Experimental analysis of solar photo voltaic panel with air cooling system to maintain its efficiency

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Abstract: The methodology proposed to maintain the efficiency of a solar panel by integrating with air cooling system. DC (direct current) fan axial flow of 30 w is connected with the copper tube for better heat transfer, Water act as refrigerant and heat transfer fluid to allow cold ambient air flow from a fan and cool back side of the solar panel; in order to maintain its efficiency. Increase in temperature beyond 40^0C reduces the efficiency of solar panel reason behind is resistance provided by material along with electrical conductivity. By the set up of accessories is drawn, pump 1w DC type, plastic container act as a reservoir for water, analysis of power output, current and voltage before and after implementation of solar PV(photovoltaic) panel cooling system is done.

IndexTerms- Efficiency, Heat transfer, Power, Temperature

I. INTRODUCTION

The renewable energy sources of becoming more population, pollution free and non- sustainability of a common source of energy. All over the world energy is an essential issue for the human. Energy can be classified into two categories which are namely, non-renewable source of energy and renewable source of the energy. Air cooling system the panels using a suitable cooling method helps to partially tackle this problem. This would help to improve the power output per square meter area and reduce the overall cost of the panel when solar panel temperature goes above 40^0C, every 1^0C surface temperature of the PV module cause a reduction of the efficiency of 0.5 % (1).

Many approaches have been made cooling design to maintain efficiency of solar panels, however externally climatic parameters such as solar radiation, ambient temperature, relative humidity, wind speed, accumulated dust are the most common natural factors which influence the surface temperature of the solar PV module (2). Solar PV cell performs better in cold climate condition than in hot climate conditions. The improve the efficiency of the solar panel and to reduce the thermal radiation of a Photovoltaic module s by reducing the surface temperature of the panel. This can be achieved by the active air cooling system to a module and reducing the heat storage of the solar panel during PV cell operating condition (3). The total energy balance in the PV module is represented by on a dynamic thermal model.

The main mechanisms of the heat transfer between the module and its environment were modeled theoretically. The solar panel was verified by the measurements data of the solar Photovoltaic power station (4).
A research of the thermal characteristics of a solar PV module by the change ambient temperature from minimum 25^0C to maximum 45^0C through a thermal analysis simulation program in additional. A simulation method to attach from the backside of the panel, this work to compares the analysis of the thermal characteristics between PV module and without fins. The result to find out with fins less temperature of module surface as compared to without fins because the heat was emitted at the fins (5).

II. Air Cooled System

An active cooling system was developed based on the forced convection induced by fans as the cooling mechanism. The DC fan attached to the back side of PV panel will extract the heat energy distributed and cool the PV panel. The battery provides the DC source to the forced active-air cooling system installed at the back side (DC fan) of the PV module. The DC cooling system reduces the temperature to improve the effective output power of the PV module.

An air cooled system for solar panels involves the installation of heat sinks on the rear side of a solar panel. Heat sinks transfer thermal energy from the higher temperature rear side of a solar panel to the lower temperature surrounding air. For the effective utilization of heat sinks, the solar panel temperature must be higher than the surroundings to transfer heat by convection, radiation, and conduction [6]. The effect of the air cooling mechanisms under indoor testing used sunlight as a light source. The impact of the air cooling mechanism was analyzed under different levels of solar radiation and surrounding temperature. Using a DC fan to reduce the PV panel temperature, the power output was observed with increasing solar radiation [7].

III. Experimental setup Process

The experiment of a scale model constructed and tested solar PV panel air cooling system was done in a roof of the UTD RGPV Campus. The experiments parameters were collected for two (2) days during the period of May 2018 from 8:00 am to 5:00 pm each day. The solar radiation and atmospheric temperature data were collected from the weather station of the School of Energy and Environment Management, UTD RGPV Bhopal. Its latitude and longitude are 23°25'N, 77°41'E, respectively.

The following measurements were collected from the weather station of the department which has been connected whit a data log monitor located on Energy Park UTD RGPV.

1. Solar irradiation or insulation
2. An ambient temperature of the location
3. Wind speed

The rest of the data were measured manually

1 .Current and Voltage

2. Top and the back temperature of the solar PV panel device.

3. Temperature inlet and outlet of the fluid.

The solar PV panel cooled by the air with the help of DC axial flow fan of 30 watts is connected to a back side of the copper tube. Water is used as refrigerant and heat transfer fluid to allow cold ambient air flow from a fan and cool back side of the solar panel; in order to maintain its efficiency. By using the set up of accessories is drawn, pump 10 watt DC type, plastic container act as a reservoir for water.

Fig.1 schematic diagram of poly crystalline solar PV module

Solar PV module Specifications:

- Maximum power (P_{mpp}) 250W
- Maximum power voltage (V_{mp}) 30.98V
- Maximum power current (I_{mp}) 8.10A
- Open circuit voltage (V_{oc}) 37.75V
- Short circuit current (I_{sc}) 8.87A

The air cooling system was tested to determine its electrical and thermal performances at steady conditions for various operating temperature. The inlet temperature of the water was not constant due to the type of system implemented "Close loop system", it changes as the outlet temperature changes too. For measuring the load current and load voltage multi-meters were used separately, besides an error of ± 0.3% was considered for all the measurements. The Solar PV collector was operated at a variable mass flow rate during the experimentation. Digital infrared temperature gun was used to record the top and the back temperature of the panel.

For the experimentally find out the thermal efficiency, the solar PV panel device was connected with a load to avoid PV module overheating of the surface and to simulate real system operation using the solar radiation that is converted into heat in the form of the electricity. All the data experimentally to thermal performances of the solar PV panel was taken with thirty (30) minutes of the interval between the values. This data was used to evaluate the overall efficiency of the Solar PV panel air based. The figure shows the illustration of the different parameters measured to analyze the performance of the collector.

Fig 2 Air cooling system of solar PV installed at roof of building UTD RGPV Bhopal

IV. Measurement instrument

Pyheliometer: - A Pyrheliometer is a device to used measure the direct solar radiation from the sun and its marginal periphery. To direct measure solar radiation correctly, it's receiving surface arrangement to be normal to the solar direction. The instrument is usually mounted on a sun tracing direction deceive called an equatorial mount. This is a highly reliable instrument used to observation of the solar radiation and has long been accepted working standard. However its manual operation required.

The solar irradiation is measured by pyrheliometer the small shutter on the front side of the cylinder shields one sensor are strip from sunlight allows reads on other sensor. A temperature different is produces between the two sensor strips because one sensor absorbs radiation and other not absorbed and thermo electromotive force is directly proportional to this differences induce current flow through the galvanometers then a current is supply to the cooler sensor strips until the pointer in the galvanometer indicated zero. Which the temperature is increases by solar radiation compensated by heat. A value for direct solar irradiance is obtained by converting the current at this time.

Fig 3 Schematic diagram Silver disk Pyrheliometer

V. Calculation and result

Solar PV Efficiency:- The PV efficiency is defined as the ratio of energy output from the solar cell to input energy from the sun, efficiency is the most used parameter to compare the performance of different solar devices. It depends on the range and intensity of the incident sunlight and the temperature.

Since,

$$P = V_{oc} * I_{sc} \tag{1}$$

And efficiency of the module is given by

$$\eta_e = V_{oc} * I_{sc} * FF / A_m . G \tag{2}$$

Where

- P Electrical power of solar PV module
- η_e Efficiency of the PV module
- V_{oc} Open circuit voltage
- I_{sc} Short circuit current of PV module
- A_m Total area of the PV module (m^2)
- G Incident solar radiation (w/m^2)
- FF Fill factor

VI. Experimental value of solar PV panel without air cooling

Table 1 voltage, current, power and efficiency of PV panel

Date.18/05/2018							
S. NO	Time	G (w/m^2)	V_{oc} (V)	I_{sc} (A)	Power (w)	T_1 (^0C)	η_e %
1	8.00AM	710	32.373	5.742	185.886	34.17	12.796
2	8.30AM	750	32.383	5.752	186.267	35.88	12.897
3	9.00AM	790	32.519	5.860	190.560	37.06	13.263
4	9.30AM	850	33.154	5.858	194.216	38.88	13.622
5	10.00AM	960	33.154	5.898	194.216	40.56	12.061
6	10.30AM	980	33.056	6.092	201.377	41.11	12.250
7	11.00AM	998	32.617	6.484	211.488	42.22	12.633
8	11.30AM	1000	33.033	7.148	236.120	43.33	14.077
9	12.00PM	1010	33.740	7.226	243.805	43.88	14.391
10	12.30PM	1020	33.496	7.460	249.880	45.27	14.605
11	1.00PM	1010	33.154	6.834	266.574	45.00	15.735
12	1.30PM	1000	33.252	7.772	258.43	43.33	15.407
13	2.00PM	990	33.544	7.420	248.896	42.77	14.988
14	2.30PM	980	33.593	7.304	245.363	44.44	14.926

15	3.00PM	970	33.691	7.226	243.451	43.33	14.963
16	3.30PM	940	33.656	7.108	239.226	42.24	15.172
17	4.00PM	900	33.691	6.592	222.091	43.72	14.711
18	4.30PM	880	32.812	6.022	197.593	42.53	13.386
19	5.00PM	870	32.959	5.852	192.876	42.88	13.216

Total Power of the solar PV module without cooling

V_{oc} = 33.151 V I_{sc} = 6.613A,

$P = V_{oc} * I_{sc}$

$P = 33.151 * 6.613$

P= 219.228 W

Overall Efficiency of the solar PV module without cooling

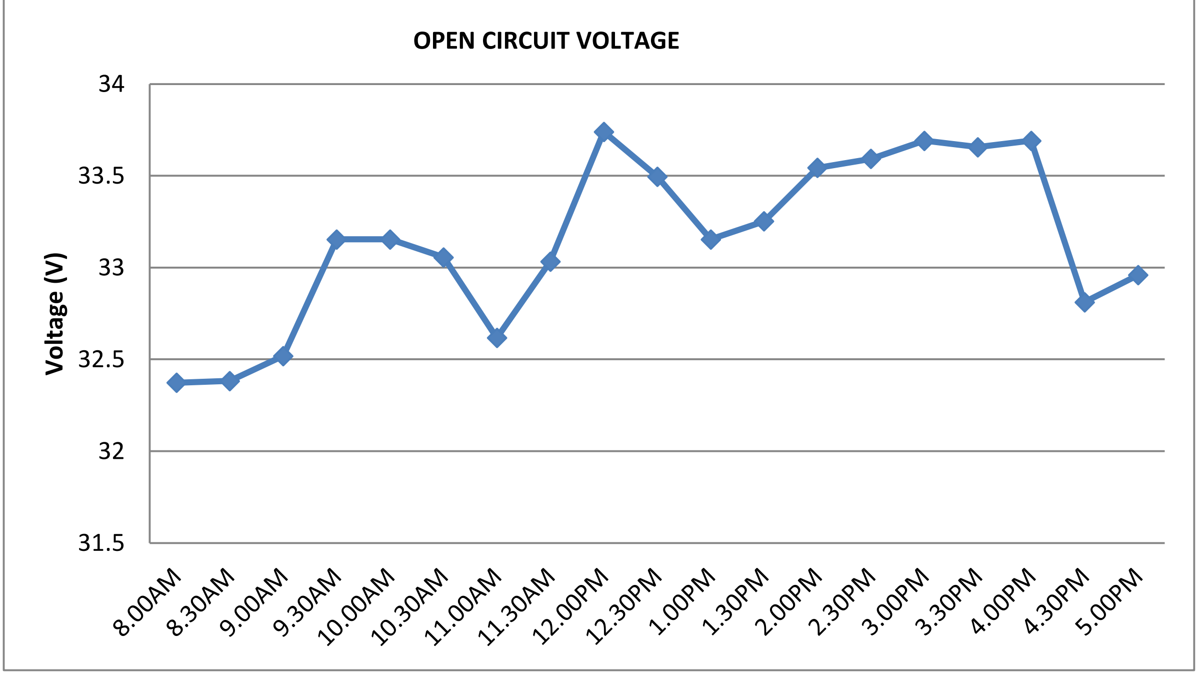
Fill factor = 0.9758, Area of the solar PV module = 1650mm * 992 mm = 1.6368 m^2

G = 926.737 w/m^2

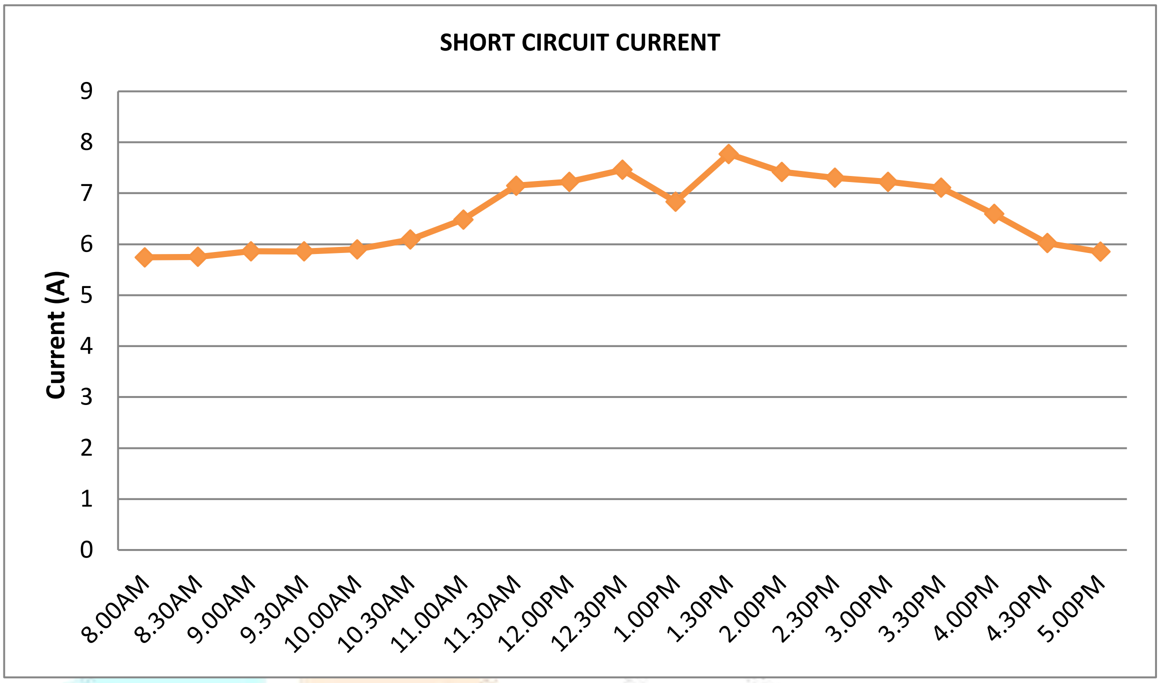
$\eta_e = V_{oc} * I_{sc} * FF / A_m . G$

$\eta_e = (33.151 * 6.613 * 0.9758) / (1.6368 * 926.737) * 100$

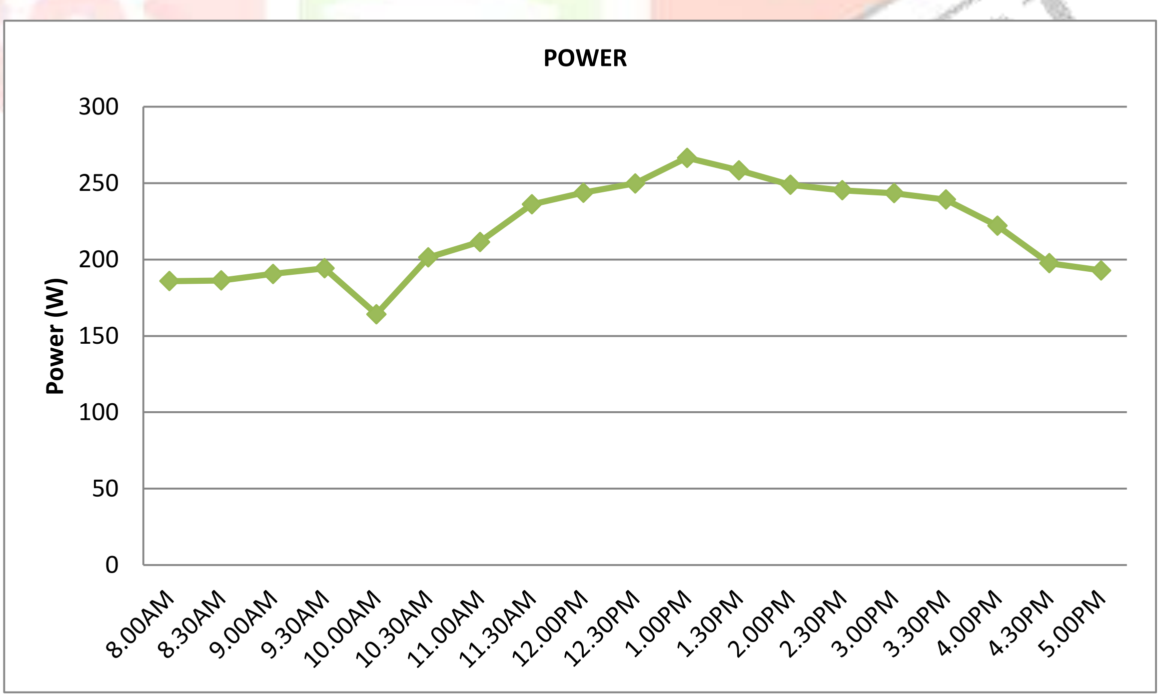
η_e= 14.10 %



Graph.1 Open circuit voltage of solar PV panel without cooling



Graph. 2 Short circuit current of solar PV panel without cooling



Graph.3 Power produced by solar PV module without cooling

VII. Experimental value of solar PV panel with air cooling

Table 2 voltage, current, power and efficiency of PV panel

Date.21/05/2018							
S. NO	Time	G (w/m^2)	V_{oc} (V)	I_{sc} (A)	Power (w)	T_1 (^0C)	η_e (%)
1	8.00AM	720	32.910	6.366	209.505	33.50	14.376
2	8.30AM	760	32.840	7.412	243.410	34.87	14.411
3	9.00AM	780	32.959	7.436	245.083	37.05	14.484
4	9.30AM	830	32.861	7.464	245.274	40.61	15.345
5	10.00AM	947	33.203	7.476	248.22	42.50	15.852
6	10.30AM	976	32.813	7.642	250.756	41.56	15.538
7	11.00AM	982	32.031	7.842	251.187	42.06	15.969
8	11.30AM	990	32.764	7.885	257.260	41.11	15.716
9	12.00PM	1000	32.764	7.854	257.326	41.11	15.563
10	12.30PM	1010	32.178	8.086	260.19	42.06	15.579
11	1.00PM	1020	33.154	8.360	277.66	42.06	16.463
12	1.30PM	1030	32.373	8.219	266.074	42.06	15.623
13	2.00PM	1010	32.349	8.016	259.309	42.08	15.527
14	2.30PM	998	32.422	7.982	258.79	43.33	15.682
15	3.00PM	980	32.128	8.046	258.502	42.56	15.953
16	3.30PM	930	32.128	7.850	252.205	42.05	16.401
17	4.00PM	870	32.959	7.538	248.44	41.11	17.270
18	4.30PM	740	31.934	7.734	246.977	40.56	16.720
19	5.00PM	690	32.081	7.656	245.612	40.61	16.310

Total Power of the solar PV module with cooling

V_{oc} = 32.729V I_{sc} = 7.729A,

$P = V_{oc} * I_{sc}$

$P = 32.729 * 7.729$

P= 252.962 W

Overall Efficiency of the solar PV module with cooling

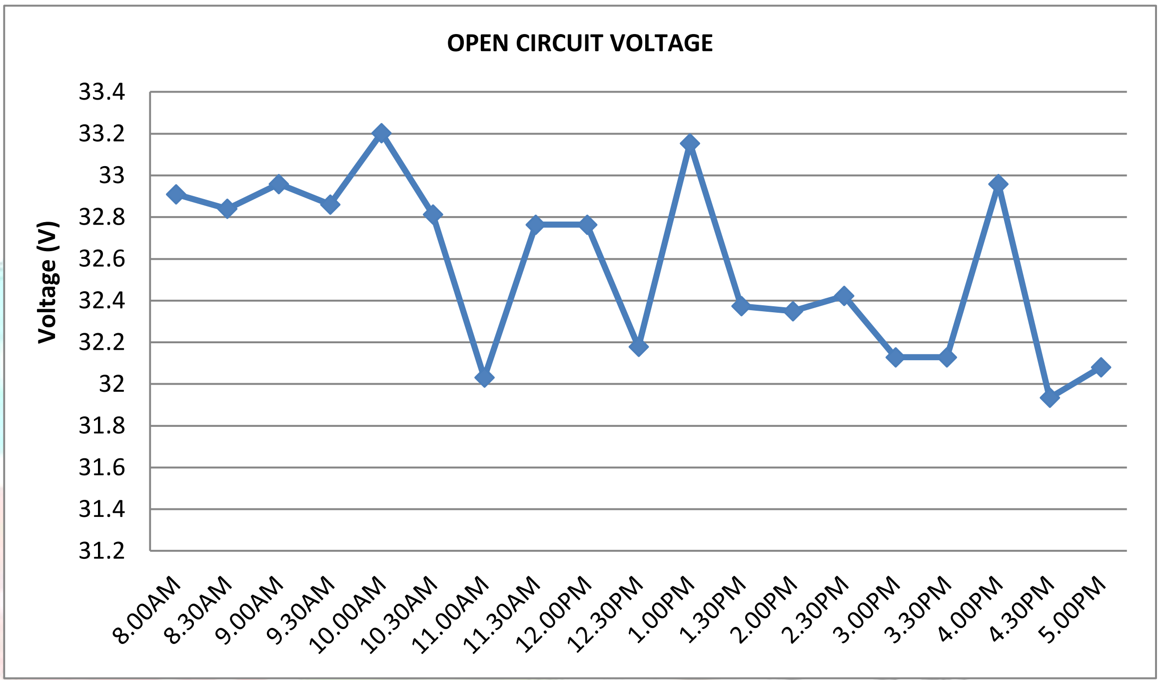
Fill factor = 0.9899, Area of the solar PV module = 1650mm * 992 mm = 1.6368 m^2

G = 908.57 w/m^2

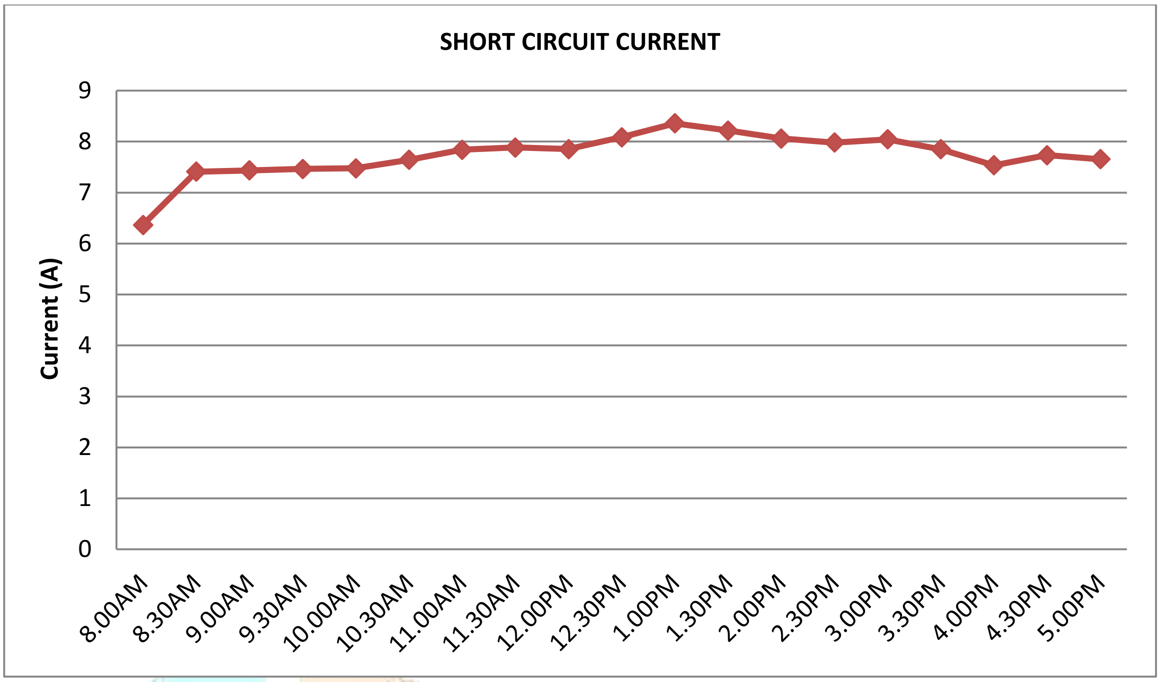
$\eta_e = V_{oc} * I_{sc} * FF / A_m . G$

$\eta_e = (32.729 * 7.729 * 0.9899) / (1.6368 * 908.57) * 100$

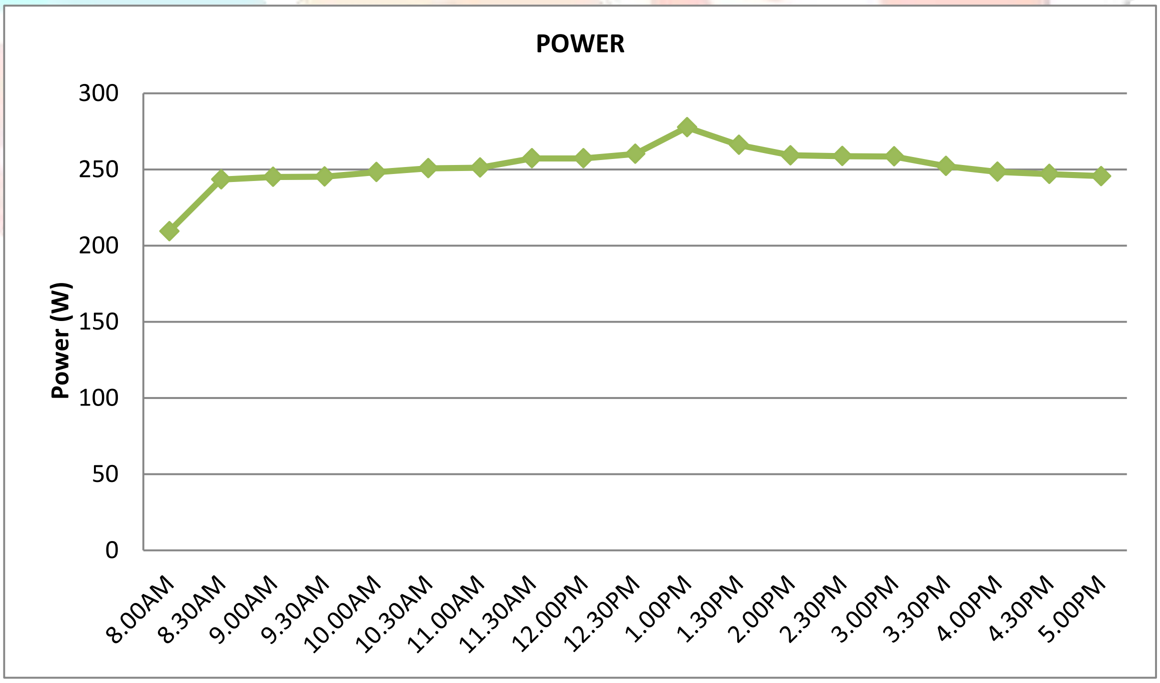
η_e= 16.84 %



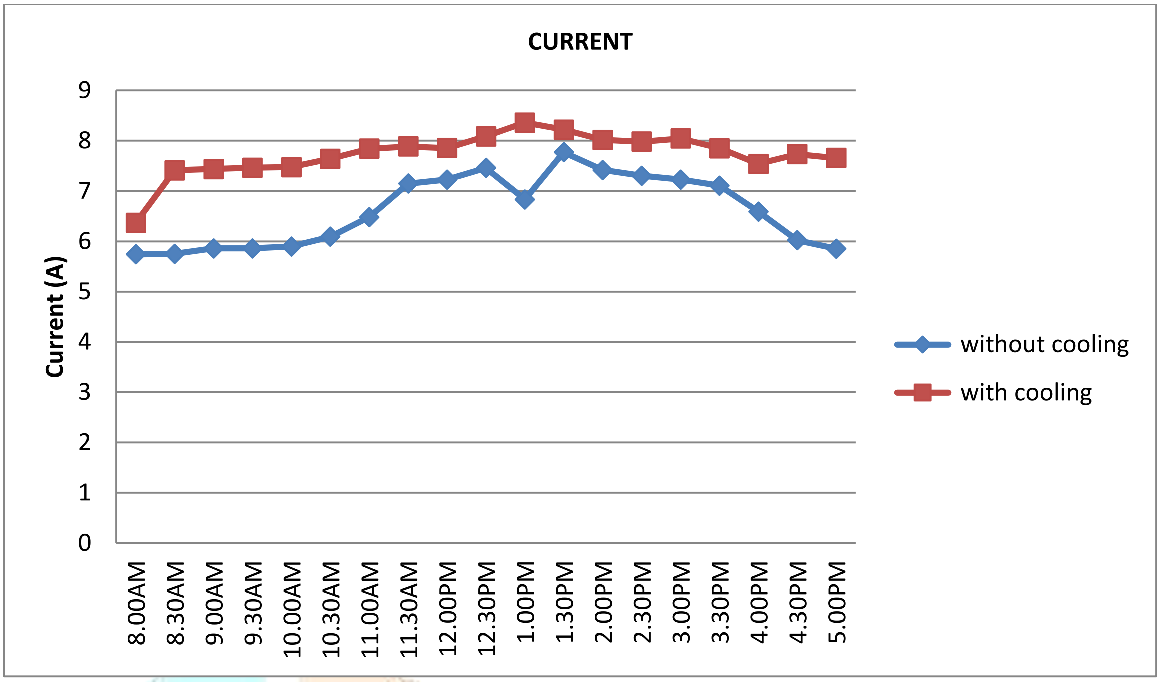
Graph.4 Open circuit voltage of solar PV panel with cooling



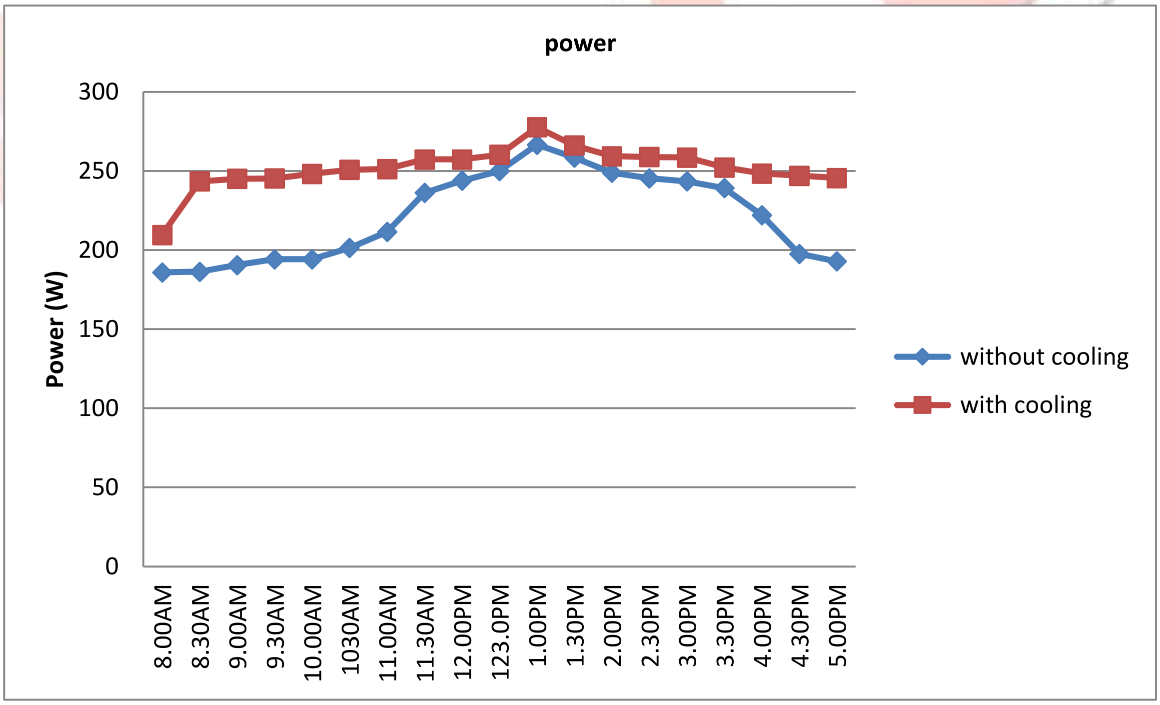
Graph.5 Short circuit current of solar PV panel with cooling



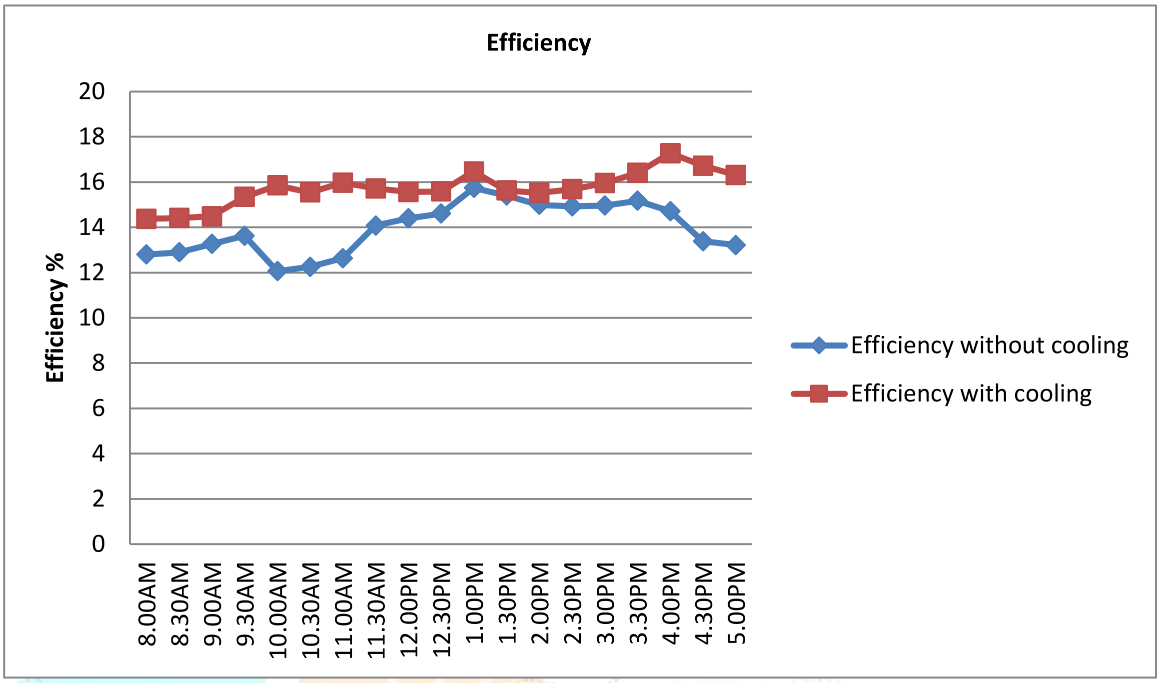
Graph.6 Power produced by solar PV module with cooling



Graph.7 Compare Short circuit current of solar PV with cooling and without cooling



Graph.8 Compare Power produced by solar PV with cooling and without cooling



Graph.9 Compare Efficiency of solar PV with cooling and without cooling

Final calculation of the solar PV module air cooling system

- Two battery = 86.4 * 2 = 172.8 W
- Two DC fan 10 W = 10 * 2 = 20 W
- One DC pump = 1W

Consumption efficiency of the fan and pump

η f = (20 +1) / (1487.03 + 172.8) * 100

η f = 1.26 %

Net increase efficiency = with cooling of solar PV - without cooling of solar PV

η = 16.84 – 14.10 = 2.74 %

Increase efficiency of solar PV module

= 2.74 – 1.26

= 1.48 %

Increment efficiency in percentage

= (1.48 /14.10) * 100 = **10.49 %**

VIII. Conclusion

All the variations of the solar radiation, current, power and efficiencies with respect to daily times were shown in this research paper. The conclusions of this experimental calculation are found as follows.

1. Analyze the performance and working of poly crystalline solar photovoltaic module at roof of UTD RGPV building.

2. The air cooling system installed at roof of UTD building and designed for back side of solar PV module and gives better performance.

3. Analyze the solar photovoltaic module voltage, current, power and it is shown that at graph 11:00AM to 02:00PM use air cooling system give better result. Use the air cooling system graph 8 clearly given that the maximum power of the solar PV module at 1.00pm.

4. In a graph 9 comparison of efficiency better result at 11.00AM to 2.00PM, with air cooling system of solar PV module and without air cooling system of the solar PV module In this paper , the comparison of the efficiency without air cooling solar PV module efficiency 14.10% and with air cooling solar PV module efficiency 16.84%.

5. The two dc fan and one pump consumption of the power inter of efficiency 1.26%. Finally overall efficiency is increases 10.49%**.**Save the energy and better utilised at roof of the building UTD RGPV campus.

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