Impact Factor (SJIF): 3.632

International Journal of Advance Research in Engineering, Science & Technology

e-ISSN: 2393-9877, p-ISSN: 2394-2444

Volume 3, Issue 12, December-2016

EXPERIMENTAL INVESTIGATION OF WATER COOLED PHOTOVOLTAIC PANEL WITH JUTE WICK STRUCTURES

Mohit Mahajan[1], Brij Bhushan[2], Tarun Mahajan[3], Rakesh Kundra[4]

[1]M.tech Scholar, Department of Mechanical Engineering, BCET, Gurdaspur, Punjab, India
[2]Associate Professor, Department of Mechanical Engineering, BCET, Gurdaspur, Punjab, India
[3]Assistant Professor, Department of Mechanical Engineering, BCET, Gurdaspur, Punjab, India
[4]M.tech Scholar, Department of Mechanical Engineering, BCET, Gurdaspur, Punjab, India

Abstract — *Photovoltaic (PV) panels are becoming popular day by day in solar energy related fields. Photovoltaic panels generate electricity by receiving solar radiation in the forms of photons and generate undesirable heat. This excessive heat leads to decrease in the electrical performance of the cell. In this paper, an experimental investigation of water cooled photovoltaic panel using jute wick structures is developed to improve the electrical efficiency of PV panel. The experimental data has been obtained on parameters (temperature, voltage and current) which influence on the power output of the photovoltaic panel. The experimental results are also compared with the electrical performance of PV panel without cooling system.*

Keywords- *Photovoltaic panel, Electrical Efficiency, Module temperature, Wick.*

I. INTRODUCTION

Nowadays, Photovoltaic (PV) systems are widely used to generate electricity power for home appliances, industries and commercial buildings. Energy is one of the most fundamental requirements for survival of every living creature on the earth and the most worldwide measure of all kinds of work to be carried out by human beings and nature. Energy sources can be broadly classified as renewable and non-renewable energy sources. Non-Renewable sources include fossil fuels (coal, oil and natural gas), hydro energy and nuclear power. Renewable sources include solar energy, wind energy and biomass energy etc. Conventional energy sources are finite, economically out of reach to many developing countries and their use has been causing environmental degradation. Burning of fossil fuels releases emissions such as carbon dioxide, nitrogen oxides, etc. which affects adversely on the environment. To solve these problems, solar energy is the most effective way of using renewable energy by different technology. Generally, solar energy conversion systems can be classified into two categories: thermal systems which convert solar energy into heat and photovoltaic systems which convert solar energy to electricity. In photovoltaic system, Photons with wavelengths above the threshold are converted into heat in the PV cells. Thus more than 50 % solar energy is converted into heat. 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. An effective way of improving performance of PV panels is cooling them during operation period. Many researchers have investigated and proposed different methods to improve the electrical performance by cooling PV panel and collecting more energy. Alami [1] investigated the utilization of an evaporative cooling technique to control the temperature rise of PV panels that occurs due to the absorption of solar radiation. The author proposed the method in which incorporating a layer of synthetic clay to the back of the module and thus reducing the module temperature. The results have showed the feasibility of the approach by a maximum increase of 19.4% to the output voltage and 19.1% to the output power. Bahaidarah et al. [2] reported that by cooling of photovoltaic panel, temperature dropped about 20% as compared to temperature of convectional PV panel and 9% increment in electrical efficiency was observed. Brink worth and Sandberg [3] made a design procedure for cooling ducts to minimise efficiency loss due to temperature rise in PV arrays in which an analysis of the flow and heat transfer in the duct under still-air conditions. Chandrasekhar et al. [4] investigated the water cooled photovoltaic (PV) panel with cotton wick structures. The thermal and electrical performance of water cooled photovoltaic (PV) panel with consisting of cotton wick structures in combination with water, Al_2O_3/water nanofluid and CuO/water nanofluid are investigated experimentally. Chandrasekhar and Senthilkumar [5] perform an experimental investigation of cooling system with heat spreaders in combination with cotton wicks for controlling the temperature of photovoltaic (PV) panel. The photovoltaic (PV) panel temperature was reduced by 12% while the electrical performance was increased by 14%. Hosseini et al. [6] performed an experimental study of combining a water cooled PV system by a thin film of water with an additional system in which the heat is transferred to the water, has been considered.

The results showed that the power and the electrical efficiency of the water cooled system are higher than the conventional PV panel. Kalogirou [7] stated that by increasing use of fossil fuel will led to increase in air pollution and also rise in temperature of earth causing global warming which is a big threat to human life.

Nomenclature

A	area of PV panel, (m^2)	***Subscripts***	
I	incident solar radiation (W/m^2)	max	maximum
I_{sc}	short circuit current (Amp)	oc	open circuit
P	power (Watt)	sc	short circuit
T	temperature (˚C)	pv	photovoltaic
V	voltage (Volt)	w	wick
V_{oc}	open circuit voltage (Volt)		

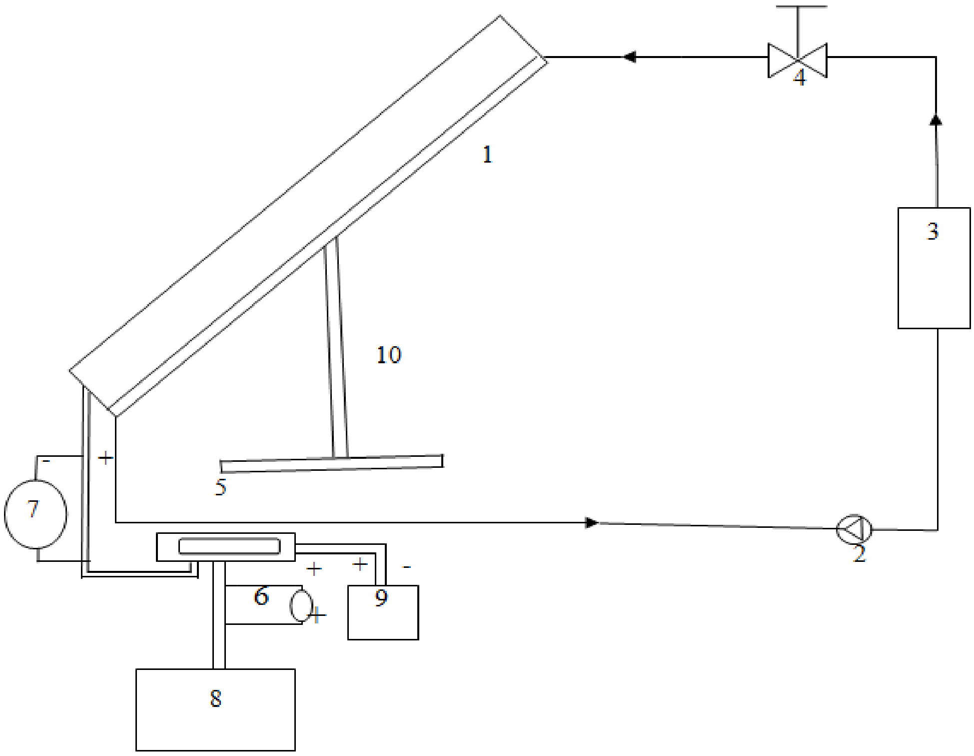
Kern and Russell [8] firstly developed and tested hybrid photovoltaic/thermal system and whole experimental setup was installed at solar energy research facility of university of Texas. One way is cooling of photovoltaic panel is to flow a film of water to decrease its temperature. One way is cooling of photovoltaic panel is to flow a film of water to decrease its temperature. By using this method Krauter [9] studied the effects on the cells by passing water on front of PV panel and nozzles located on the top of PV module to decrease its temperature up to 22°C and therefore electrical efficiency will improve. Lakshmanan et al. [10] did research on PV panel cooled by heat sink and wick Structure. It was clearly analyzed how the temperature affects the efficiency of the solar panel and it was found that there is drop in the efficiency when temperature of module is increased. Cooling was done by using aluminum fins and cotton wick. The deviation of efficiency of photovoltaic (PV) panel with time under different operating conditions was depicted. Finally, the efficiency of PV panel increased to 1.33%. Nizetic et al. [11] investigated water spray cooling technique applied on a photovoltaic (PV) panel. The experimental results showed that it is possible to achieve increment of 16.3% electric power output as compare to conventional PV panel. Du et al. [12] did research on the concentrated photovoltaic (CPV) system focuses solar radiation on the solar cells. A CPV module and its active water-cooling system are developed at the School of Energy and Environment, China. This developed system has been used for testing the PV module's performance for different parameters such as operating temperature, power output, and efficiency. The experimental results show that the operating temperature of the CPV module under water cooling is reduced 60 °C and therefore the efficiency of the CPV has increased and produced the more electric power output. Teo et al. [13] investigated an parallel array of ducts with inlet/outlet manifold designed for uniform airflow distribution was attached to the back of the PV panel. Wisam et al. [14] did the study by reducing the thermal load of a photovoltaic module through an optical water filter. The experiment in which optical water filter (OWF) is used with PV module in order to reduce the PV temperature and enhance the overall PV performance. Therefore, the PV temperature reduction with different water layer thickness (1–5 cm) in the OWF and with different distance between the PV module and OWF (1–3 cm) were tested. Results showed that increasing the water layer thickness increases the temperature drop of the PV module significantly to reach a reduction of 18.4 °C with water thickness of 5 cm. However, increasing the water layer thickness above 3 cm is resulting in little increasing the overall efficiency of the PV-OWF system. From the literature review, it is observed that several studies have been carried out for lowering temperature of photovoltaic panel using wick structures. In the same direction it is decided to carry out an experimental investigation on water cooled photovoltaic panel with jute wick to study its effects on electrical performance of the PV cell.

II. EXPERIMENTAL SETUP

Experimental set-up designed and fabricated by the authors was used for carrying out the present experimental investigation. The experimental set up consisted of two similar 100 watts PV panels which were connected in series. A digital multi-meter is used for the measuring current & voltage which is used to get the electrical power output of PV panel. Intensity of solar radiation falling at photovoltaic panel was measured by digital solar pyranometer available in thermodynamics lab of BCET Gurdaspur. One panel is a conventional PV panel used as a reference panel while the other PV panel is used in a combined cooling system with a film of water running over jute wick which is placed in a galvanized sheet tray arrangement of dimensions (1050mm x 620mm x 30mm) as shown in Fig.1. For controlling the temperature of PV panel and embedded behind the PV panel and keeps PV panel cool. Temperature of conventional PV panel as well as water cooled photovoltaic panel was measured at five different positions with the help of thermocouples at 30 min interval. Thermocouples with a twelve channel temperature indicator are used to record the temperatures of the panels. In this experiment, 35 liters of water tank is used and water is circulated to galvanized sheet arrangement filled with jute wick and pump is used for circulation of water. In order to save electricity generation of photovoltaic panels and avoid over charging of battery, solar charge controller was used and electricity is saved in battery. The experimental set up was installed on the terrace of the Mechanical Engineering Department at Beant College of Engineering and Technology, Gurdaspur, Punjab. The experiments were conducted from 9:00A.M to 4:30P.M at 30 min interval in the month of April 2016 under clear sky and sunny conditions. Fig.2 and Fig.3 shows the Final fabricated setup and schematic view of experimental setup.

Fig.1: Photographic view of galvanized sheet arrangement with jute wick structures.

Fig.2: Photographic view of final fabricated set up with jute wick structures.



1. Water Cooled PV system 2. Pump 3. Water Storage tank 4. Flow regulating valve 5. Charge Controller 6. Ampere meter/ Multimeter 7. Voltmeter/ Multimeter 8. Battery 9. Load 10. Stand.

Fig. 3: Schematic view of experimental setup.

III. DATA REDUCTION

a) Electrical efficiency of photovoltaic panel

$$\eta_{electrical\ pv} = \frac{P_{max}}{P_i} = \frac{I_{max} \times V_{max}}{Incident\ solar\ radiation \times Area\ of\ solar\ cell} \quad (1)$$

in which V_{oc} and I_{sc} is open circuit voltage and short circuit current of the PV panel.

b) Fill factor (FF)

$$Fill\ factor = \frac{(Maximum\ output\ power)_{actual}}{(Dummy\ output\ power)_{theoretical}} \quad (2)$$

IV. RESULTS AND DISCUSSION

4.1 Variation of temperature of PV panel with time

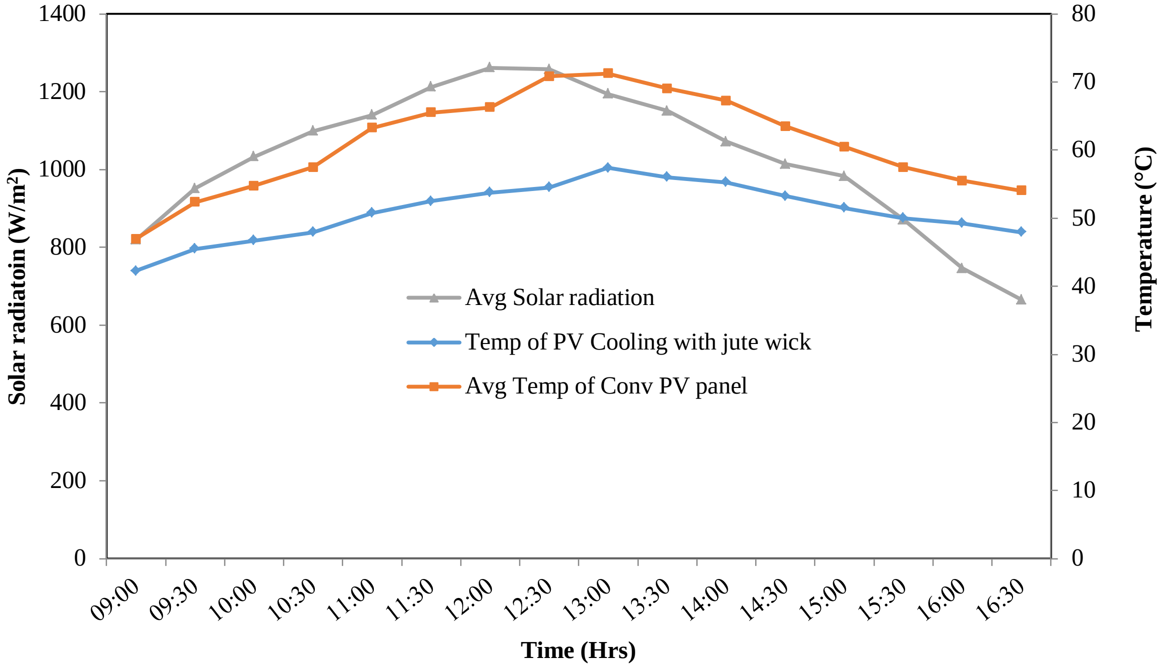


Fig. 4: Variation of PV module temperature with time having jute wick under different operating conditions.

Fig. 4 shows variation of temperature of conventional PV panel and water cooled PV panel with time under different operating conditions along with solar radiation. It has been observed that temperature of water cooled PV panel with use of jute wick structures is less than that of conventional PV panel and cooling of the PV panel resulted in the reduction of the cell temperature by 23.07%.

4.2 Variation of Open circuit voltage (V_{oc}) of PV panel with time

Fig. 5 shows variation of open circuit voltage (V_{oc}) of conventional PV panel and water cooled PV panel with time under different operating conditions along with solar radiation. It has been observed that V_{oc} of water cooled PV panel with use of jute wick structures is more than that of conventional PV panel and cooling of the PV panel resulted in the maximum increment of V_{oc} by 10.8%.

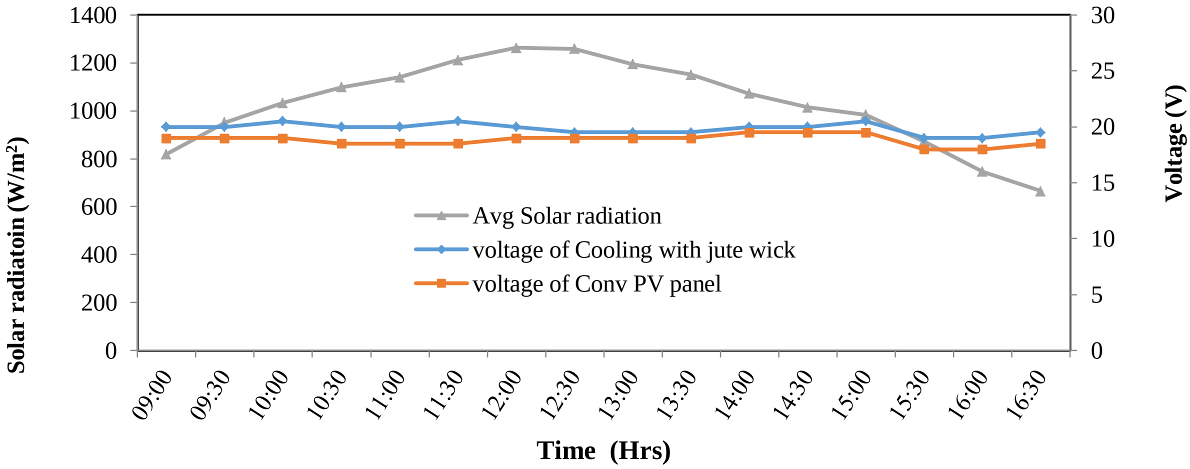


Fig. 5: Variation of Open circuit voltage (V_{oc}) of PV module with solar radiation having jute wick under different operating conditions.

4.3 Variation of Short circuit current (I_{sc}) of PV panel with time

Fig. 6 shows variation of short circuit current (I_{sc}) of conventional PV panel and water cooled PV panel with time under different operating conditions along with average solar radiation. It has been observed that I_{sc} of water cooled PV panel with use of jute wick structures is more than that of conventional PV panel and cooling of the PV panel resulted in the maximum increment of I_{sc} by 10.79%.

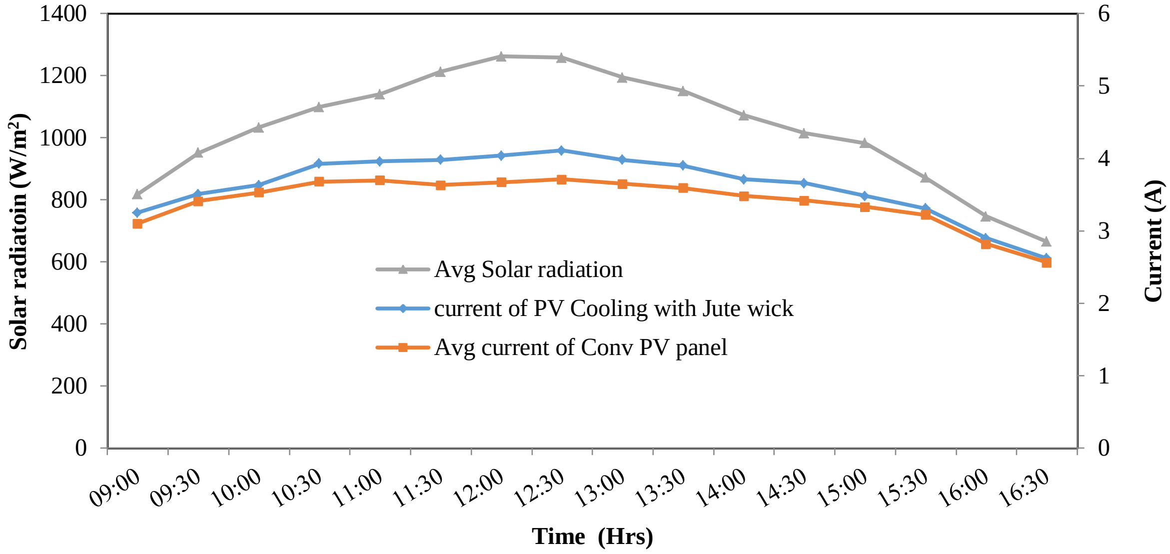


Fig. 6: Variation of Short circuit current (I_{sc}) of PV module with solar radiation having jute wick under different operating conditions.

4.4 Variation of output Power of PV panel with time

The variation of power output of conventional PV panel and water cooled PV panel with time under different operating conditions is shown in Fig. 7. It has been observed that power output of water cooled PV panel with use of jute wick structures is more than that of conventional PV panel and cooling of the PV panel resulted in the average increment of output power by 16.04% than conventional PV panel.

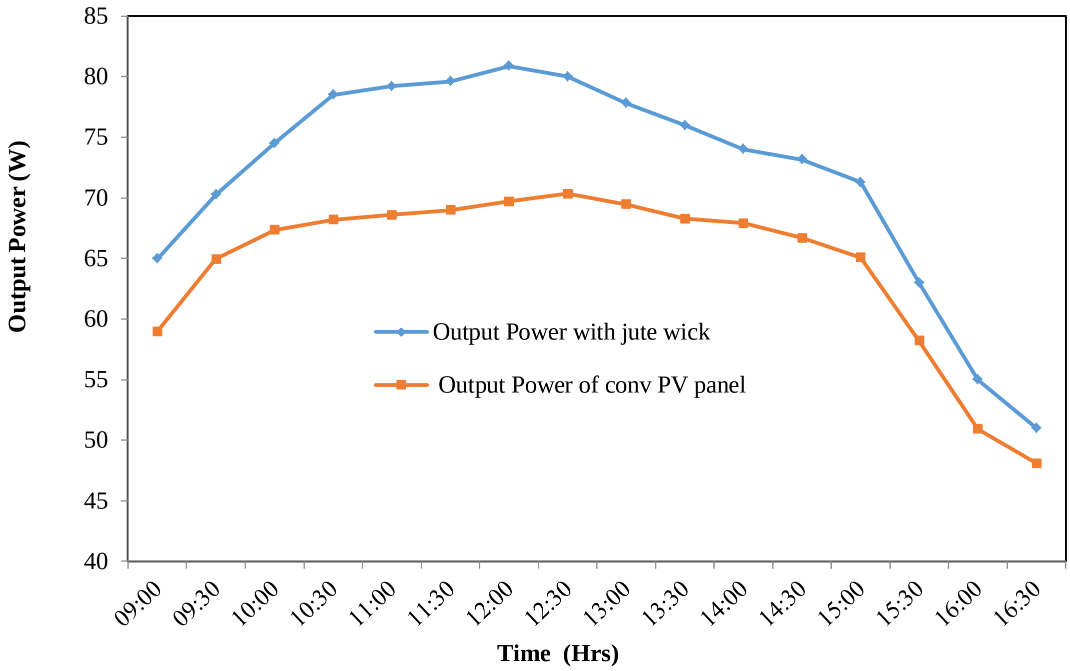


Fig. 7: Variation of Output Power (W) of PV module with time having jute wick under different operating conditions.

4.5 Variation of Electrical efficiency with time

Fig. 8 shows the variation of electrical efficiency of conventional photovoltaic panel and water cooled photovoltaic panel with time under different operating conditions along with solar radiation. It has been observed that electrical efficiency of water cooled PV panel with use of jute wick structures is more than that of conventional PV panel and cooling of the PV panel resulted in the average increment of electrical efficiency by 26.78% than conventional PV panel.

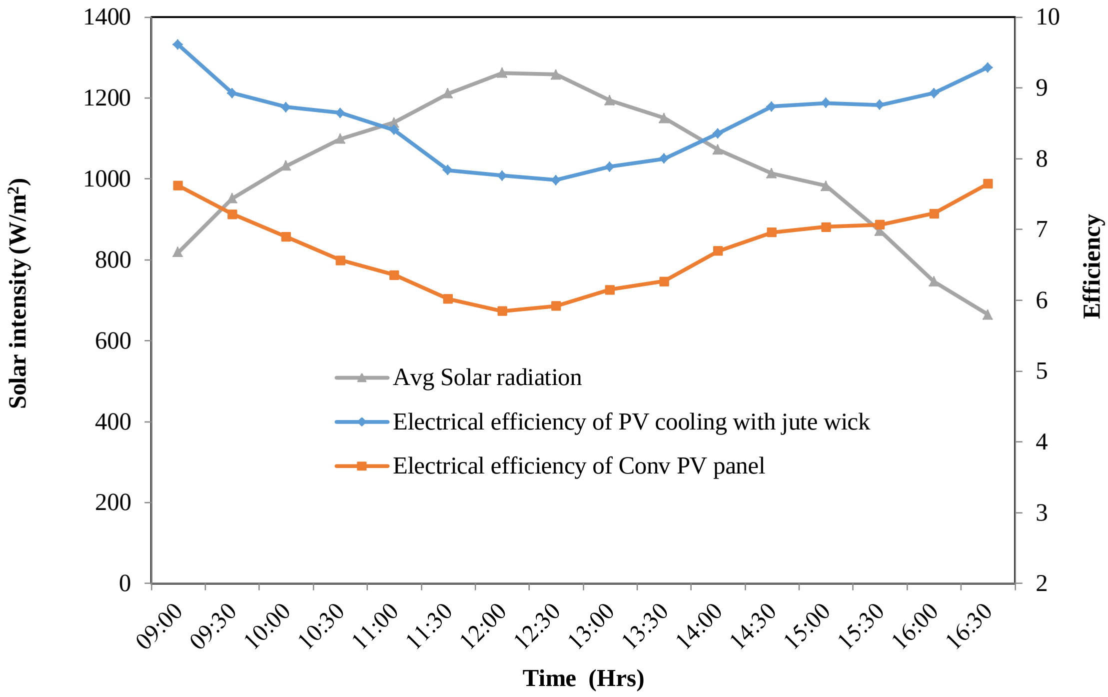


Fig. 8: Variation of Electrical efficiency of PV module with time having jute wick under different operating conditions.

V. CONCLUSION

The present paper has presented the electrical performance of water cooled photovoltaic panel with jute wick structures. There is about 23.07% reduction in module temperature which is attained with the cooling arrangement of PV panel with jute wick structures. There is average increment of V_{oc}, I_{sc} and Power output by 10.8%, 10.79% and 16.04% respectively than conventional PV panel. There is average increment of electrical efficiency of the water cooled PV panel by 26.78% with jute wick structures which clearly indicates the improvement in the performance of the panel.

VI. ACKNOWLEDGEMENT

The authors would like to express thanks to the Department of Mechanical engineering of BCET Gurdaspur for providing the facilities for research work which are to be required in the present experimental work.

VII. REFERENCES

[1] Alami AH. , "Effects of evaporative cooling on efficiency of photovoltaic modules", Energy Conservation and Management, Vol. 77, pp. 688-679, 2014.

[2] B.J. Brink worth and M. Sandberg, "Design procedure for cooling ducts to minimize efficiency loss due to temperature rise in PV arrays", Solar Energy, Vol. 80, pp 89-103, 2006.

[3] Du, B., Hu, E. and M. Kolhe, "Performance analysis of water cooled concentrated photovoltaic (CPV) system", Renew Sustain Energy Reviews, Vol. 16, pp 6732-6736, 2012.

[4] E.C. Kern, and M.C. Russell, "Firstly developed and tested hybrid photovoltaic/thermal system", Proceedings of the IEEE Photovoltaic Specialists, Washington, DC, USA, Vol.1078, pp 1153-1157, 1978.

[5] H. Bahaidarah , Abdul Subhan , P. Gandhidasan , S. Rehman, "Performance investigation of a PV (photovoltaic) panel by back surface water cooling for hot climatic conditions." Energy, Vol. 59, pp 445-453, August 2013.

[6] H.G. Teo, P.S. Lee, and M.N.A. Hawlader, "An active cooling system for photovoltaic panels", Applied Energy, Vol. 90, pp 309–315, 2012.

[7] Lakshmanan, P., Manimaran, M. and Murugan, R, "Performance of flat PV panel cooled by heat sink and wick structure", International Journal on Recent Researches In Science, Engineering & Technology, Vol. 3, Issue 2, February 2015.

[8] M. Chandrasekar, S. Suresh, T. Senthilkumar and M. Ganesh karthikeyan, "Passive cooling of standalone flat PV module with cotton wick structures," Energy Conservation and Management, Vol. 71, pp. 43-50, April 2013.

[9] M. Chandrasekar and T. Senthilkumar, "Perform an experimental investigation of enhanced solar energy in PV modules cooled by heat spreaders in conjunction with cotton wick structures", Energy, Vol. 10, pp. 1-10, June 2015.

[10] R. Hosseini, N. Hosseini and H. Khorasanizade, "An experimental study of combining a photovoltaic system with a heating system", World Renewable Energy Congress Sweden, 8-13th, May 2011.

[11] S. Krauter, "Increased electrical yield via water flow over the front of photovoltaic panels." Solar Energy Materials and Solar Cells, Vol. 82, pp 131-137, October 2004.

[12] S. Kalogirou, "Thermal performance, economic and environmental life cycle analysis of thermosiphon solar water heater." Solar Energy, Vol. 83, pp 39-48, 2009.

[13] S. Nizetic, D. Coko, A. Yadav , F. Grubisic-Cabo,"Water spray cooling technique applied on a photovoltaic panel", Energy Conservation and Management, Vol. 108, pp 287-296, October 2015.

[14] Wisam A.M. Al-Shohani, Raya Al-Dadah and Saad Mahmouda, "Reducing the thermal load of a photovoltaic module through an optical water filter", Applied Thermal Engineering, Vol.109, pp 475–486, August 2016.