Design and Fabrication of Semi Automatic Dual Axis Solar Tracking and Experimentally Analysis Its Efficiency

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***Abstract*:-Several studies reflect that, scholars had made many researches on solar panels, Conversion of solar energy into electric energy, tracking of sun, etc. In continuation to aforesaid research, this paper highlights the work done in experimenting with the Semiautomatic Dual Axis Solar Tracking of solar panels. Eventually some researchers had done sun tracking through the LDR, light sensor and photo detector. And it has been observed that these tracking systems, help in generating 20-23% extra power in comparison to fix axis solar panel system. We have deployed the solar tracking system and experimented using the Actuator (by programming C) which was optimised with the help of Keil software through microcontrollers. The actuator designed by me has Motor which runs via C programming and is based on displacement. Thus, it is 5 times cheaper than other tracking system counterpart available in market value. Experiment was conducted in Madhya Pradesh state located in centre of India and has about 300 sunny days per year with annual mean daily global solar radiation in the range of 5-7 kWh/m^2/day. Hence, the experiment duration chosen for tracking SUN was from 8am *(IST)* to 4pm*(IST)*, during which sun rays are almost perpendicular on the panel. During my study, it was observed that the other technology/equipments used for sun tracking, were less successful mainly because of seasonal variations and unable to move according to Sun path. These gaps were overcome to large extent through programming-based motor operated Actuator, where the Sun can be tracked in all the seasons*(Summer, Spring, Monsoon, Winter)*ensuring that Sun rays are perpendicular and helps in maximizing output at a reasonable cost. Although initially it is costly in comparison to fix axis panel, but in long run yields to more maximum output.**

***Keywords:* Solar energy, solar tracker, actuator, solar panel, Single axis tracking, Dual axis tracking, Keil software, microcontroller, Proload software.**

I. INTRODUCTION

1.1 Energy

Energy plays a pivotal role in our daily activities, this when coupled with development and civilization of any country is measured by the amount of utilization of energy by human beings. Energy demand is increasing day by day due to increase in population, urbanization, industrialization, etc. The world's fossil fuel-based supply viz. coal, petroleum and natural gas are depleting at fast pace and would be finished in a coming few decades. The rate of energy consumption is increasing but supply is depleting resulting in inflation and energy shortage. This cascade effect is termed as Energy crisis. This crisis can be mitigated by using alternative or renewable sources of energy which could be developed to meet future energy requirement.

1.2 Energy from Sun

Sun is hot ball of gases in which hydrogen is continuously undergoing nuclear fusion, resulting in production of heat and light. In one minute, the sun provides enough energy to supply the world's energy needs for one year. In one day, it provides more energy than the world's population could consume in 27years. India lies in the high solar insolation region, endowed with huge solar energy potential. So, harnessing this unlimited and free source can cater to all the energy needs of the country. The country receives an average radiation of 5-7KWh per square meter (m) per day and with 2300 to 3200 sunshine hours per year. The potential of solar photovoltaic has therefore been estimated at 20 MW per square km and that of solar thermal applications at 35 Mw per sq. m. As on February 2019, the solar installed capacity stands at 26GW.

1.3 Converting Solar Energy into Electrical Energy

Based on technology and its application, there are two ways mainly Thermal and Photovoltaic for converting solar energy into electrical energy. (refer figure-1,2,3)

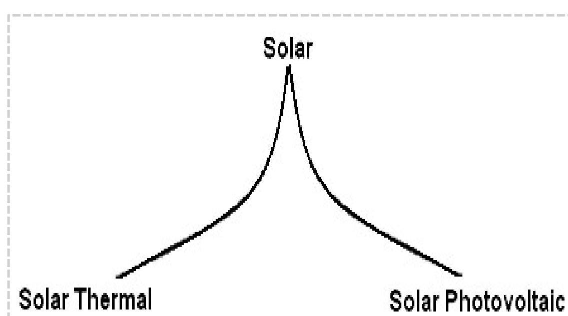

Figure 1: Ways of Converting Solar Energy into Electrical Energy[1]

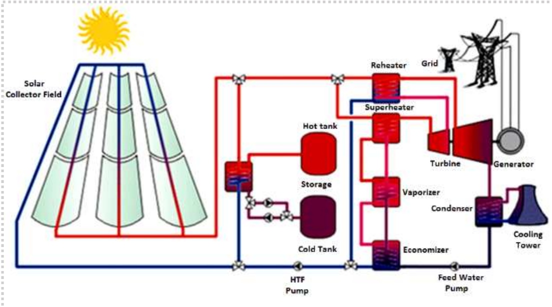

Figure 2: Solar Thermal Power Plant

Both Solar Thermal and PV are promising and provide clean, safe and strategically sound alternatives to current methods of electricity generation.

A) Solar thermal applications consist of solar collectors concentrate sunlight to heat a heat transfer fluid to a high temperature. The hot heat transfer fluid is then used to generate steam that drives the power conversion subsystem, producing electricity. Thermal energy storage provides heat for operation during periods without adequate sunshine.

B) Solar Photovoltaic uses Photovoltaic cells made from silicon that converts the solar energy falling on them directly into electricity. Presently photovoltaic is majorly used in Large scale applications for power generation, either via rooftops of houses/buildings or ground mounted, which is connected to the utility grid.[1]

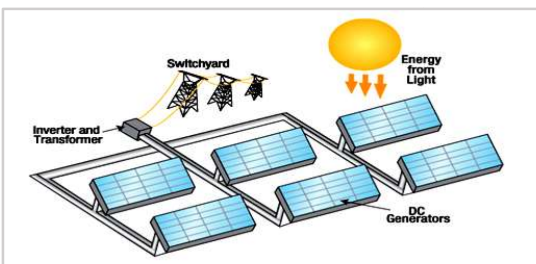

Figure 3: Solar Photo-Voltaic Power Plant[1]

II. LITERATURE REVIEW

J. Rizk, [2008], World Economy of Science Engg. & Tech. states the potential system benefits of simple tracking solar system using a stepper motor and light sensor. A solar tracking system is reportedly designed, implemented and experimentally tested. The design details and the experimental results are discussed. A solar tracker is designed employing small solar cells to function as self-adjusting light sensors, providing a variable indication of their relative angle to the sun by detecting their voltage output. By using this method, the solar tracker is found to be successful in maintaining a solar array at a sufficiently perpendicular angle to the sun. The power increase gained over a fixed horizontal array was in excess of 30%. [2]

Nader Barsoum [2010], states that research has proved that solar tracking system with single-axis freedom can increase energy output by approximately 20%, whereas the tracking system with double axis freedom can increase the output by more than 40%. Therefore, this work was to develop and implement a solar tracking system with both degree of freedom and which detects the sunlight using sensors. This Peripheral Interface Controller was the brain of the entire tracking system, and it was programmed to detect the sunlight through the sensors and then actuate the motor to position where maximum sunlight could be illuminating the surface of the solar panel. This is programmed to detect the sunlight using the photocells and then actuate the motor to position the solar panel where it can receive maximum sunlight.[3]

III. RESEARCH METHODOLOGY

To develop a solar tracking system that could work under all-weather Indian conditions

3.1 Design & fabrication of structure for Dual Solar Tracking system.

Figure 4: Structure of Solar Panel

3.2 Design of Actuator Arm for solar time tracking & its programming

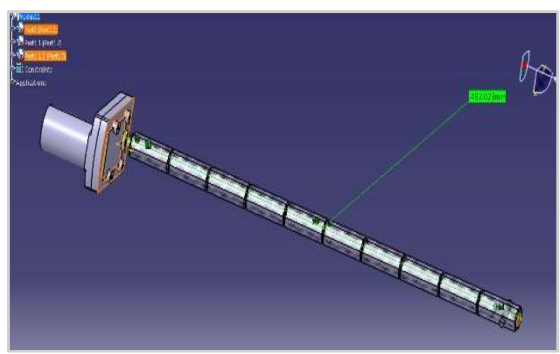

Figure 5: Linear Actuator Design on Catia Softwere

- We purcase a 1500N DC motor whose shaft is fitted by acme threads screw bar of 480mm is fitted with the help of key hole.
- 10 bolts of 50mm are screwed on screw bar and bolts are welded in a series.
- The size of this bolt bar is 500mm, and we drill on this bolt bar after leaving 10mm gap from the top, and a hook is fitted with the help of nuts and bolts.

Figure 6: Linear Actuator

3.3 Toincrease the power efficiency by dual tracking and compare it with non-tracking system. (See Result)

IV. RESEARCH APPROACH

Theoretical and experimental research work has been done to provide an economically feasible system which is described above and to develop a practical system based on above concept. The following work has been done:

1. A semiautomatic dual axis solar tracking system analysis of each part and of all process has been done individually.
2. An experimental model has been developed which might be helpful in the study of the performance of the solar system.
3. On the basis the theoretical analysis and various research work which had been carried out earlier, a new the experimental setup has been made, which includes

V. METHODOLOGY

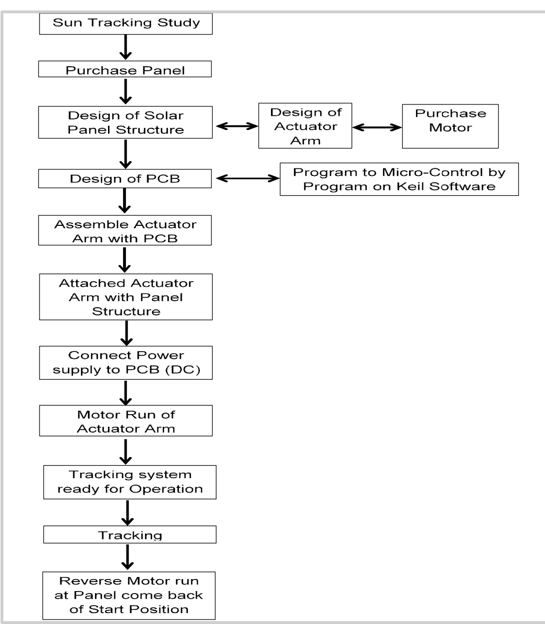

Figure 7:Flowchart for Experiments Methodology.

5.1 Concepts on Solar Radiation

Before talking about the solar tracking systems, we will review some basic concepts concerning solar radiation and mention some important values to better understand the results of this work.

The sun, at an estimated temperature of 5800K, emits high amounts of energy in the form of radiation, which reaches the planets of the solar system. Sunlight has two components, the direct beam and diffuse beam. Direct radiation (also called beam radiation) is the solar radiation of the sun that has not been scattered (cause shadow). Direct beam carries about 90% of the solar energy, and the "diffuse sunlight" that carries the remainder. The diffuse portion is the blue sky on a clear day and increases as a proportion on cloudy days diffuse radiation is the sun radiation that has been scattered (complete radiation on cloudy days). Reflected radiation is the incident radiation (beam and diffuse) that has been reflected by the earth. The sum of beams diffuses, and reflected radiation is considered as the global radiation on a surface. As most of the energy is in the direct beam, maximizing collection requires the sun to be visible to the panels if possible.[4]

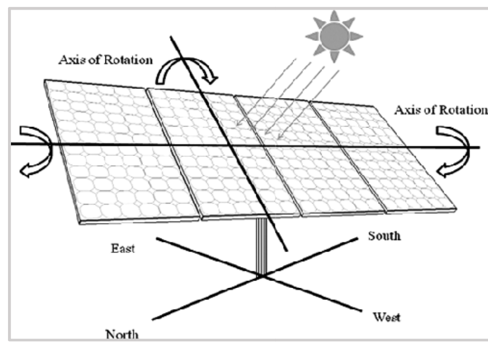

Figure 8: Dual Axis Tracking Solar System

5.1.1 Need for Solar tracker

The energy contributed by the direct beam drops off with the cosine of the angle between the incoming light and the panel.

Misalignment (angle*i)*	Direct power lost(%) =1-cos(i)
0^0	0
1^0	.015
3^0	.14
8^0	1
23.4^0	8.3
30^0	13.4
45^0	30
60^0	>50

75^0	>75

Table 1: Direct Power Lost (%) due to Misalignment (Angle i)

The sun travels through 360 degrees east-west a day, but from the perspective of any fixed location the visible portion is 180 degrees during a 1/2-day period. Local horizon effects reduce this somewhat, making the effective motion about 150 degrees. A solar panel in a fixed orientation between the dawn and sunset extremes will see a motion of 75degrees on either side, and thus, according to the table above, will lose 75% of the energy in the morning and evening. Rotating the panels to the east and west can help recapture these losses. Atrack errotating in the east-west direction is known as a single-axis tracker. The sun also moves through 46 degrees north-south over the period of a year. The same set of panels set at the midpoint between the two local extremes will thus see the sun move 23degrees on eitherside, causing losses of 8.3% Atracker that accounts for both the daily and seasonal motions is known as a dual-axis tracker.[5]

5.2 Printed circuit board

A **printed circuit board** (**PCB**) mechanically supports and electrically connects electronic components or electrical components using conductive tracks, pads and other features etched from one or more sheet layers of copper laminated onto and/or between sheet layers of a non-conductive substrate. Components are generally soldered onto the PCB to both electrically connect and mechanically fasten them to it.

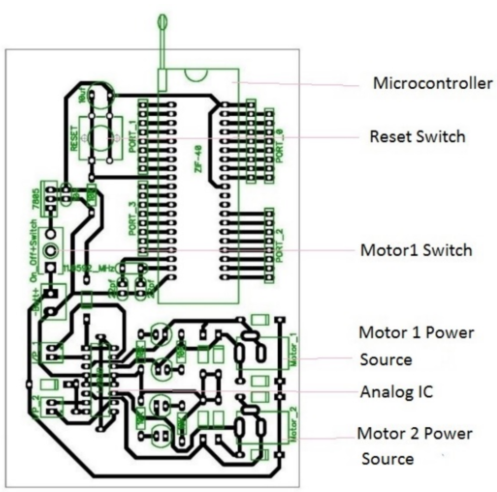

Figure 9: PCB Design for Linear Actuator

5.3 Microcontrollers

Microcontrollers can perform very similar tasks as PLCs, but the size of the device is much smaller. A processor, memory, and the input/output peripherals are all embedded into a single integrated circuit (IC) about the size of a fingernail. They are very cheap, costing around RS.20 for a single IC. But the disadvantage of microcontrollers is that they are made to control small appliances. Communication terminals such as LAN are not common in microcontroller boards, unlike the PLCs. So, using microcontrollers for solar tracking in a power plant is not very feasible in terms of status monitoring and controlling them for maintenance. But it would be the best option for a home use tracker or for a prototype.

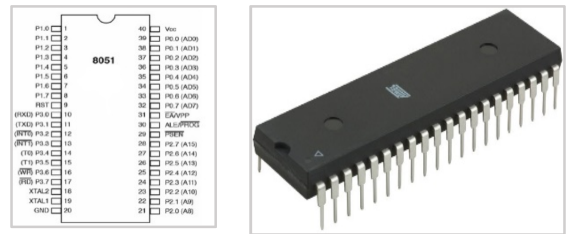

Figure 10: Microcontroller[6]

5.4 KEIL Software

The Keil Software LPC2148 development tools listed below are programs you use to compile your C code, assemble your assembly source files, link and locate object modules and libraries, create HEX files, and debug your target program.[7]

Program for Microcontroller by Keil

#include<STDIO.h>
#include<at89x52.h>
void delay(int);
void main()
{
while(1)
{
int x=0;int y=0; long z=0;
while(x<=430)
{
P0_0=0;
P0_1=1;
delay(60);
P0_0=1;
P0_1=1;
delay(3540);
x++;
}
while(y<=430)
{

P0_0=1;
P0_1=0;
delay(60);
P0_0=1;
P0_1=1;
delay(3540);
y++;
}
P0_0=1;
P0_1=1;
delay(360000);
}
}
void delay(int t)
{
int k,i;
for(i=0;i<=1000;i++)
{
for(k=0;k<=t;k++);
}
}

Table 2: Algorithm of KEIL Micro-controller-basedProgram

5.5 Proload

The function of Proload software is to accepts only hex files. After the conversion of machine code into hex code, that hex code must be dumped into the microcontroller placed in the programmer kit and this is done by the Proload. Programmer kit contains a microcontroller on it other than the one which is to be programmed. This microcontroller has a program in it written in such a way that it accepts the hex file from the Keil compiler and dumps this hex file into the microcontroller which is to be programmed.

As this programmer kit requires power supply to be operated, this power supply is given from the power supply circuit designed above. It should be noted that this programmer kit contains a power supply section in the board itself but in order to switch on that power supply, a source is required. Thus, this is accomplished from the power supply board with an output of 12volts or from an adapter connected to 230 V AC.

a) Install the Proload Software in the PC.
b) Now connect the Programmer kit to the PC (CPU) through serial cable.
c) Power up the programmer kit from the ac supply through adapter.
d) Now place the microcontroller in the GIF socket provided in the programmer kit.
e) Click on the Proload icon in the PC. A window appears providing the information like Hardware model, com port, device type, Flash size etc. Click on browse option to select the hex file to be dumped into themicrocontroller and the n click on “Auto program” to program themicrocontr oller with that hex file.
f) The status of the microcontroller can be seen in the small status window in the bottom of the page.
g) After this process is completed, remove the microcontroller from the programmer kit and place it in your system board. Now the system board behaves according to the program written in the microcontroller.[8]

VI. EXPERIMENTAL DESIGNSETUP

For experimental purpose, 240 W panel having an efficiency~ 85% was chosen.

Structure of solar panel is designed as shown in the figure 11.

Figure 11: semi-automatic dual axis solar system.

- In the very beginning we prepared its base which is made up of rectangular hollow steel bar which is like (1”×2”×50”).
- In this bar, we fitted 50” long bar which is marked with 3 points leaving 2.5” on both the end and the distance of 20” in the supporting base which is (1” ×2”×30).
- At the centre, 2 bars are fitted in a perpendicular manner so that, it makes gap of 2”, the perpendicular bar is (1”×2”×35”).
- From the centre at a distance of 10” screw bars are welded, on this screw bars 2 springs are placed which provide upward force on C section.
- With the help of rectangular hollow bar, one C section is fabricated, the complete base is of 50” (1” ×2”×50”) out of which 48” is for inside.
- The size of rectangular bar at both the ends on C section is (1”×2”×16”).

- rectangular holes are provided on C section base at both the sides from the centre at a gap of 10”
- C section is fitted over the screw bars in such a way that the screw bars passed through the rectangular holes. At both the side of a rectangular hole in the screw 2 nuts are fitted.
- With the help of these screw nuts, we provide angle to the panel at south direction.
- A frame is made up of an iron angle, whose diagonal on either side is 50.30”. This frame in C section is fitted from the centre with the help of nut and bolt which shows periodic motion. This motion is provided by linear actuator.
- To balance the frame, 4 springs are used, which adjusts the frame from all the sides in the C section.

Also, an actuator is used which runs by a programming helps to track effectively.

VII. OBSERVATIONS & RESULTS

7.1 Observations on Typical Clear and Sunny Day

A set of readings are also taken on summer day (27 March 2017). The table shows the overall average values of fixed panel output, dual axis panel output with respect to temperature and time. During the day time, presence of sunlight is very high and that increases output from PV panel. Table 3 shows the experimental results obtained during summer day.

SUMMER READING (27 March 2017).							
TIME	SUN ANGLE	PANEL MOVING ANGLE	TEMPERATURE	DUAL AXIS TRACKING	POWER GENERATION FOR DUAL AXIS	FIX PANEL	POWER GENERATION FOR FIX PANEL
	IN (˚)	IN (˚)	(IN ˚c)	(W/hr)	(%)	(W/hr)	(%)
7.00am	15	E60	25	173	72.08%	130	54.17%
8.00am	30	E60	26	178	74.17%	136	56.67%
9.00am	45	E45	28	188	78.33%	145	60.42%
10.00am	60	E30	29	194	80.83%	158	65.83%
11.00am	75	E15	33	198	82.50%	172	71.67%
12.00pm	90	EW0	35	204	85.00%	184	76.67%
1.00pm	105	W15	37	204	85.00%	187	77.92%
2.00pm	120	W30	37	201	83.75%	186	77.50%
3.00pm	135	W45	36	198	82.50%	178	74.17%
4.00pm	150	W60	35	196	81.67%	164	68.33%
5.00pm	165	W60	33	188	78.33%	153	63.75%
6.00pm	180	W60	30	184	76.67%	144	60.00%
	TOTAL MOVE	120˚	AVERAGE POWER GENERATION IN (W/hr) & (%)	192.17	80.07%	161.41	67.26%

Table 3: Experimental Results of Automatic Solar Tracking System on A Clear and Sunny Day

Where- W= West Direction, E= East Direction

The experimental results are obtained on various days. The data in the table 3 shows during **summertime reading taken between 7am to 6pm during which sun was tracked by linear actuator between 8am to 4pm**. India totally lies north of Equator Hence; it is in the northern hemisphere and during the year Sun is inclined in South. Now considering the fact that angle covered by sun every hour is 15 degree. The linear actuator was also programmed on similar principle of moving by 15 degree per hour. In the beginning around 7 am to 8 am, panel was inclined 60 degree east (E 60 degree) so that sun rays were falling perpendicular on the panel .Since Sun moves 15 degree every hour, we have now programmed linear actuator for tracking with Sun, i.e. moving 15 degree makes the panel condition perpendicular to the sun’s rays and gives the maximum output when the intensity of sun’s rays is higher it results in maximum output of solar panel (due to tracking).

In Table 3 an average output derived from dual axis is higher than the fix panel. **Average power** generated in **dual axis tracking is 80.07%** whereas **Average power** generated in **fix axis panel is 67.26%.** We concluded that average power of **Dual Axis was higher than Fix axis** and difference between Dual axis and Fix axis was *approx***19.05%.** And this Extra power (19.05%) generated by dual axis tracking

Tracking that started from Sun rise in East from 8 am to 4pm, had moved the Solar PV panel through the linear actuator by 120 degrees. Since Sun descends in West our programmed linear actuator remained in the same position from 4 pm to 6pm i.e., panel is positioned60-degree west. (W 60 degree). And when the sensor is unable to sense Sunlight then tracking gets stopped at 6 pm. linear actuator revert back to its original condition by programming after one hour.

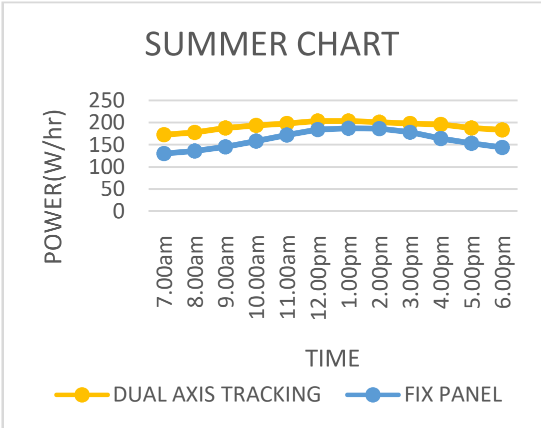

Figure 12: Summer Chart Between Dual Axis Tracking and Fix Panel

Summer chart (Figure 12) depicts the relation of time zone and the power, wherein the **Orange line** represents dual axis tracking power generation and **Blue line** represents fix panel power generation.

7.1.1 RESULT

Extra power generates by tracking panel =

$$\frac{\text{Average Power (Dual Tracking Panel } - \text{ Fix Panel) } * 100}{\text{Tracking panel avg. power generation.}}$$

$$\text{or} \quad = \frac{(80.07\% - 67.26\%)}{80.07\%} * 100 = 19.05\%$$

Result: Extra power generation (Summer) by Dual tracking panel was 19.05% (approx)

7.2 Observations on A Rainy Day

In India and particularly in Madhya Pradesh, the monsoon is active from August to October and Sun is opaque by clouds. So, during rainy season to obtain solar angle of the panel an experiment is conducted by placing the plane board and a pencil (over the board) perpendicularly and allow the sun rays to reach the object and simultaneously adjusting the panel. When the image of pencil changed to one point, the desired result is obtained.

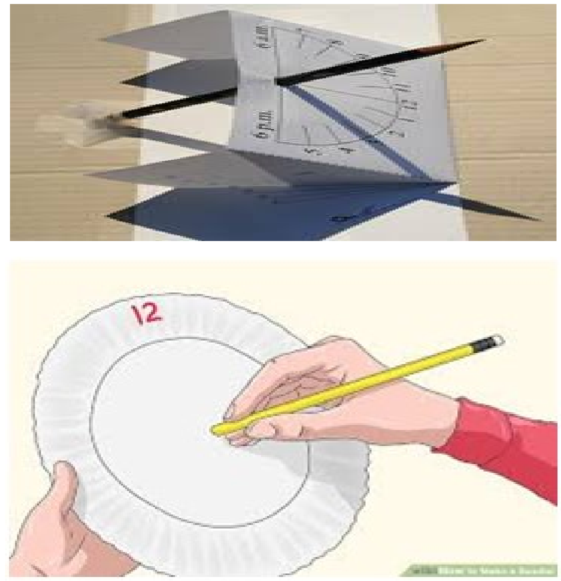

Figure 13: Plane Board and a Pencil

RAINY READING (23 August 2017).							
TIME	SUN ANGLE	PANEL MOVING ANGLE	TEMPERATURE	SEMI-AUTOMATIC DUAL AXIS TRACKING	POWER GENERATION FOR DUAL AXIS	FIX PANEL	POWER GENERATION FOR FIX PANEL
	IN ()	IN ()	(IN ĉ)	(W/hr)	(%)	(W/hr)	(%)
7.00am	15	E60	24	157	65.42%	126	52.50%
8.00am	30	E60	25	166	69.17%	129	53.75%
9.00am	45	E45	26	173	72.08%	137	57.08%
10.00am	60	E30	27	179	74.58%	142	59.17%
11.00am	75	E15	28	182	75.83%	157	65.42%
12.00pm	90	EW0	28	187	77.92%	173	72.08%
1.00pm	105	W15	29	188	78.33%	179	74.58%
2.00pm	120	W30	28	186	77.50%	176	73.33%
3.00pm	135	W45	28	178	74.17%	163	67.92%
4.00pm	150	W60	27	172	71.67%	144	60.00%
5.00pm	165	W60	26	166	69.17%	129	53.75%
6.00pm	180	W60	25	156	65.00%	120	50.00%
	TOTAL MOVE	120˚	AVERAGE POWER GENERATION IN (W/hr) & (%)	174.17	72.57%	147.91	61.63%

Table 4: Experimental Results of Automatic Solar Tracking System on A Rainy Day.

As illustrated above about the tracking performed during the summer season. A similar arrangement was adopted for the tracking during rainy season which started from 8 am to 4 pm in **which maximum power output derived between 12 noon to 2 pm**. At the time of morning and evening the power output is lesser but goes on increasing with respect to temperature and decrease during the cloudy day.

In table 4 above of Rainy day, we can observe that the **average power** generation for **dual axis tracking is 174.17W/hr** which is **higher** than **Average power** generation for **fix panel** of **147.91W/hr**.

We can also conclude that the **Average power generation percentage** for **Dual axis tracking is 72.57 %** whereas **Average power generation percentage** for **fix panel is 61.63%.**

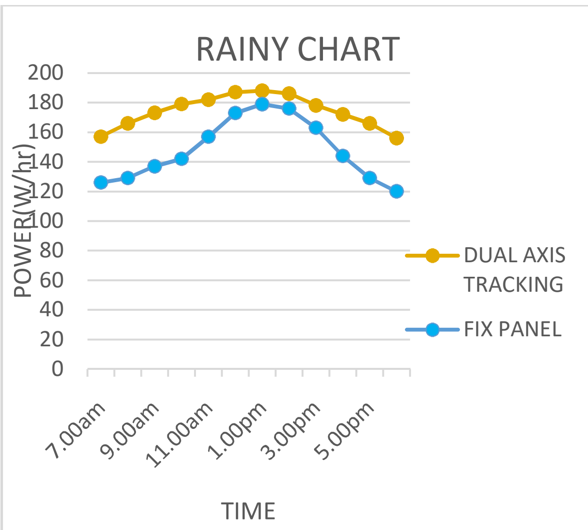

Figure 14: Chart for Rainy Day between Dual Axis Tracking and Fix Panel with Respect to Power and Time.

Rainy chart (Fig 14), shows the relation of Power with respect to Time, wherein **Orange line** represents dual axis tracking power generation and **Blue line** represents fix panel power generation.

7.2.1 Result

Extra power generates by tracking panel =

$$\frac{(\text{dual tracking panel} - \text{fix panel avg, power generate}) * 100}{\text{Tracking panel avg. power generation.}}$$

$$\text{Or}=\frac{(72.57\%-61.63\%) \ *100}{72.57\%} = 17.75\%$$

RESULT: Extra power generation (Rainy) by tracking panel was 17.75% *(approx)*

7.3 On Winter Season

A set of readings are also taken on winter day. The table shows the overall the values of fixed panel output, dual axis panel output with respect to temperature and time. During the day, presence of sunlight was very low and that is why output of PV panel reduced drasticallyin this cash than solar angle is 47degree (or find out by same board and pencil method). Table 5 shows the experimental results obtained on a winter day. In this season tracking time is also 8am to 4pm.

WINTER READING (9 January 2018).							
TIME	SUN ANGLE	PANEL MOVING ANGLE	TEMPERATURE	DUAL AXIS TRACKIN G	POWER GENERATIO N FOR DUAL AXIS	FIX PANEL	POWER GENERATION FOR FIX PANEL
	IN (˚)	IN (˚)	(IN ̊c)	(W/hr)	(%)	(W/hr)	(%)
7.00am	15	E60	18	150	62.50%	110	45.83%
8.00am	30	E60	18	158	65.83%	119	49.58%
9.00am	45	E45	19	164	68.33%	130	54.17%
10.00am	60	E30	20	169	70.42%	142	59.17%
11.00am	75	E15	21	174	72.50%	155	64.58%
12.00pm	90	EW0	22	179	74.58%	161	67.08%
1.00pm	105	W15	23	186	77.50%	171	71.25%
2.00pm	120	W30	22	185	77.08%	169	70.42%
3.00pm	135	W45	21	181	75.42%	156	65.00%
4.00pm	150	W60	20	174	72.50%	139	57.92%
5.00pm	165	W60	18	156	65.00%	125	52.08%

6.00pm	180	W60	16	149	62.08%	115	47.92%
	TOTAL MOVE	120˚	AVERAGE POWER GENERATION IN (W/hr) & (%)	168.75	70.31%	141.00	58.75%

Table 5: Experimental Results of Automatic Solar Tracking System on Winter Day

During winter season, due to low intensity of sun rays the atmospheric temperature is also low. Therefore, the maximum power output is obtained only between 12noon to 3pm and less during the morning and evening time. There is a difference between dual axis tracking and fix panel in which no effect is shown in fix panel at morning whereas the output increased due to the perpendicular sun rays over the tracking panel.

In table 5 of Winter Day, we found that **verage power** generation for **dual axis tracking** is **168.75W/hr** that is again **higher** than **Average power** generation for **fix panel** is **141.00W/hr**.

We had concluded that **Average power generation percentage** for **Dual axis tracking** is **70.31%** whereas **Average power** generation percentage for **fix panel** is **58.75%.**

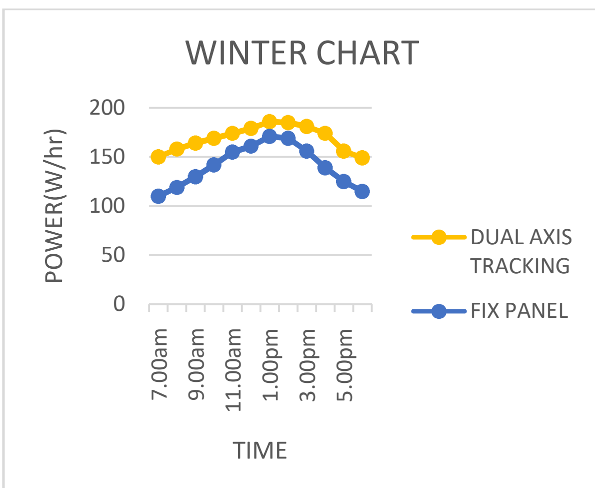

Figure 15: Chart for Winter Daybetween Dual Axis Tracking & Fix Penal with Respect To 'Power and Time'

Winter Chart (Fig 15), shows the relation of Power with respect to Time, wherein **Orange line** represents dual axis tracking power generation and **Blue line** represents fix panel power generation.

7.3.1 Result

Extra power generates by tracking panel =

$$\frac{\text{avg, power generate(dual tracking panel } - \text{ fix panel) } * \text{ 100}}{\text{Tracking panel avg. power generation.}}$$

or, $= \frac{(70.31\% - 58.75\%) * 0.3}{70.31\%}$ =19.68%

RESULT: Extra power generation (Winter) by tracking panel was 19.68% *(approx)*

VIII. CONCLUSION

The hardware model for semi-automatic dual axis tracking solar panel has been sourced and designed by Author.

Based on 12 months Experimental analysis carried out for assessing fluctuations across 3 seasons *i.e., Summer, Rainy and Winter* it can be concluded that the Dual solar tracking system is better than the fixed panel system.

For implementing the experiment and assessing efficiency of Semiautomatic Dual axis solar tracking system. We had used 'AT89S52 microcontroller based' that has been coupled with geared DC motors and Linear Actuator programmed using KEIL software.

The brief details of Average power are mentioned in table 6 below: -

S. no	Season	Average power in Tracking (W/hr & %)		
		Dual axis	Fix panel	Extra Power
1.	Summer	192.17 (80.07%)	161.41 (67.26%)	45.72 (19.05%)
2.	Rainy/ Monsoon	174.17 (72.57%)	147.91 (61.63%)	42.6 (17.75%)
3.	Winter	168.75 (70.31%)	141 (58.75%)	47.23 (19.68%)

Table 6: Summary of Average Power Across 3 Seasons

It can be seen that based on different set of readings obtained in different environmental conditions we had calculated Average power during experimentation. From the readings the dissertation following points have been analysed and concluded.

- On a **TYPICAL CLEAR AND SUNNY DAY**, fixed panel has maximum output only during 11:00 AM to 3:00 PM. Automatic tracking system panel is 72.08% efficient at 7:00 AM, 85% efficient at 12 noon, and 78.33% efficient at 5:00PM.
- The average power of the semiautomatic solar tracking system leads ahead by 19.05% to that of fixed panel on a typical clear and sunny day.

- On a **RAINY DAY**, fixed panel has maximum output only during 11:00 AM to 3:00 PM. Maximum power output of the fixed panel is only 74.58% of the rated power output. Dual axis panel is72.08% efficient at 9:00AM, 77.92% efficient at 12 noon, and 69.17% efficient at 5:00PM.
- The average power of the semiautomatic solar tracking system leads ahead by 17.75% to that of fixed panel on a rainy day.
- On a **WINTER DAY**, panel have uneven light intensity and both (Fixed and automatic tracking) had less power output than the other days.
- In winters, the average power produced by the fixed panel is 141.00 W whereas automatic solar tracking system produces 168.75 W.

Another advantage of Dual axis mechanism over the single axis and more often used the stationery model is that it always keeps the solar panel perpendicular with the sun rays thus getting maximum output.

From the above analysis, it can be concluded that if implemented properly the automatic solar tracking system on Dual axis is both efficient and much better than the fixed panel.

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