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Solar Tracker Design and Efficiency Comparison with that of Conventional Solar energy harnessing Method

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Abstract— This paper proposes a Dual Axis solar tracker alternative which uses a simple arrangement which does not require any type of programming and computer to perform tracking. This tracker uses additional mini solar panels which control motors for movement in all axes. This paper also takes efficiency difference of solar tracker with that of flat panel arrangement. Hence paper is trying to find the practicality of solar tracker in domestic cases.

Index Terms—Dual Axis Solar Tracker, Flat Panel, Efficiency, Power Logger, PV Panel, Arduino Uno.

1 Introduction

The need for renewable energy, such as sunlight, wind, rain, tides and geothermal heat is ever increasing, since these resources do not runout in human existence. Therefore, for all practical purposes, these resources can be considered to be inexhaustible, unlike dwindling conventional fossil fuels. This can be a major concern for all.

Solar energy is one of the best renewable energy that is sustainable and in-exhaustible. The use of solar panel has enabled humans to harvest this energy in an effective way, but these panels have low efficiency and the sun is not stationary throughout the day.

The introduction of solar tracker was a breakthrough in commercial sector as it allowed us to adjust the panels to get the maximum energy out of the sun. But they require large amount of geographical data and programming data which requires microprocessors.

This project utilises motors and solar panel to find a cheaper yet efficient way to track solar energy, thus making solar tracker practical in household and small-scale applications.

The aim of this project is to show a unique and simple way of implementing a solar tracker. Moreover, to show how much efficient it is when compared to normally placed solar panels.

2 Component Description

Various components used were:

1. Solar Panel 17V, 20 W
2. Mini Solar Panel 12V, 2.4 W
3. Aluminium pipes, rods
4. DC Motor 6V
5. Arduino UNO
6. INA 219
7. TP4056
8. OLED panel
9. SD card PCB
10. Li-ion Battery

1. Solar Panel: This is the primary panel. It is used for the energy harness. It is of the dimension 36x36x2cm panel. Its output is taken and recorded.

2. Mini Solar Panel: These are considered secondary panels. They are used for the control of the direction where the primary panels face with the help of motors. They are of dimension 12x5x0.3cm. They are mounted on an aluminium frame.

3. Aluminium pipes and Rods: These comprise the frame of the project. The base support, stands and other parts are made with aluminium. This makes the prototype light weight and easy to move.

4. DC Motor: The motor is used for control of the tracking. The motor used here is a geared 6V DC motor rotating at 20rpm. This makes the motor movement slow and deliberate and enables it to heavier loads.

5. Arduino UNO: It is the development board which is used to measure the voltage, current and power of the solar panel at different intervals of time. Arduino Uno is used since it is easy to program and cheaper.

6. INA 219: Its an I2C interface IC which is used to measure voltage and current thereby power of any I2C device. This is done by taking connections across the in-built shunt in the IC.

7. TP4056: It is an IC which regulates the voltage input into the Arduino. This IC is used to charge the Li-Ion battery which powers the circuit.

8. OLED panel: It is a 0.96inch panel, which is used to display the current, voltage and power values for reference.

9. SD Card PCB: This PCB is interfaced with Arduino Uno. This is useful as the data is logged in a SD-card. This data can be used for comparison and making various graphs and tables.

10. Li-on Battery: It is a rechargeable battery used for powering the circuit.

3 SOLAR TRACKER PROTOTYPE

The primary panel casts shadow on the secondary panel. When the sun hits from an angle which casts a ray on the secondary panels, the motor may be set to rotate clockwise or anti clockwise depending on which panel the light hits. Secondary panel consist of 5 mini solar panels. They are used to power two geared Motor. Horizontal panel moves the system using one motor while the vertical panel moves the system using the other.

The figure represents the Tracker system controller. It makes the system move by powering motor by small panels. Thus, it makes the arrangement super simple and both the x and y axis can be controlled by it.
The secondary panel is the main panel which is used to control the dual axis tracking of the solar panel. This basically consists of 5 panel, each control the positive and the negative part of each axis. These panels are designed such that they can control the entire motor arrangement to function as a tracker.
A metal rod of 30cm is used as a base. Each side has panels that control the axis which is required. There is a single motor which is connected to both the panels. The wiring of the first panel, is done positive wire to positive terminal and negative wire to negative terminal of the panel and motor respectively. After this, the second panel is wired opposite to that of the first panel, i.e., positive wire to negative terminal and negative wire to positive terminal of the panel and motor respectively.
This makes the motor rotate clockwise by the use of first panel and the wiring by the second panel makes it rotate counter-clockwise. These rotations make it possible to cover the entire x-axis by the single system.
This step is repeated with 2 more panels which is kept vertical, as shown in figure. They are wired in the same way as horizontal panel.
There is also a 5th panel. We know that at day time, the solar tracker will rotate in only one direction from east to west. For the next day, the solar panel needs to go to the initial position in the morning to track the sun's position again. To do so, a solar panel is kept behind the main structure. The tracker will rotate reversely in the eastern direction to set the tracker to the initial position for the next day. When it goes to initial position, primary solar panel takes sunlight input and thus power the motor. So, the tracker will start to move according to the sun position till the next morning. The work to rotate the panel to its original position is done by the 5th panel.

This figure shows the working model of the solar tracker system. The whole system is light-weight as panel casing is removed and structure is made of aluminium. With proper casing and wiring the whole system can be made waterproof. Thus, ensuring the functioning of the entire project during any season.

4 VOLTAGE, CURRENT AND POWER MEASUREMENT

The voltage and current and thereby the power of the solar panel output is done using the power logger. This circuit is not the part of the project but is plays an essential role in determining the efficiency of the Dual axis tracking.

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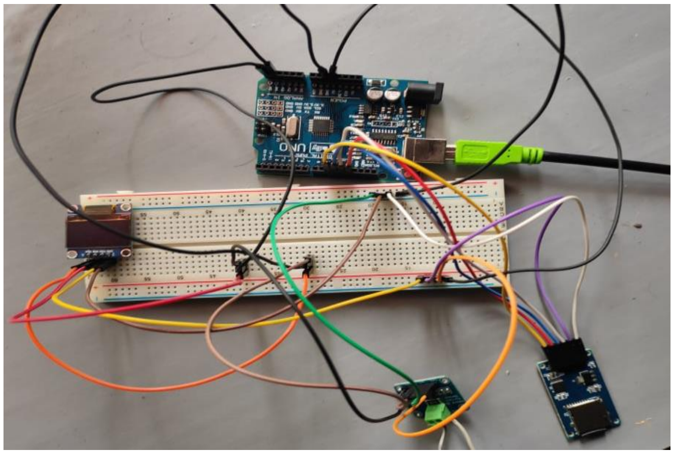
Power Logger is a device which acts as an energy meter which is usually seen in household power calculation. The solar panel output is connected as load for power logger.



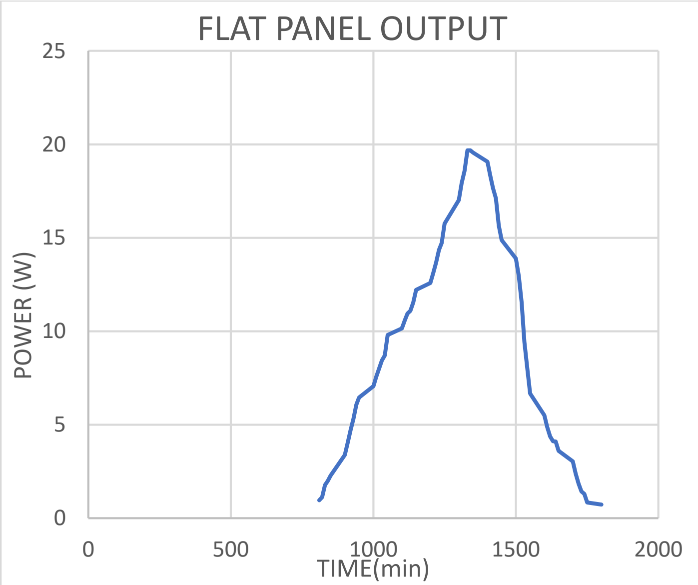
6 FLAT PANEL DATA AND OUTPUT

The Solar panel was laid flat on the ground. Then the positive of the solar panel was connected to the positive of the INA 219 and Arduino arrangement. This arrangement is kept outside from 8:00AM in the morning to 6:00PM in the Evening. This gives us a 10 hours of data collection time. The data collection interval is set 10 minutes, so in every 10 min data is collected and stored in the word file. This gives us a total data of 60 values. This arrangement is repeated for 3 days and average of these output is taken.

Sno.	Time	Volt	Amp	Power(W)
1	810	4.8	0.23	0.96
2	820	5.6	0.27	1.12
3	830	6.1	0.29	1.769
4	840	6.4	0.31	1.984
5	850	7.1	0.32	2.272
6	900	8.9	0.38	3.382
7	910	9.6	0.42	4.032
8	920	10.7	0.44	4.708
9	930	11.3	0.47	5.311
10	940	11.9	0.51	6.069
11	950	12.4	0.52	6.448
12	1000	12.6	0.56	7.056
13	1010	12.8	0.59	7.552
14	1020	13.1	0.61	7.991
15	1030	13.4	0.63	8.442
16	1040	13.6	0.64	8.704
17	1050	13.8	0.71	9.798
18	1100	14.1	0.72	10.152
19	1110	14.3	0.74	10.582
20	1120	14.4	0.76	10.944
21	1130	14.4	0.77	11.088
22	1140	14.6	0.79	11.534
23	1150	14.9	0.82	12.218
24	1200	14.8	0.85	12.58
25	1210	14.9	0.88	13.112
26	1220	15.2	0.9	13.68
27	1230	15.6	0.92	14.352
28	1240	15.5	0.95	14.725
29	1250	15.6	1.01	15.756
30	1300	15.9	1.07	17.013
31	1310	16.3	1.1	17.93
32	1320	16.3	1.14	18.582
33	1330	16.4	1.2	19.68
34	1340	16.4	1.2	19.68
35	1350	16.3	1.2	19.56
36	1400	16.3	1.17	19.071
37	1410	16.1	1.14	18.354
38	1420	15.9	1.11	17.649
39	1430	15.7	1.09	17.113
40	1440	15.5	1.01	15.655
41	1450	15.5	0.96	14.88
42	1500	15.1	0.92	13.892
43	1510	14.9	0.87	12.963
44	1520	14.8	0.78	11.544
45	1530	14.3	0.66	9.438
46	1540	14.1	0.57	8.037
47	1550	13.6	0.49	6.664
48	1600	13.1	0.42	5.502
49	1610	12.8	0.38	4.864
50	1620	12.5	0.35	4.375
51	1630	12.1	0.34	4.114
52	1640	11.7	0.35	4.095
53	1650	10.9	0.33	3.597
54	1700	9.8	0.31	3.038
55	1710	8.5	0.28	2.38
56	1720	7.7	0.24	1.848
57	1730	6.8	0.21	1.428
58	1740	5.9	0.22	1.298

TOTAL TIME - 10 Hrs
TIME INTERVAL - 10 min.
TOTAL VOLTAGE - 751.6 V
TOTAL CURRENT - 39.51 A
TOTAL POWER - 554.13 W
AVERAGE POWER - 9.2355W

We can plot the graph using the data above with X-axis as Time in minutes and Y axis as Power in Watts.



From the graph we can infer that the output of the flat panel peaks at time between 1:00PM and 2:30PM. This is a one-and-a-half-hour window where we get maximum efficiency for the flat panel system. This is a very small window in a day. It is seen that an average output window is between 11:00AM and 3:00PM. We can also observe that after this window the solar output is really low and honestly negligible. Thus, it is clear that Flat panel are not very efficient in solar energy collection. These values drastically vary in cloudy and rainy day.

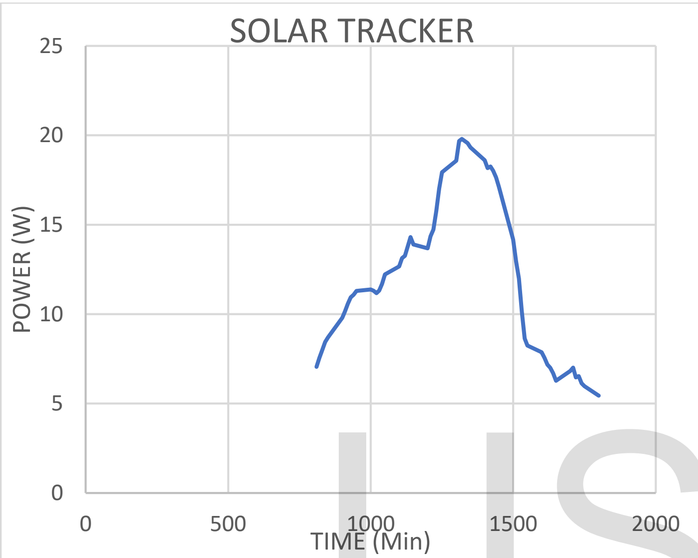
7 SOLAR TRACKER DATA AND OUTPUT

The arrangement is same for the solar-tracker. The system is placed under sunlight. Then the positive of the solar panel was connected to the positive of the INA 219 and Arduino arrangement. This arrangement is kept outside from 8:00AM in the morning to 6:00PM in the Evening. This gives us a 10 hours of data collection time. The data collection interval is set 10 minutes, so in every 10 min data is collected and stored in the word file. This gives us a total data of 60 values. This arrangement is repeated for 3 days and average of these output is taken.

Sno.	Time	Volt	Amp	Power(W)
1	810	12.6	0.56	7.056
2	820	12.8	0.59	7.552
3	830	13.1	0.61	7.991
4	840	13.4	0.63	8.442
5	850	13.6	0.64	8.704
6	900	13.8	0.71	9.798
7	910	14.1	0.72	10.152
8	920	14.3	0.74	10.582
9	930	14.4	0.76	10.944
10	940	14.4	0.77	11.088
11	950	14.3	0.79	11.297
12	1000	14.4	0.79	11.376
13	1010	14.5	0.78	11.31
14	1020	14.7	0.76	11.172
15	1030	14.7	0.77	11.319
16	1040	14.8	0.79	11.692
17	1050	14.9	0.82	12.218
18	1100	14.9	0.85	12.665
19	1110	15.1	0.87	13.137
20	1120	14.9	0.89	13.261
21	1130	15	0.92	13.8
22	1140	14.9	0.96	14.304
23	1150	15.1	0.92	13.892
24	1200	15.2	0.9	13.68
25	1210	15.6	0.92	14.352
26	1220	15.5	0.95	14.725
27	1230	15.6	1.01	15.756
28	1240	15.9	1.07	17.013
29	1250	16.3	1.1	17.93
30	1300	16.3	1.14	18.582
31	1310	16.4	1.2	19.68
32	1320	16.5	1.2	19.8
33	1330	16.4	1.2	19.68
34	1340	16.3	1.2	19.56
35	1350	16.1	1.2	19.32
36	1400	15.9	1.17	18.603
37	1410	15.8	1.15	18.17
38	1420	15.6	1.17	18.252
39	1430	15.8	1.14	18.012
40	1440	15.9	1.11	17.649
41	1450	15.7	1.09	17.113
42	1500	15.4	0.92	14.168
43	1510	14.9	0.87	12.963
44	1520	14.8	0.81	11.988
45	1530	14.3	0.71	10.153
46	1540	13.5	0.64	8.64
47	1550	13.3	0.62	8.246
48	1600	12.9	0.61	7.869
49	1610	12.8	0.59	7.552
50	1620	12.6	0.57	7.182
51	1630	12.5	0.56	7
52	1640	12.4	0.54	6.696
53	1650	12.3	0.51	6.273
54	1700	12.4	0.55	6.82
55	1710	12.3	0.57	7.011

56	1720	12.2	0.53	6.466
57	1730	12.1	0.54	6.534
58	1740	11.8	0.52	6.136
59	1750	11.7	0.51	5.967
60	1800	11.1	0.49	5.439

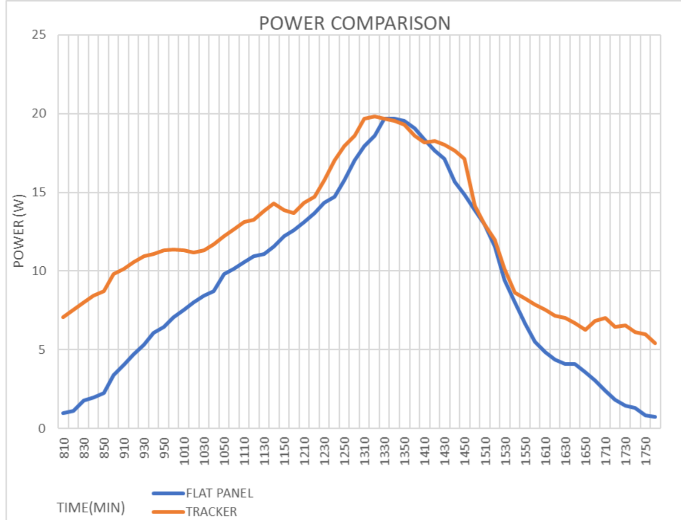
TOTAL TIME - 10 Hrs
TIME INTERVAL - 10 min.
TOTAL VOLTAGE - 860.8 V
TOTAL CURRENT - 49.22 A
TOTAL POWER - 724.73 W
AVERAGE POWER - 12.079W



From the graph we can infer that the output of the flat panel peaks at time between 12:00PM and 3:00PM. This is a Three-hour window where we get maximum efficiency which is double of that for the flat panel system. This is a comparatively bigger window in a day. It is also seen that an average output window is between 09:00AM and 3:30PM. This is much better than flat panel. We can also observe that after this window the solar output is much better than that of flat panel.
Thus, it is clear that solar tracker is much more efficient in solar energy collection than Flat panel. It is also noted that these values drastically vary in cloudy and rainy day.

8 RESULTS

Comparison of both flat panel and solar tracker arrangement is based on the power output of both the system. They are plotted together to see which system is better. But, from the previous data it is obvious that Solar tracker is the better option from the two available options.



The Power output of both flat panel and solar tracker was calculated with the help of a Power Logger. This was done with the help of Arduino and INA219 IC which was used to calculate both Voltage and Current. By multiplying both these values power was calculated. This power was logged in the interval to 10 minutes. After doing these reading simultaneously, following results were obtained:

1) Flat panel system's average power output was found to be 9.2355W.

2) Peak values were sustained from 1:00PM to 2:30PM with average value sustained from 11:00AM to 3:00PM. Following before and after this time, there is a significant drop in the power output. This makes these time negligible for energy harnessing.

3) Solar tracker system's average power output was found to be 12.079W.

4) Peak values were sustained from 12:00PM to 3:00PM with average value sustained from 9:00AM to 3:30PM. Following before and after this time, a significant drop in the power output is observed. But this drop is satisfactory because of the fact that there are only few hours left with adequate sunlight. Moreover, these drops are not as poor as that of Flat panel system.

5) Difference in power between both the system is found to be 2.8435W.

6) By comparing the difference and taking it as output with input being the flat panel average power value, the efficiency was calculated to be 30.78%.

7) By observing the graphs and average outputs and the results obtained so far, it was clear that Flat panel is not adequate enough at domestic level. Though they are cheaper,

low maintenance, mediocre output. The power harnessing of solar tracker outweighs the advantages.

9 CONCLUSIONS

The use of Dual Axis Tracking can be an extremely useful tool which is conclusive from the result obtained so far. For a domestic level with limited area to start with, solar tracker is surely a viable solution. In the case of limited area, maintenance cost is significantly low and the output is much better than that of fixed mount.

Production of large amount of solar energy required an extremely large amount of area. The solar trackers, though efficient where never fully utilised in normal household because it was considered to be simply not worth it which was not true. Moreover, the technology improvement has increased the solar cell efficiency exponentially and since the growing population requiring larger area, more compact and versatile innovations are always welcomed. This project can tackle all these problems to get a better version of already a great resource.

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