Comparative study of Solar panel positioning system using single-axis and dual-axis tracking system

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Abstract: *Solar energy is one of the most promising, sustainable green energies. As the deposits of fossil fuels are depleting day by day, the utilization of renewable sources are very much necessary for every country's development and growth. This project is designed to detect the presence of the sun and can position the solar panel towards sun's direction automatically, i.e., the system rotates the panel automatically according to the sun's position, so that maximum solar power can be utilized. The Single Axis module consists of Solar panel, battery, logic circuit, charging circuit, control circuit, Motor driver and a Stepper Motor whereas in the Dual axis module, additional LDR Sensors are used to detect the light Intensity and an extra Stepper motor to rotate the additional axis thereby tracking the position of sun. One DC motor is used for tracking the sun in east to west direction and the other DC motor is used to rotate the panel for almost 300 degrees to position it towards the sun's direction. Two LDR's are used in which one LDR is used to distinguish day or night and the second is used to trace out maximum light intensity. The output of the two LDR's is fed to Pic-controller which gives digital information and this is fed to the controller which controls the DC motors for moving the solar panel. When the panel is positioned towards the sun, the micro-controller de-energizes the motors automatically. By implementing such a model, the solar panel's directions were automatically being adjusted to the Sun's position whenever the model is placed in an open environment easily susceptible to Sunlight, thereby increasing the throughput to the panels.*

Key words: *Solar Tracking; Single axis Tracker; Double axis Tracker; Low light detection; Tracker resetting.*

1. Introduction

The tracking and panel positioning system is designed such that the panel rotation delay time is synchronized with Sun's position, hence maximizing the solar power that can be utilized. Here, the principle of 'heliotropism' is used to track the sun's movements thereby increasing the efficiency of the solar energy generated. And as it involves positioning of panels according to sun's movement it is described as 'Panel Positioning System'.

As the power generated is dependent on incident radiation and also the intensity varies with time and season at a particular point, the efficiency of the fixed system is far less to exploit commercially. For optimum generation of electric power the PV Panels need to be maintained or positioned normal always to the incident radiation. This technique, known as Solar tracking, is therefore essential for improved system performance and efficiency. The resulting increase in efficiency is substantial enough to make the tracking a feasible proportion in-spite of the improvement in the system cost.

2. Solar Tracker Description

In this section detailed information on the basics about the project, types of solar trackers, and their design methodology are presented.

A. Solar Tracker and it's types:

In the sky the sun's position varies, both with the seasons and time of day as the sun moves across the sky. The solar energy intercepted by the solar panels during the course of the day is not maximized if the position of the panel is always static. Hence, dynamically oriented solar panels can track the sun throughout each day to greatly enhance energy collection.

Single axis trackers: Single-axis solar trackers rotate on one axis moving back and forth in a single direction. The turning axis of single axis trackers is mostly aligned along a true North meridian. Different types of single-axis trackers include horizontal, vertical, tilted, and polar aligned, which rotate as the names imply. [12]

Fig.1.Single axis tracker

Dual axis trackers: Dual-axis trackers continually face the sun because they can move in two different directions. These trackers follow the sun vertically and horizontally they help to obtain maximum solar energy generation. These are several implementations of these type of trackers too namely tip-tilt and azimuth-altitude dual axis trackers. [12]

Fig.2. Dual-axis tracker

B. General Description of the Single axis solar tracker:

The Singles axis solar tracker module consists of Solar panel, Regulator Circuit, Logic circuit, charging circuit, motor driver circuit, control circuit, etc., and is designed accordingly to rotate the panel by using the microcontroller which is programmed such that the panel rotates using the delay time given in this 8051 program. Thus, by giving sufficient delay and then synchronizing with the sun's position, maximum power output is achieved. One DC motor with built in reduction gear mechanism is used for the movement of the solar panel that tracks the sun in east to west direction.
For the demonstration purpose, a small solar panel is used and this is coupled to the motor shaft using proper mechanism. The total system including the DC motor that drives the 3 Watts solar panel is designed to operate at 12V DC. This voltage is derived from a 12V and 1.2Ah rating battery which may in turn be charged by the solar panel itself.

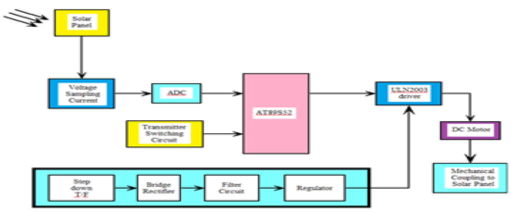


Fig.3. single axis tracker Block diagram

Major hardware components required for the single axis tracker include a transformer (step down), 8051 microcontroller, 7805 voltage regulator, stepper motor and a ULN2003 motor driver etc.

Circuit Schematic of a Single Axis Solar Tracker:

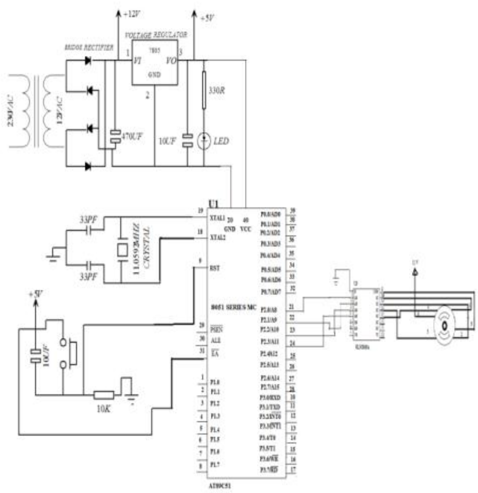


Fig.4. Circuit Schematic

C. General Description of the Dual axis solar tracker:

The Dual axis tracker consists of reading a series of light sensor values, comparing them, and then positioning a motor to align with the greatest value which corresponds to the sun's position.

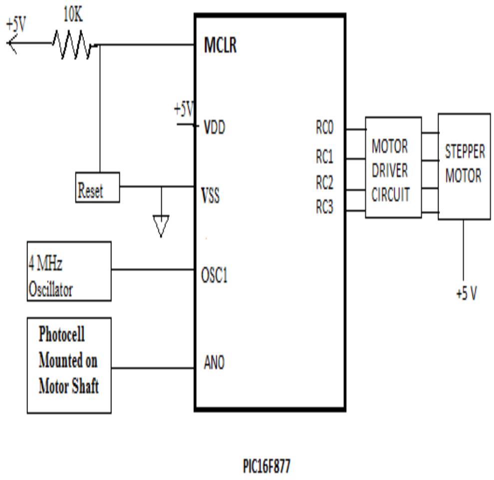


Fig.5. Hardware Block Diagram of a Dual Axis Tracker

In the Dual axis tracker, four LDR sensors are fed to two DC motors each of 10 rpm and 3.5 rpm which rotate the panel in east-west and north-south directions respectively. The LDR sensor's light intensities are compared using the microcontroller which analyses the direction of maximum sunlight and gives the turn command to the motor. This method yields higher power output than the former.

Item	Specification	Qty
Microchip microcontroller	PIC16F877	1
Oscillator, crystal	4 MHz	1
Voltage regulator	7805	1
Photocell	Cadmium sulfide	1
Step motor, unipolar	5 V	1
Capacitor	0.1 µF	3
Capacitor	47 µF	1
Resistor	10 KΩ	1
Resistor	3.3 KΩ	4
Diode	1N4003	4
Transistor, Darlington	2SD1276A	4
Switch, momentary, pushbutton	Normally open	1
Motor/sensor mounting accessories	10 rpm, 3.5 rpm	various

Table.1. Listing of Hardware components

D. Methodology :
The assembly language for microcontroller is developed for the project. It was adequate to fulfil design objectives while enhancing level of

understanding of the programming language. The Software tool used for developing the code was Keil µvision.

Software task is divided into four main parts.

- Initial positioning of a photocell.
- Sun Light tracking
- Low light detection
- Tracker resetting

Testing Procedure:

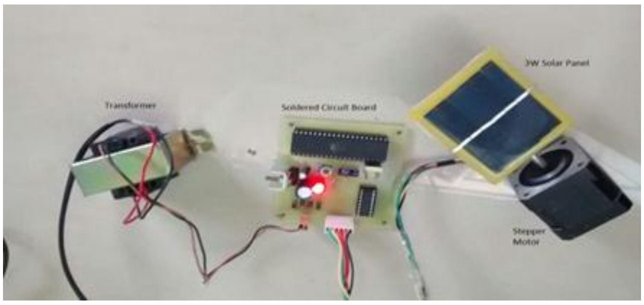


Fig.6. Single Axis Solar Tracker Testing

Fig.7. Dual axis Solar Tracker Testing

The testing of the dual-axis solar tracker was done for two different days on 16th May, 2015 and 18th, May 2015 at the MIT quadrangle. The testing was done from 9AM in the morning till 3PM in the evening. Readings were taken at every 30 minutes from the starting of the test.

Fig.8. LCD status displaying the Light Intensities of different LDR Sensors

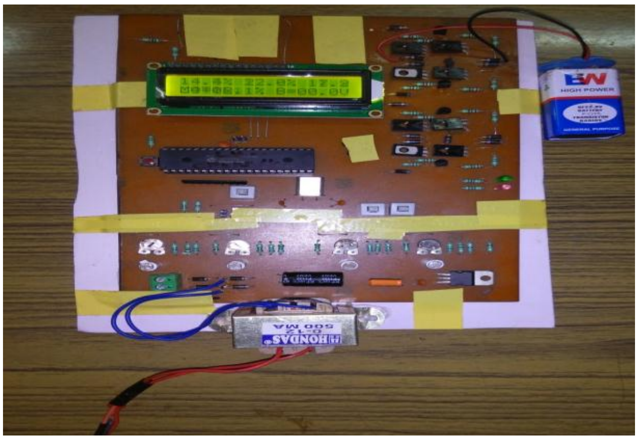


Fig.9. Hardware Components mounted (soldered) On the main Circuit Board

Tools Used:

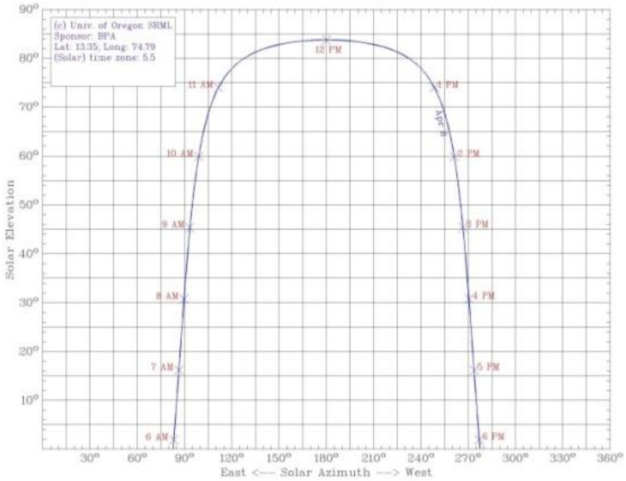
- For implementing and testing the microcontroller code, the Software used is Keil µvision.
- For dumping the code on to the IC Program Dumper is used.
- Multimeter was used to measure the voltages and currents at different positions and time of the solar panel on a particular day.

3.Result analysis

The results obtained by the implementation of the Single Axis Solar Tracker and the Dual Axis Solar Tracker along with the calculations/graphs involved are discussed and analysed briefly in this chapter.

Results and Analysis of the Single Axis Solar Tracker

Sun's Path (Plot of Altitude vs Azimuth angles) over Manipal on 8th April, 2015[14]:



Plot.1. Altitude vs Azimuth angles

Comparison of theoretical and practical values of Solar Angles for 8th April 2015:

Time	Azimuth angle (practical)	Azimuth angle (Theoretical)	Altitude angle (Practical)	Altitude angle (Theoretical)
6 AM	80.25	78	2.5	3
7AM	82	80	17	17.3
8 AM	90	87	31	29.5
9 AM	93.5	91	45	44
10 AM	96.7	96	60	61
11 AM	107	106.5	74	73.5
12 PM	180	173.46	84	82.93
1 PM	247	240	106	104.33
2 PM	258.75	254.3	60	58.2
3 PM	267	266.1	44	43.2
4 PM	270	268	32	31.3
5PM	273.75	271	17	15.2
6 PM	275.25	273	4	3.29

Table.2.Comparison of Solar Angles

The theoretical values of Solar Azimuth angle, Solar Altitude angle and other calculated parameters were obtained using the equations[8][9].

Various Calculated Parameters for 8th, April, 2015 at 12 noon:

1	Hour Angle	0
2	Declination Angle	6.327
3	Latitude Angle	13.347
4	Altitude Angle	82.93
5	Zenith Angle	7.07
6	Azimuth Angle	173.46
7	Tracking Angle (east-west)	7.02

Table.3.Various angles

Results and Analysis of the Dual Axis Solar Tracker:

The measured output voltage(s) and current(s) of the panel with the help of a multimeter in the following stages on two different days:

 Using the tracker
 Without using the tracker

The data obtained is as follows and the results are plotted and compared on a line chart.

Current and Voltage data obtained using the Dual Axis Tracker on 16th, May, 2015:

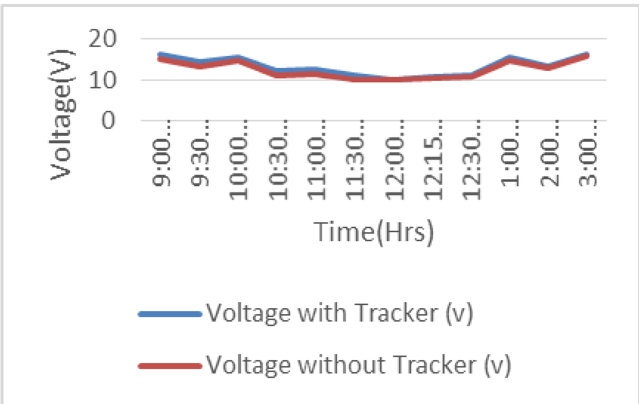
Time	Voltage (v)	Current (Amp)	Power (W)
9 AM	16.23	0.1477	2.3971
9:30 AM	14.34	0.3214	4.6088
10 AM	15.67	0.1366	4.9611
10:30 AM	12.45	0.3347	4.167
11 AM	12.77	0.1897	2.422
11:30 AM	11.21	0.2149	2.409
12 PM	10.21	0.3510	3.583
12:15 PM	10.99	0.373	4.099
12:30 PM	11.26	0.3678	4.141
1 PM	15.46	0.1725	2.666
2 PM	13.45	0.3466	4.661
3 PM	16.2	0.189	3.061

Table.4. Data obtained using the Tracker

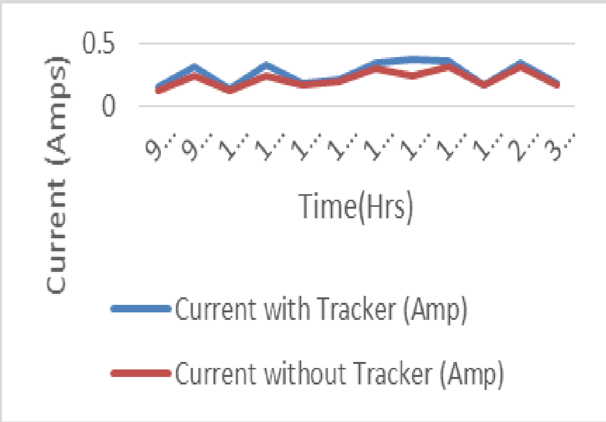
Current and Voltage data obtained without the Dual Axis Tracker on 18th, May, 2015:

Time	Voltage (v)	Current (Amp)	Power (W)
9 AM	15.31	0.1270	1.94437
9:30 AM	13.54	0.2368	3.206272
10 AM	14.98	0.1256	1.881488
10:30 AM	11.29	0.2358	2.662182
11 AM	11.48	0.1687	1.936676
11:30 AM	10.15	0.2021	2.051315
12 PM	10.01	0.3011	3.014011
12:15 PM	10.54	0.2373	2.501142
12:30 PM	10.97	0.3233	3.546601
1 PM	15.02	0.1686	2.532372
2 PM	13.11	0.3201	4.196511
3 PM	15.8	0.1654	2.61332

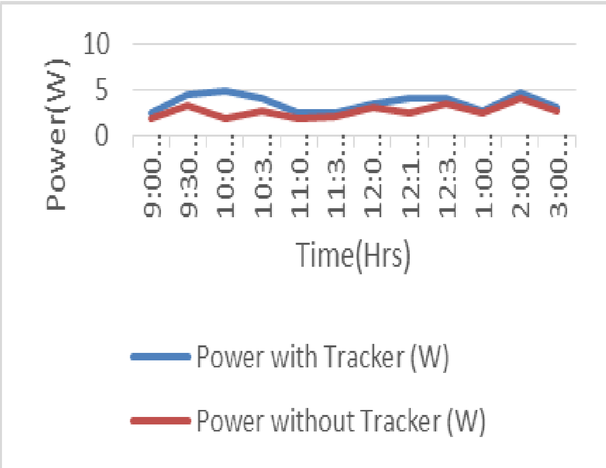
Table.5. Data obtained without the Tracker



Plot.2. Comparison of Voltage(s) vs Time



Plot.3. Comparison of Current(s) vs Time



Plot.4.Comparison of Power(s) vs Time

3. Conclusion:

The solar energy maximum utilization depends upon determining the precise location of the sun position. The design, modeling and testing of an active single-axis and dual-axis solar trackers were presented. The experimental results show that the solar panel on which the solar cell is mounted remains almost perpendicular to the Sun's rays at all times from 9 AM to 3 PM. The voltage, current and power plots show that there is an increase in efficiency in the power output in the panel which uses the dual axis tracker. This also shows that the dual axis tracker can be replaced as the best option compared to any other solar tracker which uses a microcontroller and motor drives. Therefore, the Dual axis Sunflower Solar Tracker which is used here can be cost effective and fairly efficient can be a huge turnaround in India's future of renewable solar energy. LDR Sensor based Dual axis Solar Tracker is a very simple approach than the Single Axis. Solar Tracker which is based on a delay timer because, the former uses the Light Intensities received from the sunlight and adjusts the panel accordingly thereby saving the power used for the tracker which in turn increases the efficiency.

Hence, this Project infers that, by using this model, the power output of a solar panel can be increased drastically since the panels take in more sunlight due to the tracking system applied.

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