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Research Article

Experimental Analysis of Back Plate Attached Panel Cooling System (BP-APCS) under Natural Cooling

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Abstract

The conversion efficiency of solar panels gets reduced with increase of panel temperature Convective air-cooling is one important aspect of passive cooling technology that is done under natural flow is a non-expensive and simple method of PV panel cooling. This paper presents a design of aluminium back plate for solar PV panels with fins to cool the solar PV panels. The Experimental setup consist of two panel each of 75 watt setup is kept at the roof of Truba college of science and technology with application of natural cooling with the attachment of backed plate in which fins are welded(20 in number) and keep the optimum spacing for natural circulation of air so that boundary layer is not formed between the fins and kept the setup in real weather at ambient condition where temperature varies in range from 20ºC to 42ºC .And calculated the variation in efficiency and power with respect to panel temperature and compare it with module with modification from an overage observation taken for three month (September to November)from observation we achieve there is increase in power and efficiency on rejection of excess heat that is accumulated due to overheating Average efficiency increased by 1.97% .

***Keywords**: Cooling of Solar PV Panels; Convective Cooling; Fin; Heat Sink*

1. Introduction

In the coming years, effective and efficient harnessing of Solar energy will play a crucial role in providing environment friendly energy for domestic, industrial, agricultural, transport and other needs of human beings. Solar energy will be even more relevant for developing countries whose energy requirements are increasing rapidly as a result of large scale industrialization and growing population. For these countries, it is easier to switch directly to renewable energy sources, since they are yet to choose their energy option. The sun is the largest member of the solar system with other members revolving around it. an average, 1.5 x 1011 m from earth. As observed from the earth , the sun rotates on its axis about once every four weeks, though , it does not rotate as a solid body. The equator takes about 27 days and the polar regions take about 30 days for each rotation. The sun has an effective black body temperature of 5777 K. The temperature of the innermost region, the core, is estimated between 8 x 106 to 40 x 106 K and the density about 100 times that of water.(Garg H P *et al*,1997)

The cooling of PV module is a one of important practical problem having significance in nature. It has direct impact on the tariff rate of electrical energy generating form solar energy and also add economic value .The electrical efficiency is inversely varies with temperature . The conversion efficiency of solar panels gets reduced with increase of panel temperature. It is noted that the efficiency drops by about 0.4% for increase of 1° C of panel temperature (Cruey *et al*, 2006).The cooling have tendencies to enhance the efficiency the standard PV module. Electricity generation from solar energy resources does not produce pollutants, and also fuelling is not required, as a result, it makes it a very favourable source of energy (Meral and Diner *et al*. 2011).

Cooling maintain the internal damage that occurs due to internal irreversibility that increase it's life span. Heat rejected by the PV cooling system is discharge to ambient. Further it can be utilize for domestic application .Various factor are responsible for cooling of panel and excess heat can damage the fabricated material and also decrease the life cycle of module. With the exposure of PV module to sunlight, the amount of energy from the sun converted to useful energy is about 31%, a greater percentage change to heat energy, which tends to make the temperature of the module to rise, and this leads to a reduction in electricity produced by the module. An increase in the

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temperature of the module as a result of this energy wasted as heat can damage the material used to fabricate the PV module and hence reduce the cell lifespan as well as its conversion efficiency (Koteswararao *et al*. 2016).

Solar energy is a very large, inexhaustible source of energy. The power from the sun intercepted by the earth is approximately 1.8 x 1011 MW, which is many thousands of times larger than the present consumption rate of the earth of all commercial energy sources. This makes it one of the most promising of the unconventional energy sources. (Sukhatme S P,1984).Producing of electricity from solar energy source is depend upon efficiency of module how much efficient PV module was, and several factor that directly affect the efficiency is described in chart below Fig.1

A lot of research ongoing on this topic from last few years the objective behind the research work mainly to removal of excess heat that is culprit of efficiency. Heat energy can be lost from a Photovoltaic module through conduction, radiation and convection, two major cooling techniques can be identified, namely Passive cooling, which requires natural means for heat removal without energy consumption and active cooling where energy consumption is needed for heat removal (Grubišić Čabo *et al*., 2016). For the purpose of energy conservation, this research work embraces the concept of passive cooling. Passive cooling manly categorised in three parts as shown Fig.2.Basically, a method of low energy consumption or even no energy requirement for heat dissipation. The process of cooling is base on natural circulation while an back plate is designed that is attached with fins made of aluminium act as a heat sink, is attached to the rear of the module; the PV module is also mounted at top roof of Truba college of science and technology.

A photovoltaic (PV) panel represents an ensemble made of several photovoltaic cells designed to convert solar radiation into electric energy by photovoltaic effect. The most important characteristic of a photovoltaic panel is the conversion efficiency, which expresses the amount of solar radiation that is transformed into electric power, in certain conditions. The typical maximum values of the efficiency are reached between 14% and 17%, in case of mono-crystalline silicon solar cells.

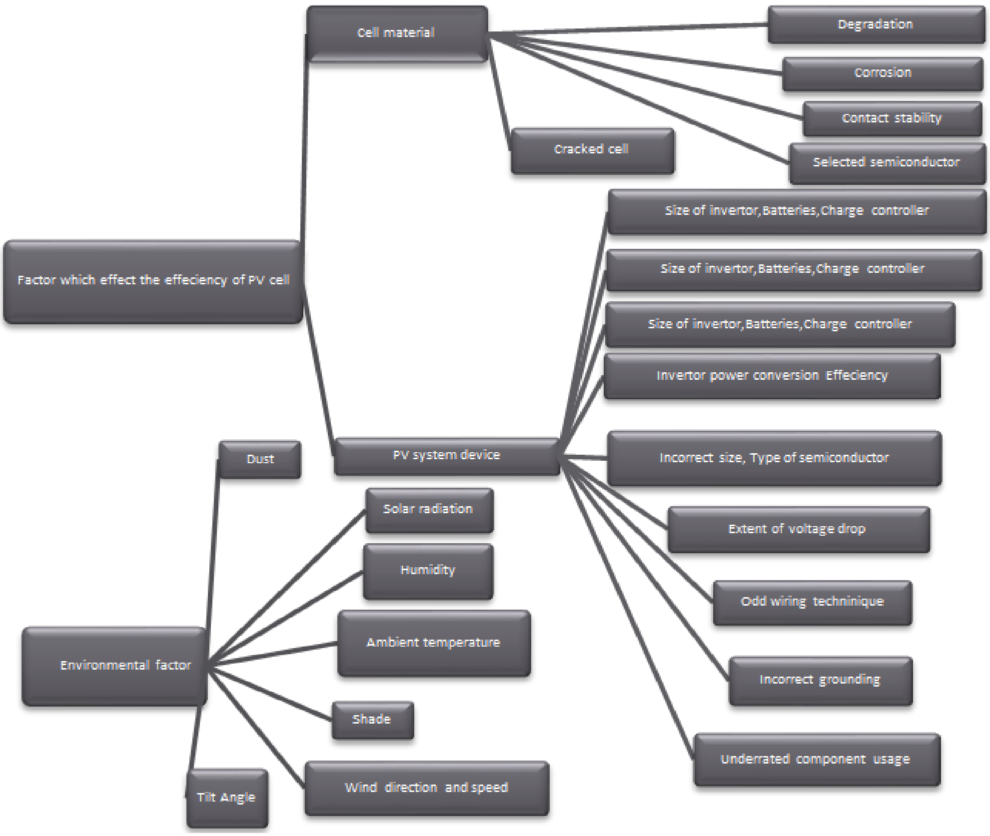


Fig 1 Factor effecting efficiency of PV module.(Linous Idoko,2018)

Nomenclature

Symbols

Pout	Output power
Vm	D.C. output voltage in Voltage(V)
Im	D.C output operating current in A.
ff	Fill Factor
NOCT	Nominal operating cell temperature
STC	Standard Testing Condition
G	Solar irradiance(W/m^2)
H	Panel efficiency

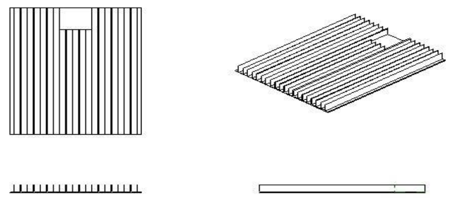
2. Experimental setup

The experimental setup was designed to investigate the effect of back plate on the performance of the PV module and to determine how much heat can be withdrawn from back plate. Finned plates of aluminium are shown in Figure 3. There are two PVs (Polycrystalline). Each panel has a length of 79 cm a width of 28 cm and detail specification given in Table 3 rated capacity of 75 W. For the further study, finned plate of aluminium was added to the first panel and compared with a fixed standard one. This experiment was done on 02 nov, 2018. The experiments were done from 10:00 am till 4:00 pm, and the two panels were placed in parallel to each other facing parallel to solar simulator that is created artificially in R&D Truba institute of engineering and information technology Bhopal central campus, as shown in Figure 2. Furthermore, two multi-meters with one rheostat are connected with each panel, such as the first multimeter represents a voltage and connected in parallel, and the second multimeter represents a current and connected in series. Accordingly, the time was adjusted, and every 30 minutes the temperatures were recorded for the two PV panels by using the connected Thermocouples k-type, the measurement temperature device thermometers as shown in Figures2 respectively. Meanwhile air flow upto 2~3m/sec measured with help of anemometer. Also,

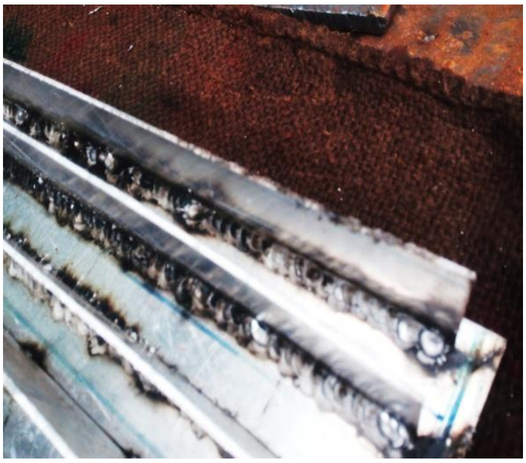
Fig.2 Temperature indicator

2.1 Prototype development

To study the effect of aluminium back plate, its characteristics in cooling mode was studied. Experimental setup was constructed as shown schematically in Figure2.The experimental setup is integrated of three main parts: PV Panels (Poly crystalline Silicon PV), back plate of aluminium, and the frame. The Poly crystalline Silicon PV was used in the experiment, because of it's reliability, works on noiseless environment, highly credible system with expectation between 20 - 30 years (J.A.Gotmare *et al*. 2016), Maintenance is quite low. Additionally, aluminium back plate is used as a design, since it has a high thermal conductivity which leads to a rapid heat transfer to an adjacent cooling fluid, such as air. , stands are used to fix the PV panels by choosing the suitable orientation and angle.



(a)



(b)

Fig. 3: (a).AUTO-CAD Design and position of aluminium fin on back side
(b).Welding of fins on Aluminium Plate

Table 2: Design of project should be very economical and feasible model

S.no.	Parameter	Value
1.	Length of Aluminium backplate	93cm
2.	Length/height of Aluminium Fin	45cm
3.	The thickness of Aluminium Fin	2mm
4.	The width of the Fin base	2.4cm
5.	Spacing between fins	3.1cm

Fig 4: Experimental set up

Table 3: Properties of the layers of photovoltaic panel (Hamrouni N *et al*,2008)

Layer	Thickness (m)	Thermal conductivity (w/m-k)	Density (kg/m³)	Specific heat (j/m-k)
Glass	0.003	1.8	3000	500
Arc	$100x10^{-9}$	32	2400	691
PV cell	$225x10^{-6}$	148	2330	677
Eva	$500x10^{-6}$	0.35	960	2090
Rear contact	$100x10^{-6}$	237	2700	900
PVF	0.0001	0.2	1200	1250

3. Methodology

3.1. Choosing an optimum Design for the finned plate

The main aim is to experimentally study the performance of PV module with back plate that is attached with fins under natural convection. The Dimensions of the finned plate were designed are 93 cm long, 28cm width, and 2mm thick fins 20nos. Moreover, before connected the back plate with PV panel, thermal heat sink paste must covered all the area of the rear of back plate to insure that we so it enhance heat transfer rate. obsolete air voids, and increase thermal conductivity. Flowchart for Experiments Methodology as shown in Figure 5 shows the step by step methodology of experiment. The main tussle is to design the back plate that work efficiently.

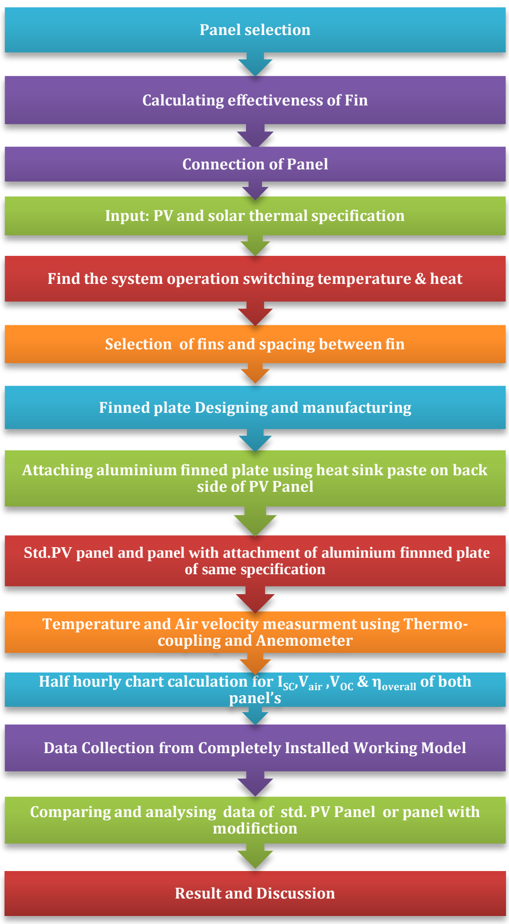


Fig 5: Flowchart for Experiments Methodology

3.2 Apparatus Used In the Experiment

The apparatus used in this experiment are as follows.

(a) IR Thermometer
(b) Thermocouple k-type
(c) Solar Meter TES is used to measure the irradiation
(d) Anemometer

4. Result and discussion

4.1 Formulation & Calculations

Conversion efficiency of solar PV panels is calculated using the following relation

$$\eta = \frac{V \times I}{G \times A}$$

where,
V =Output Voltage (Volt)
I = Output Current (Ampere)
G = Irradiance (W/m²)
A = Area of solar PV panel (m²)

And, Conversion efficiency of solar PV panels is calculated using the following relation

Power Output, $P_{out} = V_{oc} \times I_{sc} \times ff$

Where, *ff* is fill factor, , I_{sc} and V_{oc} are the short circuit current and the open circuit voltage respectively

Solar radiation and temperature of PV module which has been used in the test PVT collectors and is calculated using the (J A Gotmare *et al*,2015):

$$\eta_{el} = \frac{I_m V_m . ff}{A_{PVT} G}$$

Where,
V_m = Output Voltage (Volt)
I_m = Output Current (Ampere)
G = Irradiance (W/m²)
A = Area of solar PV panel (m²)
Ff = Fill factor

4.2 Temperature comparison

On observation of setup the maximum temperature obtained are changes with respect to intensity of solar radiation and this variation is shown in graph The maximum temperature obtained at 12:55pm is 53⁰C of standard panel and at the same time the temperature of the fin attached with back plate have 50⁰C average temperature on comparison there is drop in 3.89% of voltage output with integration of temperature this result shown in figure 6 there is good opportunity in this area with less intial setup cost and get higher energy yield ratio in comparison of other methods of cooling.

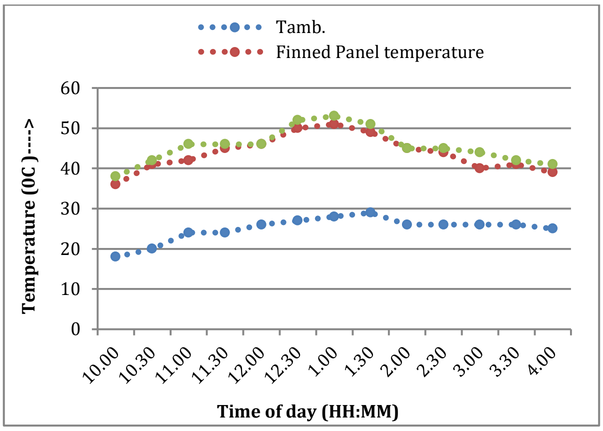


Fig 6: Comparison of PV panel temperatures with & without fin cooling

4.3 Voltage Comparison

On observation of setup the maximum voltage obtained are changes with respect to intensity of solar radiation and this variation is shown in graph The maximum open circuit (Voc)voltage obtained at 11.20am is 20.93Volt and average voltage on comparison there is increase in 1.39% of voltage output with integration of voltage this result shown in Figure 7 there is good opportunity in this area with less economic investment and get higher energy yield ratio in comparison of other methods of cooling.

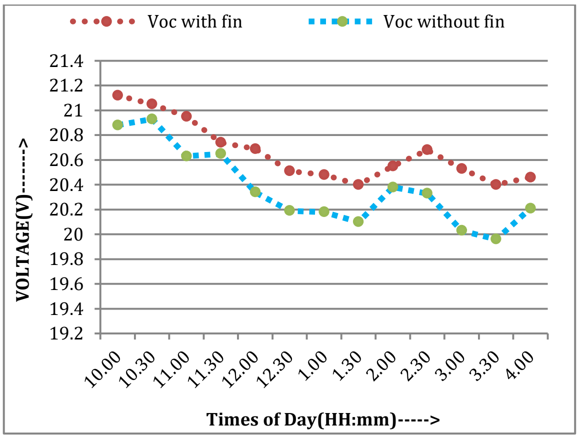


Fig 7: Comparison of PV Panel voltages with & without fin cooling

4.4 Current Comparison

On observation of setup the maximum current obtained are changes with respect to intensity of solar radiation and this variation is shown in Figure 8 The maximum short circuit current Isc obtained at 12.17pm is 2.93A of the of the fin attached with back plate and at same time the maximum short circuit current in standard panel is 2.36A average temperature on comparison there is hike in current output with integration of temperature in this area with less economic investment and get higher peak current yield in comparison of other methods of cooling.

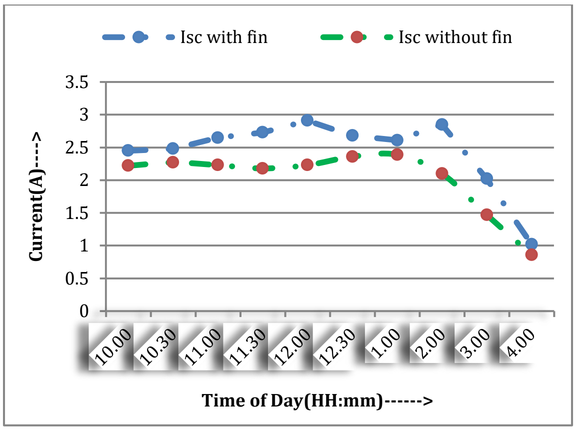


Fig 8: Comparison of PV panel current with & without fin cooling

4.3 Power results for the panels:

Power Output, Pout = Voc×Isc×ff

Where,ff is fill factor, , I sc and Voc are the short circuit current and the open circuit voltage respectively.

4.4 Power Comparison

On observation of setup the maximum power obtained are changes with respect to intensity of solar radiation and this variation is shown in Figure 9. The maximum power obtained at 12.05pm is 59.2 watt and average power on comparison there is increase in 12.8% of power output with integration of panel this result shows there is good opportunity in this area with less economic investment and get higher peak power yield in comparison of other methods of cooling.

4.5 Efficiency comparison

On observation of setup the maximum Efficiency obtained are changes with respect to intensity of solar radiation and this variation is shown in Figure 10

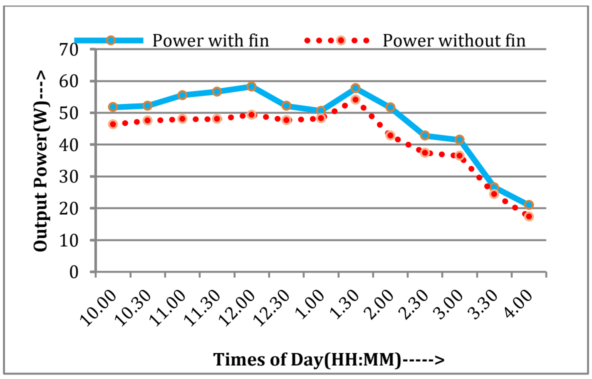


Fig 9: Comparison of output power with & without fin cooling

Results showed that the constructed system offers an improvement in electrical efficiency by an average of 1.97% this Figure 10 shows the variation of efficiency in month of November 15 days observation is done there is good opportunity in this area with less economic investment and get higher Efficiency yield in comparison of other methods of cooling.

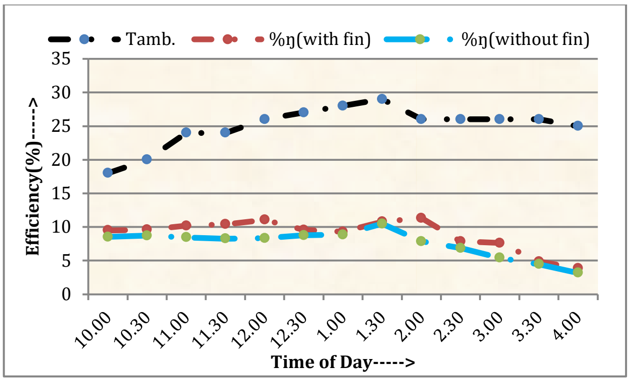


Fig 10: Comparison of Efficiency with & without fin cooling

Conclusions

Photovoltaic panel is a special source of energy, since it uses solar energy as an input power to transfer it to electrical energy; thus, more irradiation will lead to a more solar to electrical conversion. However, PV panel's efficiency drops as its temperature increases. For this reason, an optimum design of back plate as a heat sink was experimentally studied to cool the Photovoltaic (PV-module). Results showed that the constructed system offers an improvement in electrical efficiency by an average of 1.97% while the output power is enhanced by an average of 12.8%. On the other hand, the front temperature was decreased by an average of 3.9% This indicates that the finned plate act as an efficient heat sink to absorb excess of heat from the solar cells, and maintained PV panel's temperature below the maximum allowable temperature. Finned surface of aluminium have good thermal conductivity and lower in cost so it is viable solution. The attributes which makes it a viable solution are discussed in this paper. Scopes for the further development are discussed.

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