
3 PM	0.14	0.31	2.21

In Table 2, the net output power is calculated from the panel for different times of the day, at one-hour intervals. The relevant time period for which the experiment is carried out is from 10 AM to 3 PM. Readings are taken at the stroke of each hour. Using the stationary panel data as well as the solar-tracking panel data, the relative efficiency parameter ε is calculated for each time of the day. Examining the values of ε obtained in this manner, we can see that ε is initially less than 1, however it becomes equal to 1 at 12 Noon, since the Sun is overhead at that point of time, after which output power from the static panel reduces due to the effect of tilt angle, while the sun-tracking system maintains its attitude with respect to the solar rays. Hence, after 12 Noon, we see a gradual increase in the value of ε even though the power obtained from both the stationary and sun-tracking panels decreases to levels below the maximum value observed at 12 Noon. Thus, if the variations of output power with respect to time for the static panel as well as the panel with two-axis tracking are plotted with respect to time, the results are seen in Figure 3 which follows.

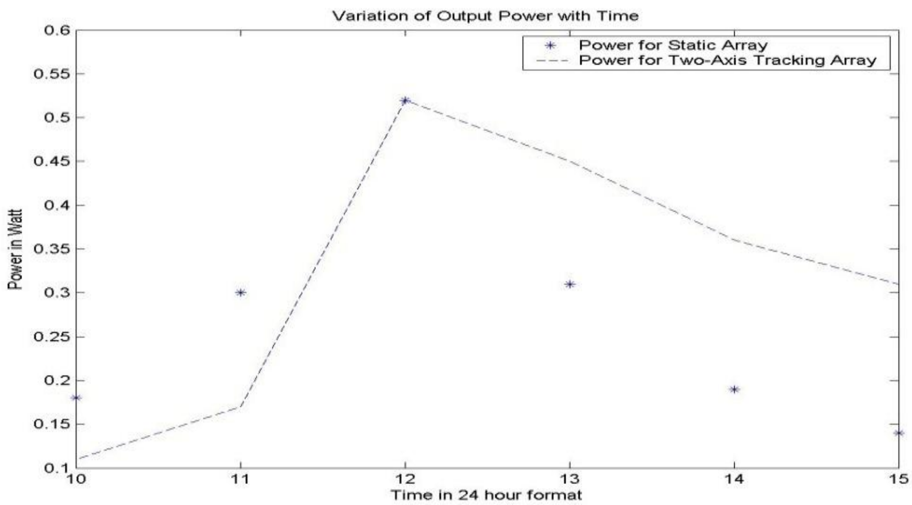

Fig. 3 Variation of the power output of static and two-axis tracked PV array with time

From the results obtained in figure 3 as well as the results from Table 2 it is clearly observable that the power obtained through two-axis tracking is clearly larger during the peak hours of operation (12 PM to 3 PM). Hence, we can

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conclude that the two-axis tracking system enhances the power output from the solar panel during the period of maximum insolation. Since the power obtained during this period is much higher than the power obtained during the other period (10 AM to 12 Noon), the total power obtained for the dual-axis tracking solar panel during the day is higher overall compared to the stationary solar panel. We can also observe the variation of relative efficiency from figure 4 below.

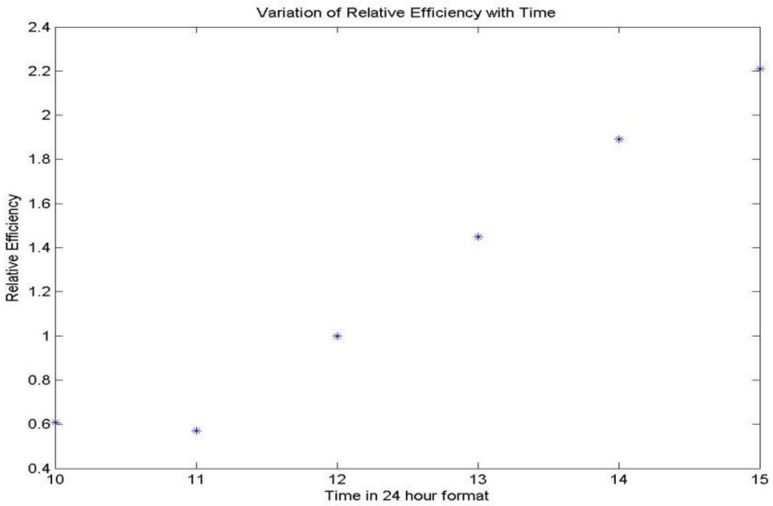

Fig. 4 Variation of Relative Efficiency with time

Figure 4 clearly shows the results previously obtained in the experiments and represented in Table 2 earlier in terms of the relative efficiency ε. The variation of this factor is virtually linear after 11 AM and this linearly increasing nature clearly shows that the dual-axis tracking system dominates the stationary system in terms of performance based on output power available from the systems.

CONCLUSION

The current work accomplished by us comprised of design and implementation of a two-axis solar tracking system for enhancing the power output of a PV module. We intend to investigate possible panel configurations coupled with novel algorithms to increase the value of the slope of the relative efficiency graph obtained in figure 4 above, in our future work. This will enable the power output of the system to increase and will make the system more efficient overall. Thus, we shall endeavour to come up with enhanced algorithms for tracking as well as innovations in the tracking hardware which will enable us to further increase the output power obtainable from the PV module.

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