EXPERIMENTAL INVESTIGATION OF PV PANEL WITH FIN COOLING UNDER NATURAL CONVECTION

J.A.Gotmare[1], D.S.Borkar[2], P.R.Hatwar[3]

[1,2,3] Department of Mechanical Engineering,

Dr.BabasahebAmbedkar College of Engineering & Research, Nagpur, (India)

ABSTRACT

Photovoltaic solar cell generates electricity by receiving solar irradiance in the forms of photons. Photons with wavelengths above the threshold are converted into heat in the PV cells. This waste heat must be dissipated efficiently in order to avoid excessive high temperatures, which have an adverse effect on the electrical performance of the cell. Therefore, in this paper, performance enhancement of PV panels was experimented utilizing passive fin cooling under natural convection. To properly cool the PV panel, different cross sectional fins with perforation was attached at the backside of the panel. Comparative experimental study on PV panels with and without fin cooling was carried out to investigate the effect of operating temperature on the voltage, current & power output developed by the panel. The results showed that due to fin cooling temperature of the PV panel dropped significantly & the power output was improved by 5.5% under natural convection.

Keywords: Aluminium Fins, K-Thermocouple, Passive Cooling, PV Panel, RTD Meter

I INTRODUCTION

The concern for environment due to ever increasing use of fossil fuels & rapid depletion of these resources have led to the development of alternative sources of energy, which are renewable & environment friendly. Solar energy can be a major source of power & can be utilized by using thermal and photovoltaic conversion systems. India, receives solar energy equivalent to more than 5,000 trillion KWh per year, which is far more than its total annual consumption. The daily global radiation is around 5 kWh per sq. m per day with sun shine ranging between 2,300 and 3,200 hours per year in most part of India. Though the energy density is low and the availability is not continuous, it has now become possible to harness this abundantly available energy very reliably for many purposes by converting it to usable heat or through direct generation of electricity.[1] Photovoltaic cell / Solar cell has a potential to convert the solar energy into electricity.

The solar cell works in several steps:

- Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon.
- Electrons are excited from their current molecular/atomic orbital. Once excited an electron can either dissipate the energy as heat and return to its orbital or travel through the cell until it reaches an electrode. Current flows through the material to cancel the potential and this electricity is captured.
- An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity.

The solar energy technology or synonym as photovoltaic andsolar thermal technology has many advantages and disadvantages comparing to others energy.

The potential advantages such as:

- It works on noiseless environment; do not produce any unwanted waste such as radioactive materials;
- High performance and reliable system;
- Clean technology – does not produce any toxic waste orradioactive material;
- Highly credible system with life span expectation is between 20and 30 years;
- Low maintenance system.

The disadvantages:

- Non-uniform cooling – need innovative absorber design;
- Payback – less efficiency, longer payback period;
- Production and installation cost–expensive and high cost;
- Not suitable for integration with present roof system;
- Need larger space for separate systems (hot water and electricityproduction). [2]

The performance of the PV system is affected by several parameters including temperature. The part of absorbed solar radiation that is not converted into the electricity converts into heat energy and causes a decrease in electrical efficiency. This undesirable effect which leads to an increase in the PV cell's working temperature and consequently causing a drop of conversion efficiency can be partially avoided by a proper method of heat extraction [3].

Many researchers have investigated & proposed different methods to optimize the performance of Photovoltaic panel& to reduce the installation costs. Hosseini et al. [3] experimentally studied the performance of a PV system combined with a cooling system consisting of a thin film of water running on the top surface of the panel & an additional fabricated system to use the hot water produced by the system. The results showed that the power output and electrical efficiency of combined system were higher and lower module temperature and reflection losses compared to conventional PV system. Furushima&Nawata [4] developed a photovoltaic system with cooling device utilizing siphonage& evaluated the performance of photovoltaic panel for the summer condition. The study showed that the cooling of the PV module increased the electrical power output & the hot water produced could be used for heating purposes. In order to reduce the cell reflection & improve the PV performanceAbdolzadeh&Ameri [5] evaluated the performance of the photovoltaic water pumping system by spraying water over the front of the photovoltaic cell & concluded that the PV cell efficiency, subsystem efficiency & total efficiency were increased by 3.26%, 1.40% & 1.35 % respectively at 16 m head due to spraying water over the cell.Teo et al. [6] developed ahybrid photovoltaic / thermal system consisting of a parallel array of ducts with an inlet/outlet manifold designed for uniform airflow distribution attached to the back of the PV panel. The experimental study showed that with an air cooling, the temperature of the panel dropped significantly & solar efficiency increased between 12% to 14%. Bahaidarah et al. [7] experimentally investigated the performance of photovoltaic module by incorporating a heat exchanger (cooling panel) at its rear surface. The water circulated through the heat exchanger absorbed the heat from the panel & the hot water produced could be utilized for the domestic applications. The result showed that with an active cooling, the module temperature dropped significantly to about 20% & the panel efficiency increased by 9%. Gang et al. [8] experimentally studied the performance of a novel heat pipe photovoltaic/thermal system and validated the model output with measured data. The experimental results showed an improvement in the system efficiency with cooling with water circulation. Krauter[9] used a method of reducing the reflection by flowing water over the top surface of the panel. The result showed that cell temperature dropped to 22°C & improved electrical yield 10.3% over the day. Many researchers employed air or water for active cooling of PV to achieve higher electrical efficiency, but additional energy consumption for air or water circulation may reduce the net power output. Therefore, Hongbing Chen et al. [10] conducted an experimental study to compare the performance of photovoltaic panel with & without fin cooling to investigate the effect of PV panel inclination, ambient temperature, and solar radiation & wind velocity on the electrical efficiency & power output. The study showed that the average power output of the PV panel with fin increased by 1.8% - 11.8% than without fin.

The objective of this study is to investigate the possibility of improving the performance of PV panel with fin cooling under natural convection.

II EXPERIMENTAL SETUP

The experimental setup was designed to investigate the effect of fin cooling on the performance of the photovoltaic panel. Figure2.1 shows the experimental setup consists of two 37W PV panel having area of 0.351m^2. The maximum output voltage and current developed by the panel are 17.7V, 2.09A respectively at irradiance of 1000 w/m^2 andambient temperature of 25°C.For the passive cooling, fins made up of aluminium sheet of 0.8 mm thickness are used & glued evenly to the backside of the panel with thermal grease. Total 9 fins with different cross-sections are attached alternately with a constant spacing of 50 mm to restrict the flow of air in order to improve the heat transfer rate from the PV panel.Perforation has been done on the fins at an equal distance by a 10 mm drill bit.

The panels tilt angle are set to 21 deg with respect to the horizontal, which is the local latitude of Nagpur (Latitude 21.1500° N, Longitude 79.0900° E), India, so as to face in the south direction. The temperatures of the panels are measured by K-thermocouples which can sense the temperature from 0°C - 300°C & the readings will be shown on the RTD meter.Total 4 thermocouples are used to measure the temperatures at different locations. Two thermocouples are installed at the top & two at the backside of both the panels. Also the current & voltage are measured by the Omega type multimeter. The experiment was conducted from 9.00am to 3.00pm for 10 days & recorded the data for every 5 min.

Figure 2.1 Experimental setup (PV panels with & without Fins)

Table: 1Details of fin dimension & no of perforation shown in figure 2.2

Case	Size of fin	No. of perforation	Distance of perforation from bottom
1	600mm×100mm	09	50mm
2	600mm×60mm	09	30mm

Figure 2.2 Backside of the PV panel with Fins

2.1 Mathematical Formulation

Incident solar radiation on the PV panel gives the input power (in W) to the system which is given by

Pi = Is × Ac

The D.C. output power from the PV panel is given by

Po = V× I

Panel efficiency (Ea) is the measure of how efficient the PV panel is in converting sunlight to electricity.

Ea = Po / Pi [11]

III RESULT & DISCUSSION

In this experiment, work was conducted to investigate the effect of fin cooling on the PV power output & efficiency for that two separate PV panels with & without fins were developed. Both the panels were placed close to each other to have same solar radiation. Readings were taken on both the panels simultaneously for comparison.

A PV solar cell's electrical power generation depends on its operating temperature. The impact of fin cooling on the cell temperature throughout the day is shown in figure 3.1. The variation of cell temperature for cooling & non-cooling case is presented and respective average cell temperatures were 59.5˚C& 62˚C. Cooling the PV Panel resulted in the reduction of the cell temperature by 4.2%. This temperature reduction resulted in a noticeable improvement in power output.

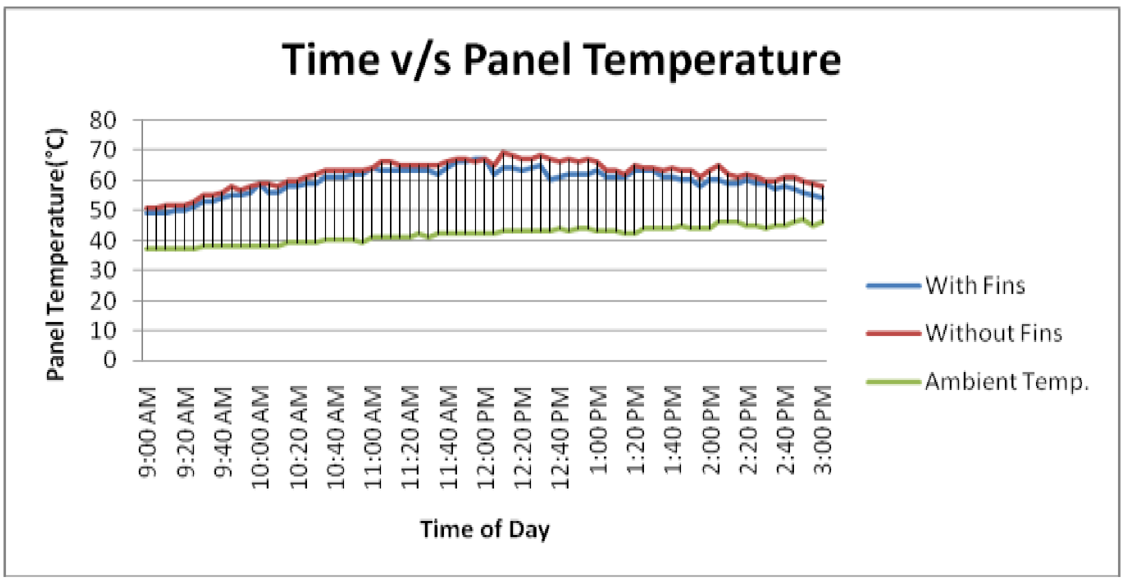

Figure 3.1 Comparison of PV panel temperatures with & without fin cooling

The maximum power output from the panel varies with the intensity of the solar irradiance and the temperature of the cell. It can be seen in the figure 3.2 that themaximum power developed by the module without fins was 53.24W at 11.55am whereas maximum power with fins was 58.5 W. An average increase of 5.5% in the power output of the module was observed in the case of fin cooling.

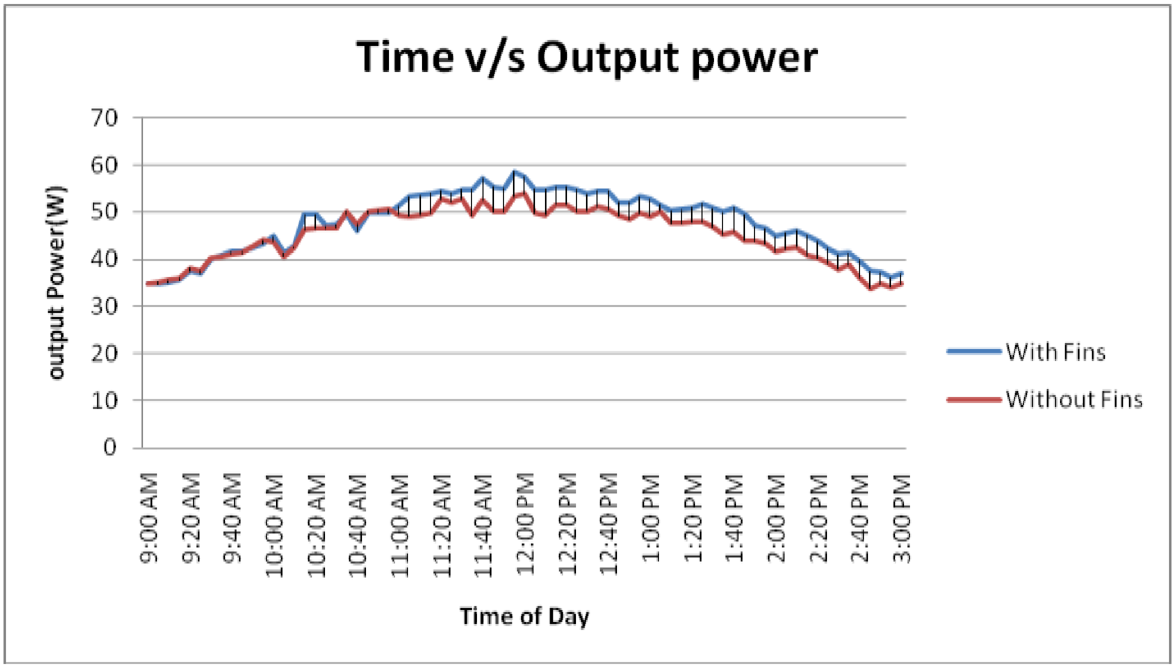

Figure 3.2 Comparison of output power with & without fin cooling

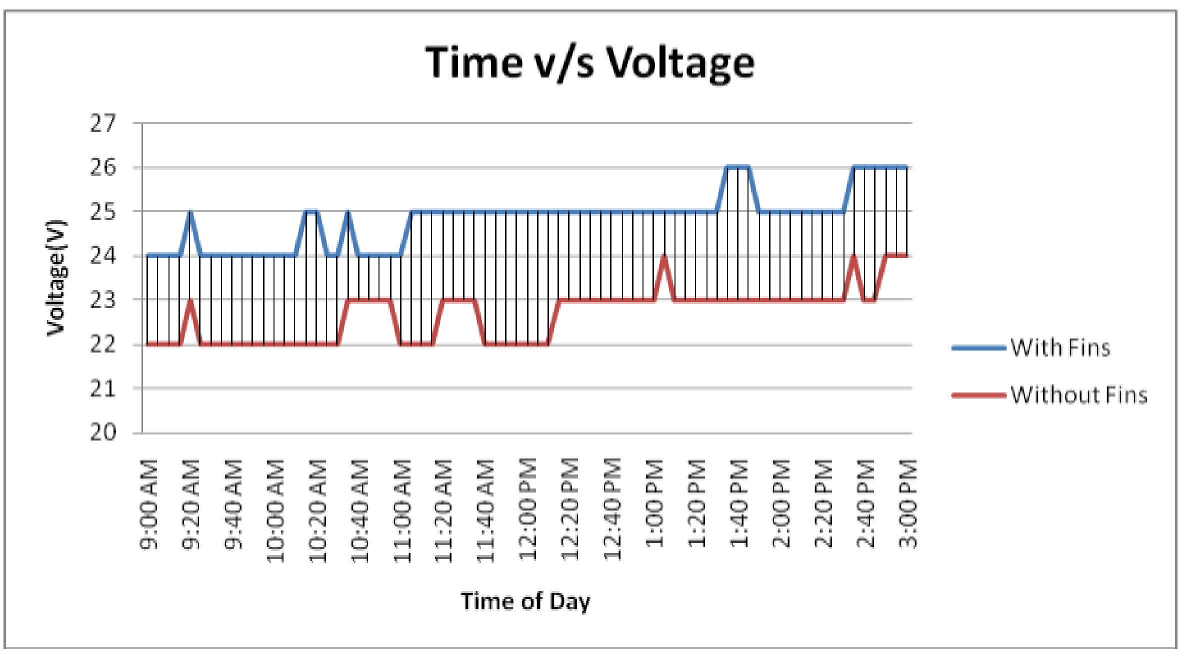

Figure 3.3 Comparison of PV Panel voltages with & without fin cooling

The short circuit current (Isc) increases slightly with increasing temperature & the open circuit voltage (Voc) decreases significantly with increasing temperature. This results in a reduction of electrical power output. Since efficiency and electrical yield decrease with increased operating temperatures, it is preferable to keep cells temperature as low as possible. In the present study, fins are used to cool the PV panel.Cooling of the PV panel with fins affects the variation of voltage & current as shown in the figure 3.3 & 3.4. It is clear from both the figures that due to the use of fins, temperature of panel decreases which slightly drops the current but increases the voltage. This ultimately increases the power output from the PV panel.

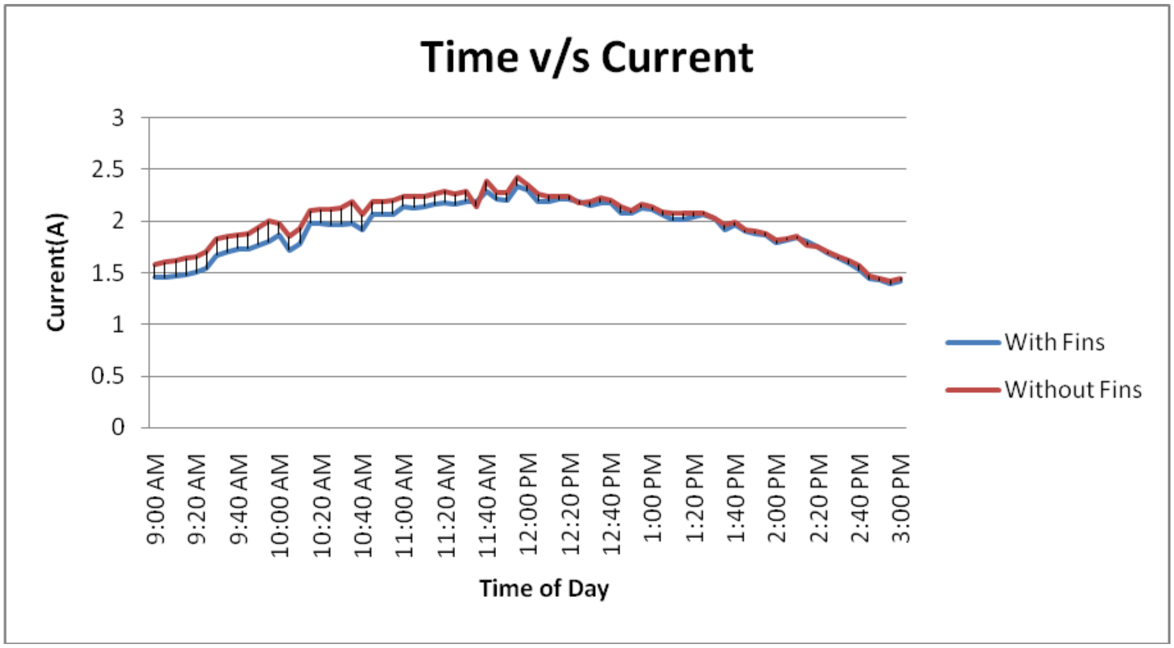

Figure 3.4 Comparison of PV panel current with & without fin cooling

IV CONCLUSION

Solar cells generates more electricity when receive more solar radiation but the efficiency drops when temperature of solar cell increases. Loss of efficiency due to raised temperature of PV panel can be reduced by the heat removal from the back surface of the panel with the help of fins which absorbs the heat generated by the cells during the day. This study examines the performance of the 37W PV panel with the fins. It is shown that with passive cooling technique, the operating temperature of the PV panel dropped significantly to about 4.2% and an increase of 5.5% in power output was observed. This increased power output increases the electrical efficiency of the panel.

NOMENCLATURE

Pi = Input Power in W

Is = Solar radiation in W/m^2

Ac = Effective module cell area in m^2

Po = Photovoltaic array output power in W

V = D.C. output voltage in Voltage (V)

I = D.C. output operating current in A

Ea= Panel efficiency

REFERENCES

Books:

[1]B.H.Khan,Non Conventional Energy Resources (Tata McGraw Hill Pulication, 2006), 5-21.

Journals:

[2]Adnan Ibrahim, MohdYusof Othman, MohdHafidzRuslan, Sohif Mat, KamaruzzamanSopian, Recent advances in flat plate photovoltaic/thermal (PV/T) solar collectors, Renewable and Sustainable Energy Reviews, 15, 2011, 352-365.

[3]R. Hosseini, N. Hosseini, H. Khorasanizadeh, An experimental study of combining a photovoltaic system with a heating system, World Renewable Energy Congress 2011 Sweden, 8-13th may 2011.

[4]K. Furushima, Y. Nawata, Performance evaluation of photovoltaic power generation system equipped with a cooling device utilizing siphonage, Journal Solar Energy Engineering ASME, 128(2), 2006, 146-151.

[5]M. Abdolzadeh, M. Ameri, Improving the effectiveness of a PV water pumping system by spraying water over the front of photovoltaic cells, Renewable Energy,34, 2009, 91-96.

[6] H.G. Teo, P.S. Lee, M.N.A. Hawlader, An active cooling system for photovoltaic modules, Applied Energy, 90, 2012, 309-315.

[7]H. Bahaidarah, Abdul Subhan, P. Gandhidasan, S. Rehman, Performance evaluation of a PV (photovoltaic) module by back surface water cooling for hot climatic conditions, Energy, 59, 2013, 445-453.

[8]P. Gang, Fu Huide, Z. Huijuan, JiJie, Performance study and parametric analysis of a novel heat pipe PV/T system, Energy, 37(1), 2012, 384-395.

[9]S. Krauter, Increased electrical yield via water flow over the front of photovoltaic panels, Solar Energy Materials & Solar Cells, 82, 2004, 131-137.

[10]Hongbing Chen, Xilin Chen, Sizhuo Li, Hanwan Ding, Comparative study on the performance improvement of photovoltaic panel with passive cooling under natural ventilation, International Journal of Smart Grid and Clean Energy, 3(4), 2014, 374-379.

[11]Shiv Lal, Pawan Kumar, Rajeev Rajora, Performance analysis of photovoltaic based submersible water pump, International Journal of Engineering and Technology, 5(2), 2013, 552-560.