EXPERIMENTAL INVESTIGATON OF SOLAR PANEL PERFORMANCE AT VARIOUS ENVIRONMENTAL CONDITIONS

Ashok Raja E[1], Akhash R S[2]

[1] *Ashok Raja E, Mechanical Engineering, PSVPEC, Tamil Nadu, India*
[2] *Akhash R S, Mechanical Engineering, PSVPEC, Tamil Nadu, India*

ABSTRACT

The main aim of this paper is to experimentally investigate the solar panel performance at various environmental condition. As the photovoltaics are fixed outdoor exposed to external meteorological conditions, which vary from one area to another, the atmospheric condition can be considered as the major factor in impressive performance of cells, therefore the efficiency and productivity of photovoltics cells vary from one location to another. The output of the solar cells depends upon the intensity of sunlight and the angle of incidence. It means to get maximum efficiency; the solar panels must remain in front of sun during the whole day, and must be placed under different environmental conditions. The Automated Solar Tracking System (ASTS) was made as a prototype and it is completely automatic and keeps the panel in front of the sun until it is visible during summer and various environmental changes. Due to the changes in the environment the solar radiations being obtained would be changed, there would be variations in power and efficiency obtained. This investigation is being done to find the parameters under different environment and differentiate between them.

Keyword : - *PV Solar panel, Experimental Investigation of Solar Panel, Testing of Solar panel, Environmental Testing of Solar Panel.*

---

1. INTRODUCTION

The output of the solar cells depends upon the intensity of sunlight and the angle of incidence. It means to get maximum efficiency; the solar panels must remain in front of sun during the whole day, and must be placed under different environmental conditions. The Automated Solar Tracking System (ASTS) was made as a prototype and its completely automatic and keeps the panel in front of the sun until it is visible during summer and various environmental changes. Due to the changes in the environment the solar radiations being obtained would be changed, there would be variations in power and efficiency obtained. This investigation is being done to find the parameters under different environment and differentiate between them.

1.1 Solar Panel Specification

The solar panel specification includes types, dimensions, electrical characteristics, temperature characteristics and mechanical characteristics with its respective values as shown in the table - 1 as follows.

Table - 1 Specification of Solar Panel

Type	Polycrystalline
Dimensions	400*150*10mm(L*W*H)
Electrical characteristics	Peak power(P=40W) Voltage V=12V Current = 5A
Temperature characteristics	Normal operating cell temperature 45 degree celcius
Mechanical characteristics	Weight =8KG Front glass = white toughened safety glass Cell = 10 pieces (20*20mm) Cell type - Polycrystalline solar cell Back sheet - Composite film Fuse rating = 20A Cable = 300 mm

2. WORKING OF EXPERIMENTAL SETUP

The solar panel frame is being fabricated with help of square tubes and channels with the help of metal cutting and metal joining process. At the top portion of the frame, solar panel is attached with a shaft mounted with the help of bearings on its two sides. The shaft is mounted with the help of bearing on its two sides. The shaft is rotated with the help of motor arrangement connected to ECU for controlling its activation by LDR sensor. A light-dependent resistor (LDR) has it resistance inversely proportional to the intensity of light and this is often used as a sensor in electronic projects that makes the use of light. The speed of servo motor is controlled by means of the light intensity falling on an LDR. Here we control the speed of servo motor using LDR arrangement system with the help of microcontroller. When the light falling on LDR varies its resistance also varies.

This variation in resistance acts as input to the microcontroller(ECU) Electronic Control Unit which in turns provides variation in speed of servo motor as per the variation in light intensity. The solar panel is being fixed 12-13 degree (N-S) direction to test the overall performance of solar panel during a hot weathered climate. This overall setup being consist of a blower and a sprinkler. Blower is being is fixed in opposite direction to the solar panel and are being used when there is a low and dry air flow in the system , in order to find out the performance at less humid condition. Sprinklers are being used at the top of the panel to spray water in it, order to find the performance of panel during rainy environmental condition. Fig -1 shows working of experiental setup.

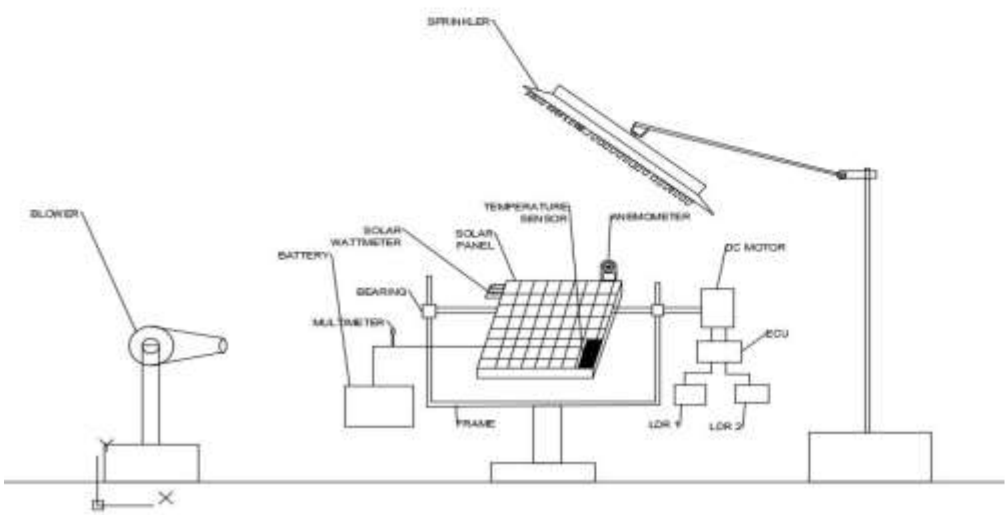

Fig -1: Experimental Design Layout

2.1 2D Design Layout of Experimental Setup

The fig-2 shows the top view of 2D design layout of the experimental setup. It is designed by the CREO Software. Thus the fig-2 represents the 850mm length of the setup and 570mm breadth of the setup. It also consists of a anemometer probe with 100mm in length. The fig-3 shows the left side view of the 2D experimental deign layout. The fixation is at the radius of 25cm which shows the thickness of the rod which is connected to the bearing in solar panel.

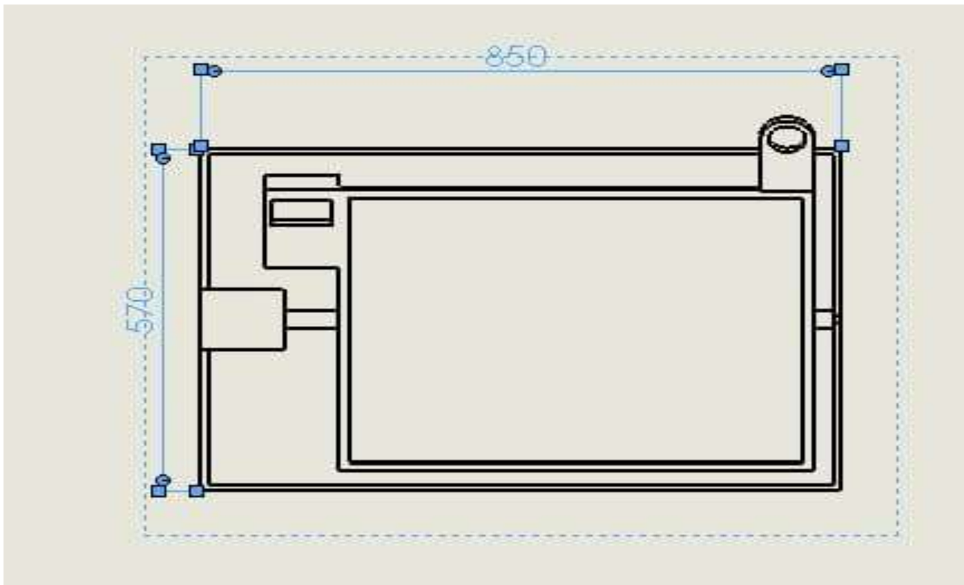

Fig -2: 2D Design Layout Top view

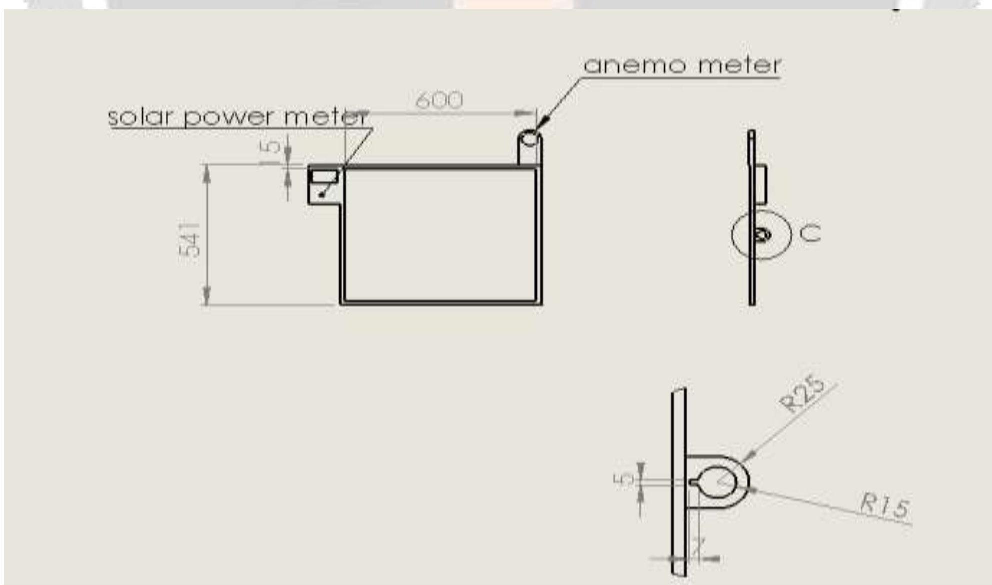

Fig -3: 2D Experimental Layout Left Side View

2.2 3D Design Layout of Experimental Setup

The fig-4 shows the top view of 3D design layout of the experimental setup. It is also designed by the CREO Software. The fig-4 represents the 850mm length of the setup and 570mm breadth of the setup. It also consists of a anemometer probe with 100mm in length at one edge of the solar panel. The fig-4 shows the stepper motor at the side with temperature sensor attached to the one corner of the solar panel also it consists of the anemometer probe at the top in the panel. The fig-5 also shows the 3D experimental setup layout showed in an animated view as follows.

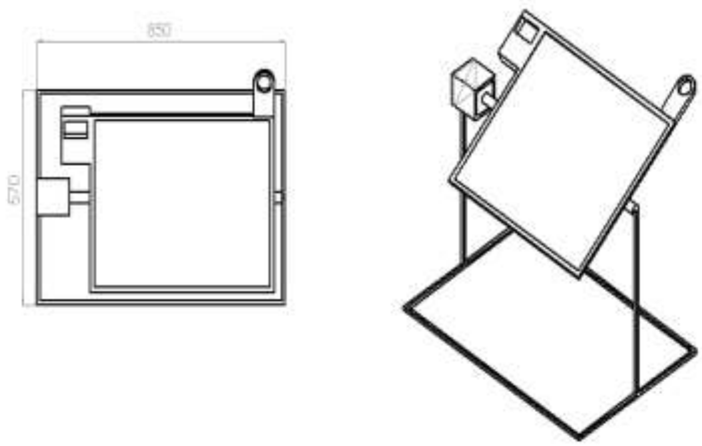

Fig -4: 3D Experimental Setup Layout

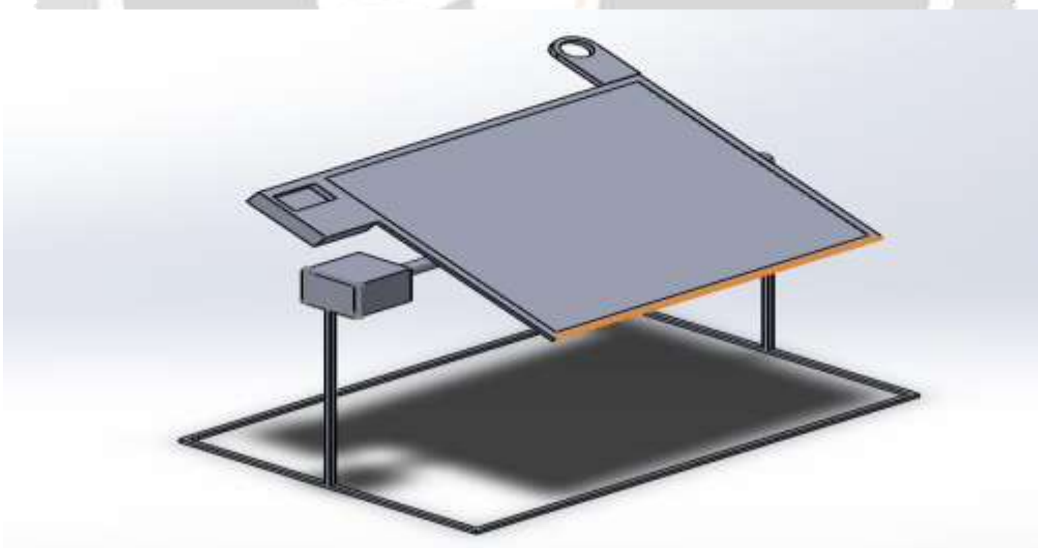

Fig -5: 3D Experimental Setup Layout in Animated View

3. DESIGN CALCULATION OF LOAD

The following table - 2 explains the design calculation of load as follows. The load mentioned here refers to two bulbs which is helpful in indicating the power delivered by the solar panel.

Table - 2 Design Calculation

Total connected load to PV panel system	No. of units × rating of equipment = 2 × 18 = 36 watts
Total watt-hours rating of the system	Total connected load (watts) ×Operating hours = 136 × 6 = 216 watt-hours
The power used at the end use is less (due to lower combined efficiency of the system)	Actual power output of a panel × combined efficiency = 30 × 0.81 = 24.3 watts (VA)
Energy produced by one 40 W panel in a day	Actual power output × 6 hours/day (peak equivalent) = 24.3 × 6 = 145.8 watts-hour

3.1 Mathematical Calculation

The electrical power is defined as the rate per unit time at which the electrical energy is transferred by an electric circuit. The SI unit of power is Watt and the electrical power is expressed in equation [1] as follows.

$$P_{ele} = V.\ I \quad [1]$$

The kinetic power of an object is the power that it possesses due to its motion and it is obtained from the flow speed (V_{air}) and expressed in equation [2] as follows.

$$P_{kinetic} = \frac{1}{2} m_{air} v^2 \quad [2]$$

$$m_{air} = \rho_{air} \ . V_{air} \quad [3]$$

The total useful power can be expressed as a summation of the electrical power output Pele from the solar cell and kinetic energy $P_{kinetic}$ of flowing air and it is expressed above in following equation [3] and [4].

$$P_{useful} = P_{ele} + P_{kinetic} \quad [4]$$

The efficiency of the solar panel is expressed in the below equation in [5] as shown below.

$$\text{Efficiency (\%)} = \frac{\text{incident radiation flux}}{\text{area of panel}} \quad [5]$$

Thus the required mathematical expression for the solar panel design and its parameters are shown above.

4. PHOTOGRAPHIC VIEW OF EXPERIMENTAL SETUP

The photographic view of the experimental setup with various views as shown below and its specific readings under various conditions in the following fig- 6.

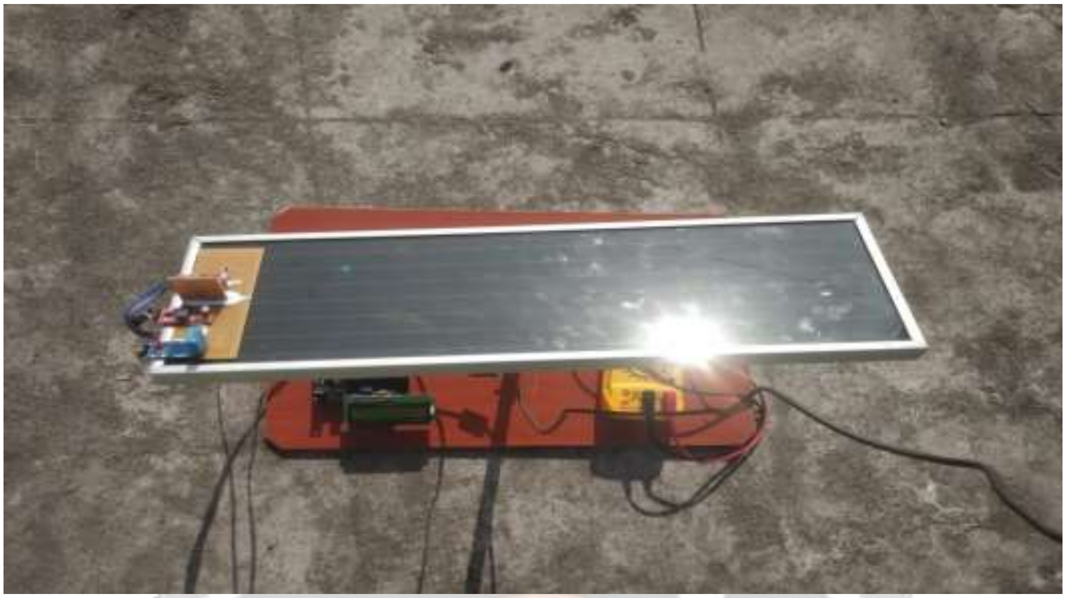

Fig -6: Top View of the Setup

5. RESULT AND DISCUSSION

The various analysis have undergone and the various results of the experimental setup as shown as follows.

5.1 Power and Efficiency Calculation Using Solar Tracker at Hot Weather Condition

The investigation of the experimental setup for calculating the power and efficiency using solar tracker at hot weather condition shows various readings as shown in the table -3 and the area of solar panel is (400*150*10 mm).

Table -3 Calculation of Power and Efficiency using Solar Tracker at Hot Weather Condition

Day	Environmental Condition	Timing	Wind Speed (m/s)	Humidity	Peak Temperature 0_C	Radiation Induced (Watt/m^2)	Power Produced (Watt)	Efficiency (%)
1	Sunny	9 am	9	31	39	1016	14	0.169
	Sunny	12pm	17	40	44	1240	26	0.206
	Sunny	3 pm	18	41	43.5	1306	25	0.217
	Sunny	5 pm	10	42	35	1160	18	0.193
	Sunny	6 pm	8	38	32	996	10	0.166
Average							18.6	0.1902

5.2 Power and Efficiency Calculation Using Solar Panel at Hot Weather Condition

The investigation of the experimental setup for calculating the power and efficiency using solar panel at hot weather condition shows various readings as shown in the table 4.8 as follows. Thus from the various values from the table it can be able to conclude the result of hot weather using the solar panel as shown below in the table - 4.

Table - 4 Calculation of Power and Efficiency using Solar Panel at Hot Weather Condition

Day	Environmental Condition	Timing	Wind Speed (m/s)	Humidity	Peak Temperature 0_C	Radiation Induced (Watt/m^2)	Power Produced (Watt)	Efficiency (%)
1	Sunny	9 am	8	31	39	1100	13	0.183
	Sunny	12pm	20	40	44	1300	26	0.216
	Sunny	3 pm	18	44	32	1206	16	0.201
	Sunny	5 pm	11	39	30	980	11	0.163
	Sunny	6 pm	16	40	24	860	7	0.143
Average							14.6	0.18

5.3 Power and Efficiency Calculation Using Solar Tracker at High Wind speed Condition

The investigation of the experimental setup for calculating the power and efficiency using solar tracker at high wind speed condition shows various readings as shown in the table -5 as follows.

Table - 5 Calculation of Power and Efficiency at High Wind Speed Condition using Solar Tracker

Day	Environmental Condition	Timing	Wind Speed (m/s)	Humidity	Peak Temperature 0_C	Radiation Induced (Watt/m^2)	Power Produced (Watt)	Efficiency (%)
1	Windy	9 am	15	34	40	1116	18	0.18
	Windy	12pm	21	32	36	1000	25	0.166
	Windy	3 pm	26	28	34	989	12	0.164
	Windy	5 pm	30.5	26	33	960	11	0.160
	Windy	6 pm	35	20	31	948	10	0.158
Average							13.2	0.168

5.4 Power and Efficiency Calculation Using Solar Panel at High Wind speed Condition

The investigation of the experimental setup for calculating the power and efficiency using solar panel at high wind speed condition shows various readings as shown in the table -6 as follows.

Table - 6 Calculation of Power and Efficiency at High Wind Speed Condition Solar Panel

Day	Environmental Condition	Timing	Wind Speed (m/s)	Humidity	Peak Temperature 0_C	Radiation Induced (Watt/m^2)	Power Produced (Watt)	Efficiency (%)
1	Windy	9 am	15	35	38	1066	18	0.177
	Windy	12pm	21	31	36	1035	16	0.1725
	Windy	3 pm	26	26	30	900	10	0.15
	Windy	5 pm	31	22	28	868	9	0.144
	Windy	6 pm	36	21	20	727	8	0.121
Average							12.2	0.153

5.5 Power and Efficiency Calculation Using Solar Panel at Hot Weather Condition

The investigation of the experimental setup for calculating the power and efficiency using solar tracker at rainy condition shows various readings as shown in the table -7 as follows.

Table - 7 Calculation of Power and Efficiency at Rainy Condition using Solar Tracker

Day	Environmental Condition	Timing	Wind Speed (m/s)	Humidity	Peak Temperature 0_C	Radiation Induced (Watt/m^2)	Power Produced (Watt)	Efficiency (%)
1	Rainy	9 am	31.5	38	27	300	15	0.05
	Rainy	12pm	32.5	45	25	206	8	0.03
	Rainy	3 pm	28	42	30	225	11	0.0375
	Rainy	5 pm	27.5	41	32	235	13	0.039
	Rainy	6 pm	25	36	28	275	10	0.045
Average							11.4	0.04

5.6 Comparison Chart between Solar Tracker Mechanism and Solar Panel Under Hot Weather Condition

The comparison chart between solar tracker mechanism and solar panel under Hot Weather Condition is expressed in the chart in the chart -1 as shown below.

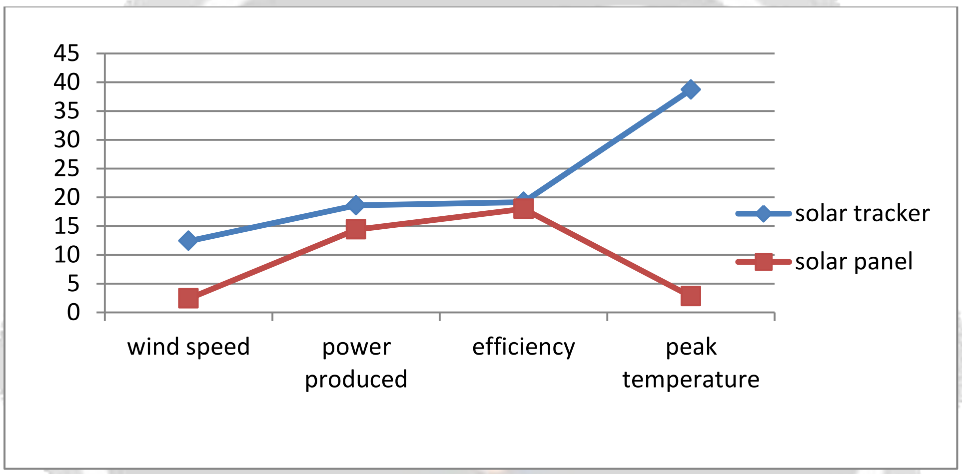

Chart -1: Comparison Chart for Hot Weather Condition

5.7 Comparison Chart Best Solar Tracker Mechanism and Solar Panel Under High Wind Speed Condition

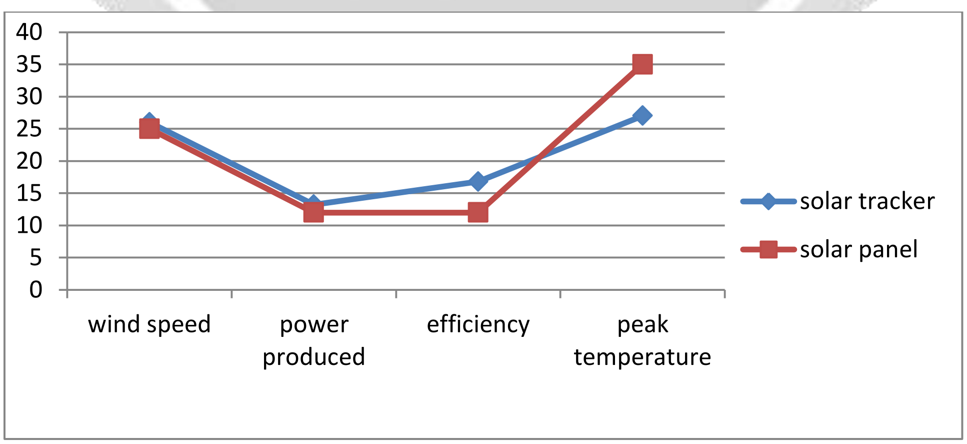

Chart -2: Comparison Chart for High Wind Speed Condition

The comparison chart between solar tracker mechanism and solar panel under high wind speed condition is expressed in the chart -2 as shown below.

5.8 Graphical Representation of Solar Performance Under Various Environmental Condition

The graphical representation of solar panel performance under various environmental condition chart -3 as shown below.

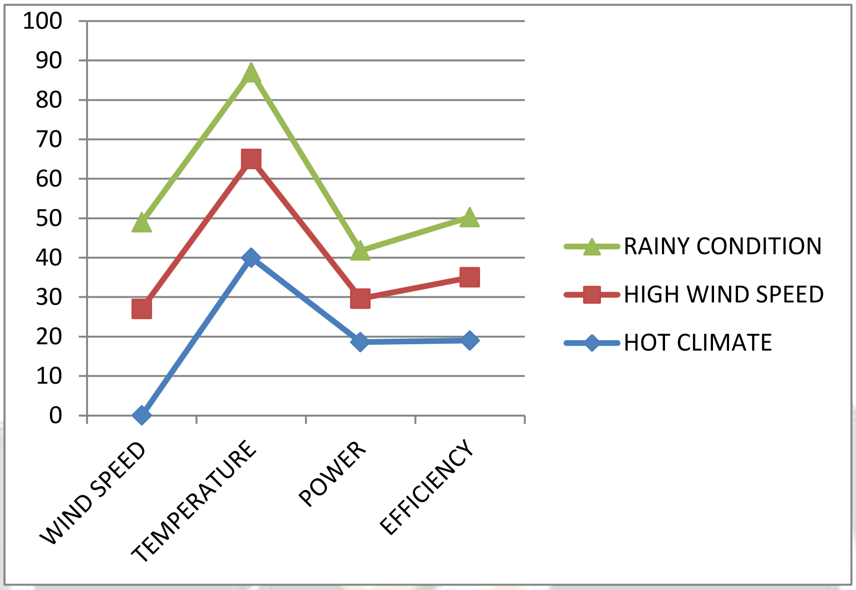

Chart -3: Graphical Representation of Solar Performance under Various Environmental Conditions

6. CONCLUSIONS

We have experimentally investigated the solar panel performance at various environmental conditions such as hot weather, high wind speed and rainy. We have noted that our solar tracker setup have produced high power and solar panel efficiency than that of a normal polycrystalline solar panel at any environmental condition. This investigation being done upon a single 400 mm shaped solar tracker provided an efficiency of 21.6% on hot weather condition and 4.5% at rainy condition, if it is being setup as a large solar form it would give high efficiency and power output up to 20 MW/acre/year as they are being exposed to sun all time. Solar panel tends to be charging according to the amount of irradiance being present up on them among any environmental conditions.

7. REFERENCES

[1]. Bhattacharya, T. Pal, K. (2014) 'Effects of Ambient Temperature and Wind Speed on Performance of Monocrystalline Solar PV Module', Journal of Solar Energy, Article ID 817078.
[2]. Cherif, A. Anzanpour, (2016) 'Solar Radiation and Ambient Temperature Effect on Performance of Solar Panel'.
[3]. Hosseini, R. (2011) 'An Experimental Study of Combining System with a Heating System', Renewable Energy Congress.
[4]. Pant, P.C. (2013) 'Energy Performance Evaluation of Typical Solar PV Module, Journal of Thermal Science.
[5]. Kokala, A. (2015) 'Quantifying the Decrease of PV Panel Energy due to Phenomenon of Air Pollution'.

BIOGRAPHIES (Not Essential)

1.	Ashok Raja. E, UG Student from PSVPEC pursuing Mechanical Engineering. His area of interest include Thermal Engineering. mailId-elango.ashok1997@gmail.com
2.	Akhash. R.S, UG Student from PSVPEC pursuing Mechanical Engineering. His area of interest include Thermal Engineering.