AN EXPERIMENTAL INVESTIGATION ON SINGLE AXIS SUN TRACKER BY WIPER MOTOR

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ABSTRACT

In this paper, a logic circuit solar-tracking system is proposed, implemented and tested. The controlling motion for PV panel has been provided by discrete motion of the motor. Integrated Circuits (ICs) with timer-IC555 and relays are used in the control circuits, which generate pulses for rotation of the motor drive. A disc is attached with the panel and indexed with contact points according to design. A micro-switch is used to switch the control circuit for rotation of the disc at required time interval to track the Sun's position. When compared with the conventional tracking systems like stepper motors with driver circuits and program with computer systems, this tracking system has been found independent of computer system which makes it for standalone application. Finally this system is simple and high efficient for trapping the Sun's incident energy. The power developed by tracking system is greater than without tracking system.
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Keywords: IC-555 Timer, Wiper Motor, Solar Energy, Single Axis Tracker, Solar Insolation.

1. INTRODUCTION

The solar tracker, a device that keeps photovoltaic or photo thermal panels in an optimum position perpendicularly to the solar radiation during daylight hours, can increase the collected energy by up to 50%.Commercially; single-axis and two axis tracking mechanisms are available. Usually, the single axis tracker follows the Sun's East-West movement. Sun tracking systems have been studied with different applications to improve the efficiency of solar systems by adding the tracking equipment to these systems through various methods [1-7]. A tracking system must be able to follow the sun with a certain degree of accuracy, return the collector to its original position at the end of the day and also track during periods of cloud over.

Theoretical calculation of the energy surplus in the case of tracking collectors is as follows: Assume, the maximum radiation intensity is I=1100 $W\text{-}m^{-2}$ falling on the area which is oriented perpendicularly to the direction of radiation. It is assumed, the day lengths t=12h=43000s as well as the daylight length and it is compared, the tracking collector which is all the time optimally oriented to the sun with the fixed collector which is oriented perpendicularly to the direction of radiation only at noon.

For fixed collector, The projection of the sun beam on the PV Cell, which is oriented perpendicularly to the radiation direction, is equal $S=S_0\cos\varphi$ and the angle φ is changing in the interval $[\pi/2,-\pi/2]$ during the day where S_0 is the collector area. The angular velocity of the sun moving cross the sky is equal $\omega=727\times10^{-5}s^{-1}$ and the differential of the falling energy is equal dW=IS dt. When it doesn't consider the atmosphere influence and can calculate the energy, which is fallen on the collector area $S_0=1m^2$ during one day.

$$w = \int_{-21600}^{+21600} IS_0 \cos \omega t dt = IS_0 \left[\frac{\sin \omega t}{\omega} \right]_{-21600}^{+21600}$$

$$= \frac{2IS_0}{\omega} = 303 \times 10^7 \; watt.s .... (1)$$

For the tracking collector which is all the time optimally oriented to the sun: When it isn't considered the atmosphere influence, it can be calculated the energy, which is fallen on the collector area $S_0=1m^2$ during one day

$$W = IS_0 t = 475 \times 10^7 \; watt.s \qquad ....(2)$$

(Since$\varphi=0^o$)

Comparison Equation 1 and Equation 2 show the energy surplus 57% when it isn't considered the atmosphere influence. It would be really obtained this surplus for example on the Moon surface[1], [2].

The aim of this work is to compare the effect of using fixed sun tracking systems on the electrical generation of a flat photovoltaic system (FPVS) with single axis solar tracking system. An experimental study is carried out to evaluate their performance under local climate. The measured variables are compared with the fixed axis for both the fixed panel and single axis solar trackers.

2. CONSTRUCTION

The solar tracking system is constructed according to the design. The construction was done in two stages.

1. Mechanical construction
2. Electrical Construction

2.1 Mechanical Construction

Wooden base was surrounded by ¾ inch angle bar. After this two stands are set on the bed. The stands were made up so they can carry the bearing at the top. Two bearing cases were made in the lathe machine and those were welded at the top of the stand. Then the mild steel shaft was reshaped of 5/8 inch in diameter. The MS plate sheet on which the solar panel will stand was constructed after this. The plate was constructed according to the dimensions of the solar panel. The plate was welded with the shaft. One end of the plate was hinged with the shaft and the other end of the plate having a screw system. By which the plate can be up-down. The wiper motor was set to a stand and was mechanically coupled with the shaft. For that the shaft can rotate with the rotation of the wiper motor.

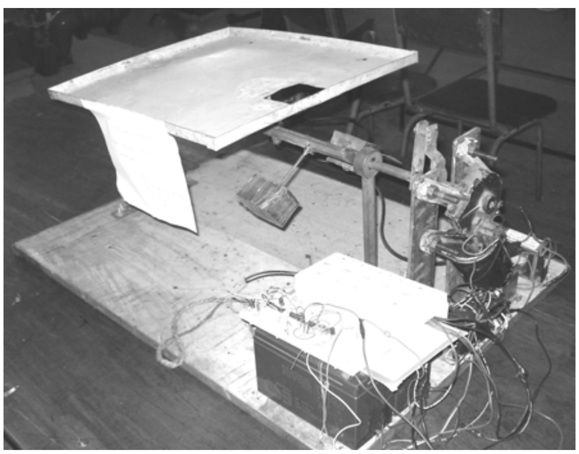

Fig 1. Mechanical Construction

2.2 Electrical Construction

In order to rotate the solar panel for tracking the maximum radiation of the sun, it is needed to supply pulse to the wiper motor after constant time. The earth rotates with respect to the sun approximately 15^o per hour. So, the wiper motor has to be rotate at this rate. The circuit was designed as to set up first an astable multi vibrator. Then the output was transferred to the 4020 BC. From this the output goes to monostable driver. The pulse we get from the monostable is used to drive the wiper motor. But this pulse can't be used directly to the motor, because the current supplied from the monostable is very low. So, a relay was used to supply the pulse to the motor.

First the time was determined at which the motor will get the pulse. The wiper motor rotates 5^o for a single pulse from the driver circuit. That means we have to supply pulse to the motor at every 20 minutes. The time can be set by taking output from desired output of the 4020 Binary Counter (viz. Q1, Q2, Q3, Q4 etc.). The rotation of the wiper motor can be controlled by varying the resistance of the variable resistance. The output of the binary circuit becomes double at every next output. The time was set according to the following method-

Table 1: The time required for the pulse

Output of the 4020 BC	Time(sec)
Q3	2.42
Q4	4.84
Q5	9.7
Q6	19.4
Q7	38.8
Q8	77.6
Q9	155.2
Q10	310.4
Q11	620.8
Q12	1241.6

So, the output from the 4020 BC at Q12 was taken and the pulse was generated at every 1241.6 seconds or 20 minutes and 21.6 seconds.

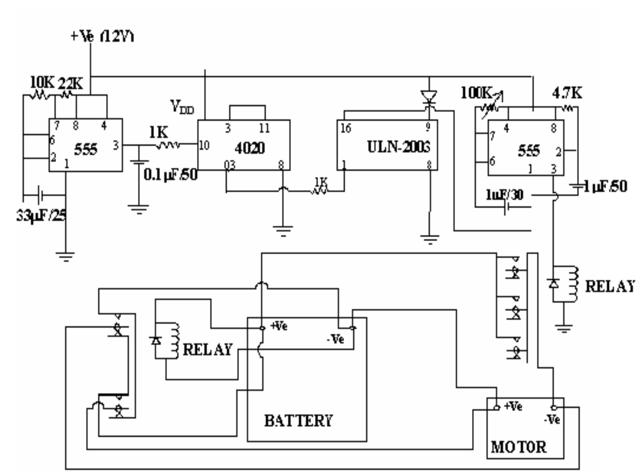

Fig 2. Circuit Diagram for generating pulse

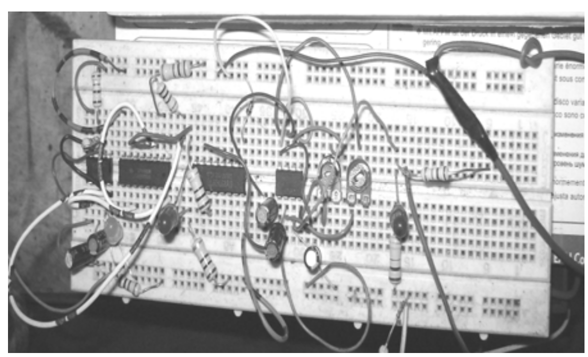

Fig 3. Photograph of the electrical Setup

3. SOLAR PANEL

The solar panel which was used in the project is a photovoltaic solar panel. The specification of this solar panel is given below-

Manufacturer--------------------- Micro Electronics

Model No. ------------------------ 100099

Number of solar cells------------ 36
Each Cell produces voltage of maximum 0.55 Volt. So totally the maximum capacity of this solar panel is (36 x 0.55 Volt) 19.8 Volt.

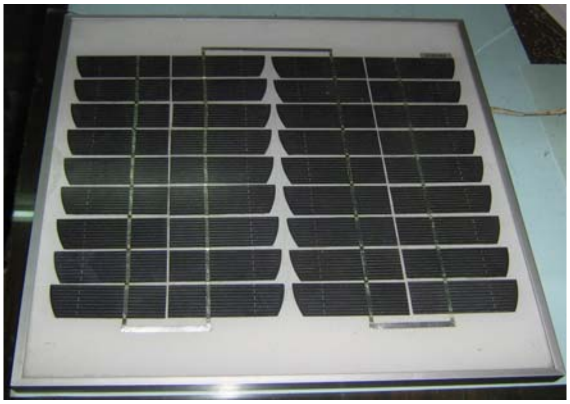

Fig 4. Photograph of the PV solar panel

4. EXPERIMENTATION

Specification in Table-2 was used to obtain the tracker performance of the tracking module where one system was kept in fixed mode and other one was kept in tracking mode. The simplest method to obtain an I-V characteristic is to load the module with a variable resistor, and measure the voltage and current through digital Multimeters [8], [9]. Fixed panel was kept tilted at an angle of 40° where the tracking panel is tracked through changing the azimuth position so that it was always remained perpendicular to the solar beam radiation. The measured value of voltage and current was the open circuit voltage and short circuit current of the PV cell. Also there was a digital arrangement with the PV panel that could give the solar irradiation in W/m^2, cell temperature etc and power could be obtained from measured voltage and current. Also surplus energy of tracking module with respect to fixed module of PV panel was obtained by the following equation:

Energy Gain (%) = {(power obtained by tracking mode – power obtained by fixed mode) / power obtained by fixed mode} *100%

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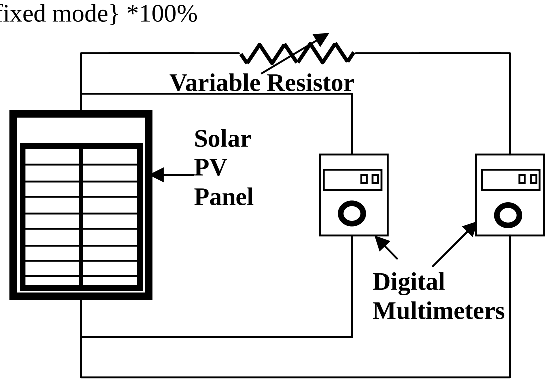

Fig 5. Connection diagram for determination of I-V characteristics of PV panel

Table-2: Specification of Intensity measuring Instrument

	Model	ET 250
Current Measurement	Shunt	0.01 Ohm
	Measuring Range	0-20A DC
Voltage Measurement	Voltage Divider	0.11/100 kOhm
	Measuring Range	0-20 V DC
Iluminance Sensor	Measuring Range	0-2000 W/m2
	Output Signal	0-5V DC
	Transducer	photodiode

4. EXPERIMENTAL RESULTS & DISCUSSION

From the experimental results of variation of irradiance with day time characteristic (Figure 6) it has seen that solar intensity increases with day time up to 13 PM and then decreases but there is some fluctuation of intensity due to flow of some cloudy sky and abnormal atmospheric condition. As a result there is some fluctuation on solar cell characteristic. The data is taken several days through the month February, March, April 2008 and the results which are shown in fig-6, 7, 8 and 9 for dated 16/03/2008.

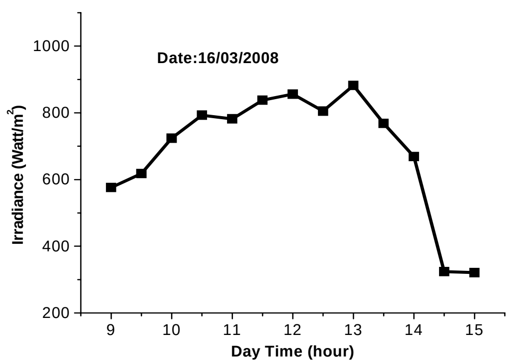

Fig 6. Day Time trend of Irradiance data

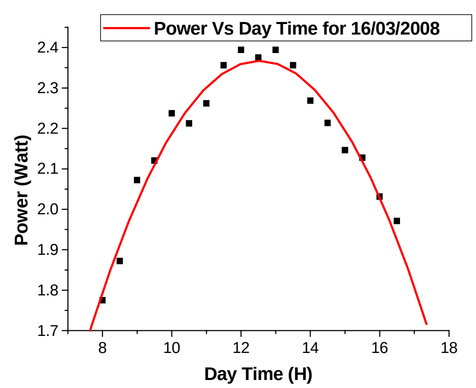

Fig 7. Power Vs Day Time data for single axis tracker

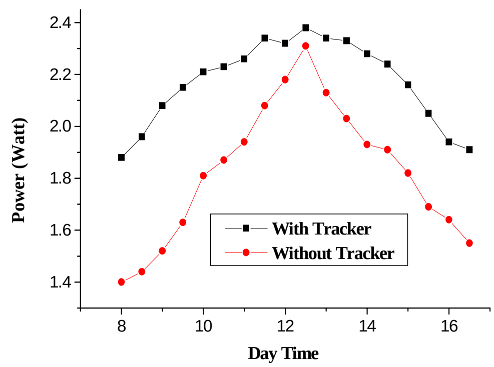

Fig 8. Comperasion on Power Vs Day Time data

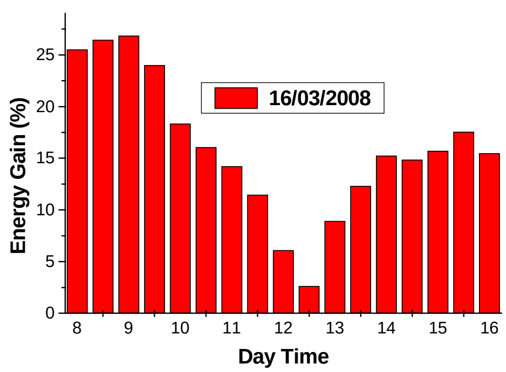

Fig 9. Energy Gain Vs Day Time data

The results indicates that PV output power is more about 18% for single-axis tracking PV panel compared to fixed PV panel as shown in Fig-8. From the analysis of figs 6 to 8 it has seen that some fluctuation of solar intensity because the experiment has done in the winter season and so whole the day was not sunny. From Fig-9 it has seen that the energy gain is much at around the lowest intensity time and vise versa at heighest intensity as it compared it with fixed one.

The designed tracking system is beneficial because the component used in the system is locally available with low cost. The total cost in the control circuit and IC's with 555-timer system becomes about 500Tk only.

5. CONCLUSION

- From the performance study, the graph (Figure-8) shows that the power developed with tracking system is greater than without tracking system.
- This tracking system is independent of computer system, so it is simple to operate and maintenance is easier.
- The logic circuitry of this tracking system is more compact and easier than any other tracking system with least cost.

So, considering all above aspects of this tracking system, it is simple, cost effective & highly efficient for trapping the Sun's abundant free energy.

In this research a sun tracker has been developed to increase the amount of power generated by the solar panel as the sun traverses across the sky and also an experimental study is performed to investigate the effect of using two-axis tracking system on the PV power output. The system was designed to be autonomous, such that energy generated by the solar panel would be maximum. The tracker designed here provided good power output performance.

From the result of the performance test of designed system the following conclusion can be drawn.

- The designed solar tracker automatically controlled and follows the sun path according to the direction of beam propagation of solar radiation;
- The maximum power output of the tracking solar panel was 2.4 Watt (rated of 3.5 Watt)at average intensity 1100 W/m^2;
- The surplus output-power of the tracking solar panel with respect to fixed panel was 23.6-31.3% at average intensity 1100 W/m^2;
- The use of software outside the mechanical part makes the tracker flexible for future development.
- Design simplicity, Low cost and material availability will make the designed tracking system more effective and acceptable in the market.

Considering all above aspects of this tracking system it can be concluded that, it is a flexible tracking system with least cost electromechanical set-up, low maintenance requirements and ease on installation and operation.

6. DISCUSSION & RECOMMENDATION

The tracking system tracks the sun every 1 hr with 15° rotation of the solar panel. But it is possible to track in every 20 minutes by modification in the plate and in the circuit. The system rotates 5 degree at every 20 minutes for a pulse. But the solar panel can be rotated 1 degree after every 4 minutes by using stepper motor and its performance can be improved by programmable logic circuit. Also the system performance can be improved by using high capacity panel, so that it will need no battery and it can be operated with its own power generation.

7. REFERENCES

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8. NOMENCLATURE

Symbol	Meaning	Unit
I	Intensity	$(W\text{-}m^{-2})$
S_0	Collector area	(m^2)
ω	Angular velocity	(s^{-1})
W	Falling energy	Watt .s
t	Day length	s