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Performance and Comparison Analysis of Improvement in Efficiency and Power output of solar panel without or with using Arduino based Dual-axis Solar Tracking System

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ABSTRACT: In this paper the performance and comparison analysis of improvement in Efficiency and Power output of a solar panel is accessed with and without using dual-axis solar tracking system using Arduino. The major objective of this project is to analyze the performance of a solar panel both in fixed at one location and using traction of sun with respect to panel orientation so as to enhance the rate of harnessing power from sun. The energy crisis is one of the main issues of the present era and the rate at which resources are being exhausted, there is a gap in demand and supply for the generation of power. We need to switch to a reliable and sources for energy which are green, eco- friendly, clean and approximately produces no carbon emission during their operation. Solar energy is one of the best options we can use for harnessing the energy in the form of radiation and convert this radiated energy into useful electrical energy. This paper put a light on the performance analysis of dual axis solar tracking system using Arduino. The main objective of this is to utilize the maximum of sunlight to convert into useful electrical energy with minimum loss in absorption of sunlight on solar panel and also to compare it with solar panel which is fixed only at one position whose movement is restricted whereas the other solar panel tracking the sun in the dual direction. The research comprises of hardware design and software program. The hardware part includes LDR to track the path of the sun & servomotor which upon receiving signal from the central processing unit that is Arduino will rotate the solar panels to appropriate point which is exactly for optimum performance of solar panel as it receives maximum solar radiation. The results are compared with the fixed & dual axis solar tracking systems. This research provides optimal utilization of solar energy to get maximum power output and increase in efficiency.

KEYWORDS: Solar Energy, Dual-axis Solar Tracker using Arduino, Power output and efficiency, LDR based driver system.

I. INTRODUCTION

Renewable energy source means energy that is sustainable or we can say something that can't run out or is endless. The best example is the sunlight. When we use the term 'alternative energy' it usually refers to renewable energy sources of energy too, as we use these sources of energy as a substitute for the non-renewable sources like coal, petroleum etc. The most popular renewable sources are solar energy, Biomass energy, Wind energy, hydro energy etc. Global investments in new renewable energy capacity installations in the past decade was over \$2.5 trillion. The solar power capacity installed is more than the other generation technologies [Acc. to the Global trends in Renewable Energy investment go a report published by UN environment program]. India has set a target to install 100 GW of solar energy by the end of 2022 and this number will increase 3 folds by 2030.

In the previous decade, the number of people dependent on the solar energy for electricity has considerably increased. The main reason, for this increase is that, the technology used for converting solar energy into. electricity offers a onetime investment and a little maintenance thereafter. In the initial days of development of this technology, the performance of solar PV systems is quite poor. But, as now a days the use of this technology is increasing so in order to improve its performance, we came up with a solution titled tracking. The device used for tracking is called a SolarTracker.

Solar tracker is a device, that we use to divert the position of solar panel with the changing position. of sun throughout

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a day. By the use of solar tracker, we came to know that the instantaneous solar radiations collected by the PV cells, assembled in a tracker system is much more than a fixed system[y]) The output of panel can be increased by 30 to 60% by using a dual and Solar tracker system. [5] Nowadays, many types of solar tracking systems are available but the dual axis solar tracker system yields the best results among all others- A dual-axis tracker can be moved along both horizontal s well as vertical axis, thus making it possible to capture maximum sunlight anywhere across the world.

In this project, we analysed the improvement in performance of the dual axis solar tracker system, as compared to a simple panel. It was separated into three parts which were input, controller and output Theinput was taken from the LDRs which are connected to IR sensors. IR sensors gives input to the Arduino uno ,which is the controller. The output of Arduino directs the motor driver L298 N to drive themotors.

II. METHODOLOGY

As stated before, the aim of this project is to analyze the performance of dual-axis solar tracking system. It consists of three main structures which are the inputs, the controller and the output. The inputs are from the LDRs, the Arduino as the controller and, the servo motor as the output. The overall system is presented in Figure 2. In this project, the main controller which is the Arduino receives analog input from LDRs and it converts the input into digital signal by using analog- to-digital (A-D) converter. Then the controller sends the signal to the servo motor in order to determine the movement of the solarpanel.



Figure 2. Block diagram of overall system Panel

Model type: SBE15070 Monocrystalline				
Power Output (Wp)	2 Wp			
Current at Maximum Power (Imp)	0.273A			
Voltage at Maximum Power (Vmp)	7.3 V			
Short-Circuit Current (Isc)	0.295A			
Open-Circuit Voltage (Voc)	8.5 V			
Fill Factor (F.F)	80%			
Panel Area (m ²)	0.013 m ²			
Irradiance (W/m ²)	$1000 W/m^2$			
Efficiency (%)	15.38%			

Table 1: Parameters of Monocrystalline Solar

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In this methodology we performed two operations at a latitude of 32.72 degrees and collected the data at different time intervals for each parameter of solar panel and the time interval taken was 1 hour. The rating of solar panel is 2W, we use a multimeter to measure open circuit voltage Vo.c and short circuit current Is.c, and a solar power meter to measure solar Irradiance. As the fill Factor (F.F) of the given mono crystalline solar panel is assumed to be constant as 80% throughout the overall calculation in both the operations and observations. Two operations which were performed simultaneously, as in one operation the position of inclined solar panel at 32 degrees is fixed and was facing towards south and was exposed to irradiance from 8:00 AM morning to 5:00 PM evening. And on the other side an Arduino based dual axis solar tracking system consists of solar panel with light detecting resistors and servomotor was exposed to irradiance. In this type of operation, the position of panel with respect to sun was controlled directly by the Arduino based tracking system and panel follows the path of sun as servomotor gets signal from LDR's at both the axis as horizontal and vertical respectively.

Formula Used in above methodologies to evaluate different parameters like power, efficiency and percentage increase in efficiency by using Arduino based dual axis solar tracking system is as given below:

Power Output = $V_{o.c} \times I_{s.c} \times F.F$

Efficiency = $(Power Output)/(Irradiance \times Panel Area) \times 100$

Percentage increase in Efficiency =(Efficiency obtained by using Dual Axis Solar Tracker – Efficiency obtained for Fixed Inclined Panel)/ (Efficiency obtained by using Dual Axis Solar Tracker)

Percentage increase in Power Output =(Power Output btained by using Dual Axis Solar Tracker – Power obtained for Fixed Inclined Panel)/ (Power Output obtained by using Dual Axis Solar Tracker)



III. RESULTS ANDDISCUSSIONS

The results revealed that the location of the solar panel was one of the important things in collecting its output voltage and current. It was also discovered that solar panel would perform the best when facing south as this would help to receive the most exposure from the sun as it moved from east to west. For most locations, the peak performance hours of the day were between 11:00 A.M to 2 P.M. This was when the sun was at its highest illumination.

The measurements of the data were taken from a wide area where there was no obstruction that would prevent the tracker from getting the maximum sunlight. The measurement of output voltages and currents were taken from 8:00 A.M to 5:00 P.M. The data collected is demonstrated in the graphs below. It was a very. There were two similar types of solar panels used which followed theseconditions

- Fixed solar panel with 32 degree of tilt angle facingsouth
- Solar panel with tracking system facingsouth.

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Condition -I

In this investigation we fixed the solar panel at 32 degrees facing towards south and obtained the different output parameters of solar panel which are shown in the given below table:

Time	Irradiance (W/m2)	Panel Area (m ²)	Open Circuit Voltage (V _{o.c}) Volts	Short-Circuit Current (Is.c) Amperes	Fill Factor (%)	Power Output (W)	Efficiency (%)
8:00	993	0.013	8.42	0.287	80	1.93	14.98
9:00	882	0.013	8.12	0.243	80	1.58	13.77
10:00	818	0.013	7.98	0.197	80	1.26	11.83
11:00	992	0.013	8.41	0.284	80	1.91	14.82
12:00	1011	0.013	8.52	0.297	80	2.02	15.40
13:00	940	0.013	8.28	0.264	80	1.75	14.31
14:00	892	0.013	8.09	0.213	80	1.38	11.89
15:00	879	0.013	8.06	0.211	80	1.36	11.91
16:00	676	0.013	6.97	0.184	80	1.03	11.67
17:00	576	0.013	6.09	0.138	80	0.67	8.98

Table 2: output parameters of Solar Panel fixed at 32 degrees facing towards south

In the above-mentioned table, it is observed that at the start of experiment we take time at 8:00 AM and the irradiance was taken 993 watt per square meter. As after an hour sun movement is 15 degrees with respect to earth therefore a change in the output parameters of solar panel were observed. Therefore, during first half of day that is from 8:00 AM to 1:00 PM both power output and efficiency changes as the amount of radiation received by solar panel changes due to fixed position of panel with respect to sun. The obtained results show that irradiance received on the panel changes with time from morning to afternoon and at 12:00 PM we get peak in the amount of irradiance received on surface of solar panel from sun which is about 1011 watts per square meter. Therefore, for a fixed operation of solar panel the maximum power output was 2.02 Watts and maximum efficiency achieved during this operating point was 15.40%. After 1:00 PM the irradiance changes as the movement of sun with respect to panel surface is changed and we obtained a decrease in efficiency after noon to evening. Therefore, we can see that for the whole day operation and performance for a solar panel at fixed position, both power output and efficiency first increase from morning to afternoon and then decreases afternoon to evening as mentioned in Figure.6 as below.

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As shown in above Figure 7. it was observed that power output with respect to fallen irradiance varies and a peak power for fixed inclined solar panel was observed at the rate of irradiance 1011 watt per square meter. Also, it is seen from the graph that power output increases from 10:00 AM to 1:00 P.M after that a linear decrease in power output can be seen as irradiance decreases with respect to length of day tends to evening. The output Power varies from 1.93W to 0.67W from morning 8:00 A.M to evening 5:00 P.M respectively.



Figure 8. Graph of Efficiency V/S Time of day for fixed inclined panel facing south

As the intensity of irradiance varies on a fixed inclined solar panel therefore the open circuit voltage which is logarithmic function of solar intensity and short circuit current which is exponential function of solar intensity therefore, we can have a varied power output over a different intervals of time period. From Figure 7. It is clearly observed that how output power is changed with respect to change in irradiance. Also, the efficiency of a solar panel is a function of solar intensity fallen over its surface therefore we can also see a drastic variation in efficiency of a solar panel which is fixed and can be observed from Figure8. In which a graph between efficiency and time of day is shown and we can conclude that the efficiency of fixed solar panel varies with respect to length of day as irradiance fallen on inclined panel is not linear enough to get an approximately constant efficiency.

The maximum achievable efficiency is at 12:00 P.M which is 15.40% and then decreases as length of day tends to



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evening. In figure 8. In morning the efficiency is 14.98% which then decreases to 12.03% and then increases to 15.40% as maximum intensity of irradiance was received by panel and then as day tends to evening efficiency tends to decrease up to 8.98%.

From the above discussion it is concluded that both power output and efficiency of fixed solar panel changes drastically and we are not able to extract as much available energy from sunlight with fixed inclined solar panel.

Condition -II

In this investigation an Arduino based dual axis solar tracking system was used to observe the behavior and performance of solar panel. In this system LDR's placed with the panel tracks the path of sun due to which maximum possible solar radiation energy can be harnessed by solar panel and this gives approximate linear performance than affixed inclined PV panel.

All the parameters which were obtained during experimental work are given in Table 3. It is seen that the operating parameters during this operation remains almost constant and shows a linear behavior, which can be seen from the table and figures showing the performance of panel at different intervals of time of day. From Figure 9. It can be observed that curve between irradiance and day time is almost constant however there is small change can be observed during afternoon which is higher of all the other obtained values. The irradiance in morning was 1025 watt per square meter and changes at afternoon and it is 1010 watt per square meter and then it is almost constant and in evening there is decrease in value and reaches to 798 watt per square meter.

			Open				
			Circuit	Short-Circuit	Fill	Power	
		Panel Area	Voltage	Current (Is.c)	Factor	Output	
Time	Irradiance(W/m2)	(m ²)	(V _{o.c}) Volts	Amperes	(%)	(W)	Efficiency(%)
8:00	1025	0.013	8.57	0.297	80	2.04	15.28
9:00	997	0.013	8.48	0.289	80	1.96	15.13
10:00	993	0.013	8.41	0.282	80	1.90	14.70
11:00	981	0.013	8.4	0.281	80	1.89	14.81
12:00	1010	0.013	8.59	0.298	80	2.05	15.60
13:00	998	0.013	8.28	0.291	80	1.93	14.86
14:00	975	0.013	8.09	0.275	80	1.78	14.04
15:00	954	0.013	8.06	0.268	80	1.73	13.93
16:00	805	0.013	7.75	0.232	80	1.44	13.74
17:00	798	0.013	7.98	0.208	80	1.33	12.80

Table 3. Output Parameters of Solar Panel Using Arduino Based Dual Axis Solar Tracking System

In Figure 9. A curve between Power Output and time of day is drawn and it is clearly seen that the curve of power output is close to the maximum output value of power at each interval of time. In morning the obtained output was 2.04W and then it slightly decreases but remains close to 2W and in evening it decreases to value 1.33W. therefore by using dual axis tracking system it is observed that the output power value is more than the value of fixed panel. Figure 11. Shows the curve between efficiency and time of the day and is observed that efficiency curve is also so close to the maximum achievable efficiency under testing conditions. For whole of day at different time intervals efficiency remains close to 15.60% and changes from 15.28% to 15.60% to afternoon and then decreases up to 12.80% which is greater than the value of inclined panel. Hence from above discussion in view of power output and efficiency obtained by using dual axis solar tracker both values are exceeded at each interval of time as compare to inclined panel.

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Figure 11. Efficiency V/S Time of day for Arduino based dual axis solar tracking system

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Figure 13. Comparison of Efficiency with and without using Arduino based dual axis solar tracking system

IV. CONCLUSION

In conclusion, the performance of dual-axis solar tracking system was successfully analyzed. Based on the data collected, it can be concluded that the dual-axis solar tracking system is better than the fixed inclined solar panel in terms of output voltage, current, power and efficiency. For this reason, the system has been proven effective for capturing maximum sunlight source for solar harvesting applications. The economically and environmentally friendly dual-axis solar tracking system also can be a great technique in utilizing the superiority of solar energy thus solving the increasing demand of electricityproblem.

From Figure 14 & 15 it is concluded that there is percentage increase in both efficiency and power output at each of the different intervals. From these figures it is shown the time intervals at which less power and efficiency were obtained at fixed panel, at those time intervals there is more percentage increase in both efficiency and power output.



Figure 14. Percentage Increase in Efficiency by using Arduino based dual axis solar tracking system

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Figure 15. Percentage Increase in Power Output by using Arduino based dual axis solar tracking system

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