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 PHOTOVOLTAIC THERMAL (PV/T) SYSTEM USING 0.3% CuO-H_2O NANOFLUID

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

[1]*M.tech Scholar, Department of Mechanical Engineering, BCET, Gurdaspur, Punjab, India*

[3]*Associate Professor, Department of Mechanical Engineering, BCET, Gurdaspur, Punjab, India*

[4]*Assistant Professor, Department of Mechanical Engineering, BCET, Gurdaspur, Punjab, India*

[4]*M.tech Scholar, Department of Mechanical Engineering, BCET, Gurdaspur, Punjab, India*

Abstract — *Photovoltaic thermal (PV/T) system was developed to prevent the degradation of the PV panel efficiency due to overheating of cells through heat removing process by air or water. In this study, the effect of nanofluid as coolant on both electrical and thermal performance of photovoltaic thermal system at different mass flow rates is evaluated. The effect of 0.3% volume concentration of CuO nanoparticles and different mass flow rates on electrical and thermal performance of photovoltaic thermal system is investigated. The experimental results are also compared with conventional photovoltaic (PV) panel. The electrical efficiency of the hybrid system calculated by measuring temperature of photovoltaic panel and fluid outlet.*

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

I. INTRODUCTION

A photovoltaic thermal (PV/T) system consists of conventional photovoltaic (PV) module and a thermal collector in which photons diffused from the sun are converted into electricity along with absorption of the extra photons energy and heat produced by photovoltaic cell simultaneously. A hybrid system for generation of electricity and heat energy makes this system more efficient and economical. In the recent years, several techniques are developed to improve the efficiency of these systems. Although, the structural design is main aspect to have an efficient system, the design variation in hybrid system is limited. To illustrate, the thermal efficiency of sheet and tube collector is only 2% lower than other types of collectors [1]. Yousefi et al. [2] performed experiments to study the effects of using Al_2O_3/ H_2O nanofluid as a heat absorber medium in a flat plat solar collector. The study involved different mass flow rates of 1, 2 and 3 L/min and two different nanofluid concentrations of 0.2% and 0.4% by weight. The result showed that with the increase of mass flow rate for a constant concentration, the collector efficiency increased. Yun and Qunzhi [3] used MgO-H_2O nanofluid as a film with different concentrations of 0.02%, 0.06% and 1% by weight, on the surface of PV module in order to absorb the extra heat of cells and solar intensity. The study involved output power of solar cells also. The results showed that an increase of thickness of film of nanofluid or concentration reduces the thermal and electrical efficiencies at constant solar intensity. Chien et al. [4] investigated experimental and theoretical study of a two-phase thermosyphon solar water heater. The study includes two approaches to improve the thermal performance of the collector. In the first approach, double fins tubes were used which increased the absorbed heat by 3% and 4% absorbed heat was increased by introducing nanofluid in the second approach. Most of the experimental studies have focused on the optimization of the conventional fluids such as water and air in the systems. However, studies on using nanofluids as a coolant in photovoltaic thermal systems are rare. Working fluids like nanofluid having enhanced heat transfer characteristics can significantly improve the overall efficiency of the system without changing the design [5]. Elmir et al. [6] simulated the cooling of solar cells by the use of Al_2O_3- H_2O nanofluid. The study involved finite element method. Assuming a laminar model, the authors investigated the effects of solid volume fraction and Reynolds number on the flow pattern and heat characteristics of the system. It was found that an increase of the volume fraction from 1% to 10% enhanced the heat transfer rate by nearby 27%. During study, the authors did not consider the effects of various parameters such as cell temperature variations, solar intensity and climate change in their model. Chandrasekhar et al. [7] investigated experimentally the performance by water cooled PV panel using cotton wick structure with water, Al_2O_3, CuO / water nano fluids respectively. The experimental results were also compared with PV panel without cooling system. The authors found that the temperature of the photovoltaic panel was reduced to 45°C, 59°C and 54°C when cooling was done using cotton wick structures with water and nano fluids respectively. Karami and Rahimi [8] investigated heat transfer enhancement in a PV cell using Boehmite nanofluid. Results showed that the nanofluid perform better than water and caused higher decrease in the average PV cell temperature. Sardarbadi et al. [9] performed experimental investigation of the effects of silica-water nanofluid on PV/T. In paper, the effects of using silica-water nanofluid on the thermal and electrical efficiencies of a PV/T are experimentally studied. The results showed that the overall efficiency of PV/T collector for the case of silica-water nanofluid was raised to 3.6 % as compared to case of pure water. Nizetic et al. [10] investigated water spray cooling technique applied on a photovoltaic panel. The experimental results showed that it is possible to achieve maximum total increase of 16.3% electric power output. Michael and Iniyan [11] investigated the performance analysis of a copper sheet laminated photovoltaic thermal collector using copper oxide-water nanofluid. A novel PV/T system was created and its performance was tested using 0.05% volume fraction CuO/water nanofluid. The maximum thermal efficiency achieved by nanofluid was 45.76%. An et al. [12] performed investigation on a spectral splitting PV/T system based on Polypyrrole nanofluid. The results indicated that the temperature of nanofluid and the performance of photovoltaic panel increased with the particle concentration, but the thermal performance decreased simultaneously. The maximum overall efficiency of the photovoltaic thermal system with polypyrrole nanofluid filter was 25.2 %, which was 13.3% higher than that without filter. Sardarbadi and Pasondideh [13] did experimental and numerical studies of metal oxides/water nanofluids as coolant in photovoltaic thermal system. The study included Al_2O_3-H_2O, ZnO-H_2O and TiO_2-H_2O nanofluids as working fluids. The results showed that ZnO- H_2O is found to have highest thermal efficiency as compared to other nanofluids and deionized water.

II. EXPERIMENTAL SETUP

An experimental setup was fabricated to investigate the effect of the CuO-H_2O nanofluid on the performance of Photovoltaic thermal (PV/T) system. The photograph of the experimental setup is shown in Fig.1. The experimental PV/T system consists of 100 W poly-crystalline silicon photovoltaic modules. One of the photovoltaic modules is equipped with a thermal collector embedded behind PV module, while the other one has no thermal collector. Both units are performed in same environmental conditions. In order to recover heat from the backside of the PV panel, an aluminium sheet is attached to the Tedlar by using thermal conductive silicone adhesive sealant. Further, in order to transfer the heat to working fluid, serpentine copper tubing arrangement is attached to the aluminium sheet with a thermal insulation underneath. For a closed flow circuit of working fluid, a shell and tube heat exchanger of capacity 80 litres is used to cool the working fluid after being heated in PV/T system. The working fluids considered in the experiments are pure water and copper oxide-water nanofluid with 0.3% volume concentration. The required amount of nanoparticles are mixed with pure water by ultrasonic dispersion method. The working fluid kept in the reservoir, from there, it was pumped through valve and PV/T collector and finally it was recycled into the reservoir. Three different mass flow rates i.e. 0.33 kg/min, 0.5 kg/min, and 0.66 kg/min are taken to investigate electrical and thermal performance of PV/T system. 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. Experiments were conducted in the month of April 2016 under clear sky and sunny conditions.

Fig.1: Photographic view of experimental set-up photovoltaic thermal system (left), reference photovoltaic panel (right).

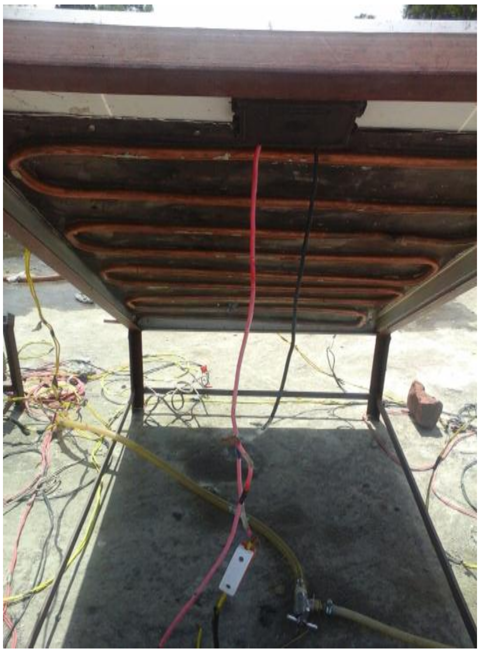
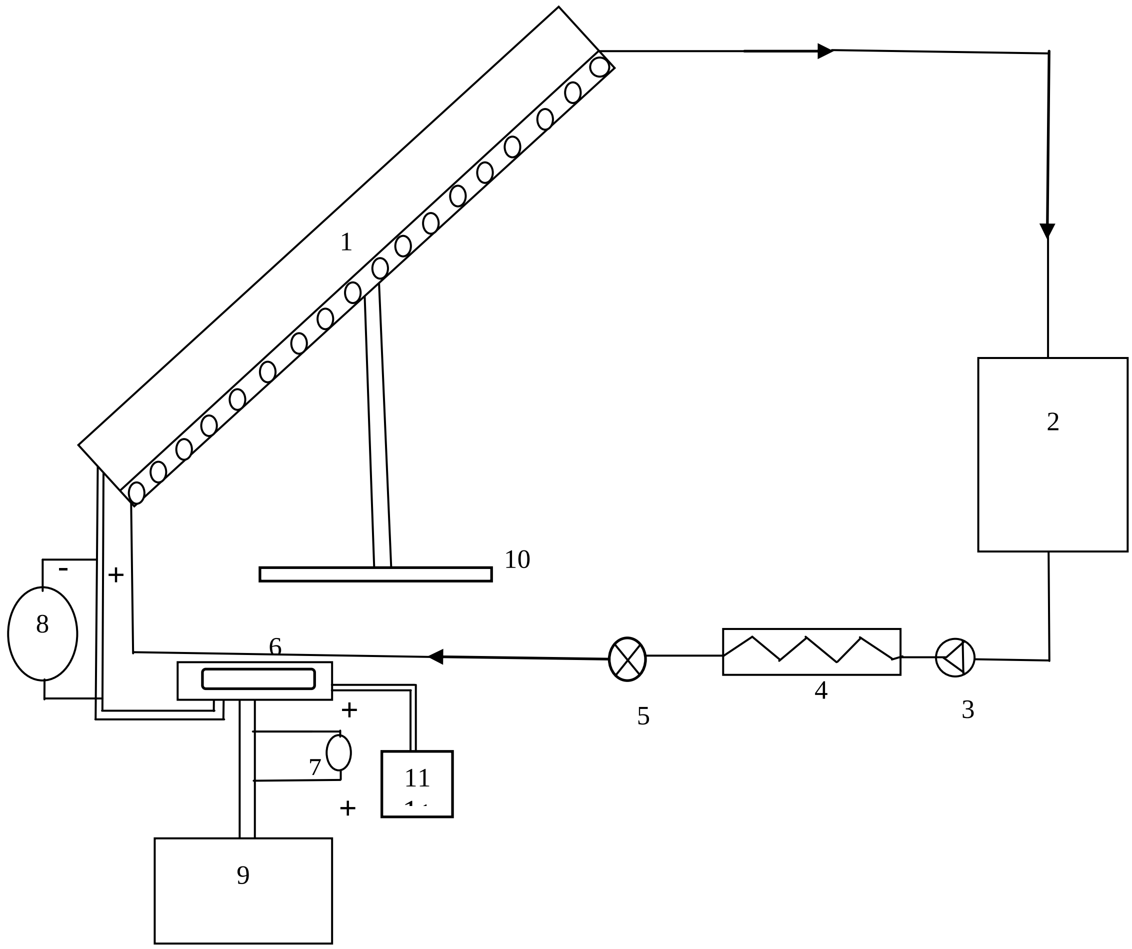


Fig.2: Rear view of experimental set-up.



1. Photovoltaic thermal system, 2. Prestorage tank, 3. Pump, 4. Heat exchanger, 5. Flow regulating valve, 6. Charge controller, 7. Ampere meter/Multimeter, 8. Voltmeter/Multimeter, 9. Battery, 10. Stand, 11. Load.

Fig. 3: Schematic view of experimental setup.

III. DATA REDUCTION

a) Electrical efficiency of photovoltaic panel

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

Where, V_{oc} and I_{sc} are open circuit voltage and short circuit current, respectively.

b) Fill factor (FF)

$$FF = \frac{P_{max}}{V_{oc} \times I_{sc}} = \frac{V_{max} \times I_{max}}{V_{oc} \times I_{sc}} \quad (2)$$

c) Electrical efficiency of photovoltaic/thermal system

$$\eta_{electricalpv/t} = \frac{V_{oc} \times I_{sc} \times FF \times \beta_c}{I \times A} \quad (3)$$

Where β_c is packing factor , $\beta_c = \frac{\text{area of solar cells}}{\text{area of photovoltaic panel}}$

d) Thermal efficiency of photovoltaic/thermal system

$$\eta_{thermal} = \frac{m \times C_p \times (T_o - T_i)}{I \times A} \quad (4)$$

Where, I is solar radiation.

IV. RESULTS AND DISCUSSION

4.1 Variation of temperature of PV panel with time

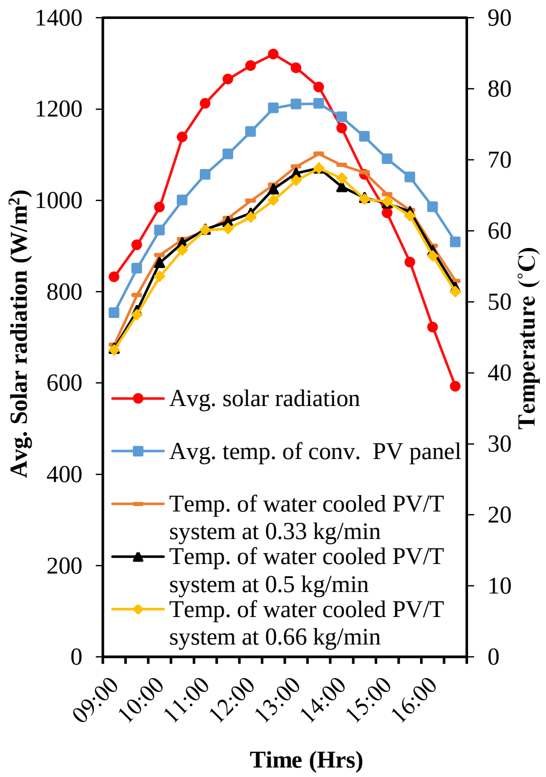


Fig. 4: Variation of PV module temperature with time under different operating conditions during a day time at different mass flow rates.

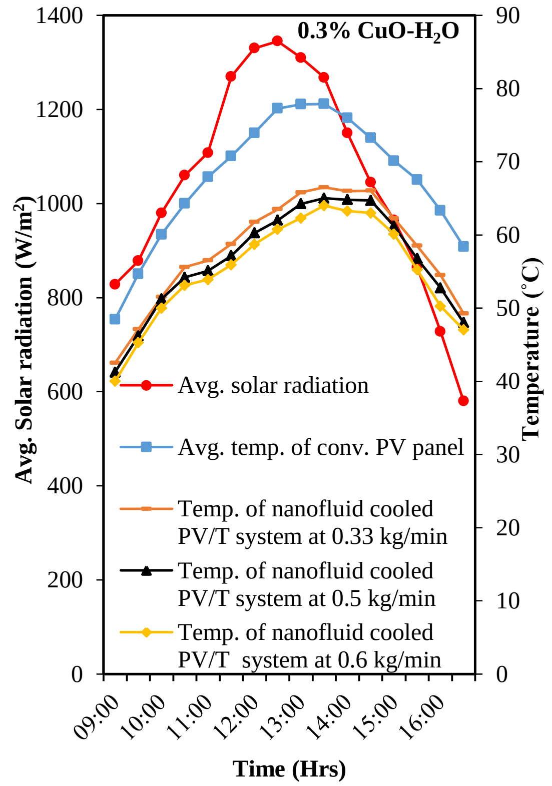


Fig. 5: Variation of PV module temperature with time under different operating conditions during a day time at different mass flow rates.

Fig. 3 shows variation of temperature of conventional panel and water cooled photovoltaic thermal system with respect to average solar radiation during days in which experiment is performed with different mass flow rates. It has been observed that the temperature of photovoltaic thermal system with pure water is less than conventional PV panel. The maximum temperature reduction with water cooled PV/T system at 0.33 kg/min mass flow rate is 13.9%, at 0.5 kg/min is 15.53% and at 0.66 kg/min is 16.3% as compared to conventional PV panel.

Fig. 4 shows variation of temperature of conventional panel and photovoltaic thermal system with 0.3% volume concentration of CuO-H_2O nanofluid as working medium, with respect to average solar radiation at different mass flow rates. It has been found that the temperature of PV/T system with 0.3% vol. concentration of CuO-H_2O nanofluid as working medium is less than convention PV panel. The maximum temperature reduction with 0.3% vol. nanofluid PV/T system at 0.33 kg/min mass flow rate is 16.5%, at 0.5 kg/min is 18.52% and at 0.66 kg/min is 21.61% as compared to conventional PV panel.

Fig. 5 shows variation of temperature of conventional panel, water cooled photovoltaic thermal system and 0.3% vol. concentration of CuO-H_2O nanofluid cooled photovoltaic thermal system at 0.66 kg/min (maximum) mass flow rate. The maximum temperature reduction with water cooled PV/T system is 16.3% and 0.3% vol. concentration of CuO-H_2O is 21.61% as compared to conventional PV panel.

4.4 Variation of output Power of PV panel with time

Fig. 6 shows variation of output power of conventional panel and water cooled photovoltaic thermal system at different mass flow rates. It has been found that the output power of water cooled photovoltaic thermal system is higher than conventional photovoltaic module. The average increment of output power at 0.33 kg/min mass flow rate is 4.12% at 0.5 kg/min mass flow rate is 5.44% and at 0.66 kg/min mass flow rate is 6.8% as compared to conventional PV panel.

Fig. 7 shows variation of output power of conventional panel and photovoltaic thermal system with 0.3% vol. concentration of CuO-H_2O nanofluid at different mass flow rates. It has been found that the output power of photovoltaic thermal system with 0.3% volume concentration nanofluid is higher than conventional photovoltaic module. The average increment of output power at 0.33 kg/min mass flow rate is 9.30% at 0.5 kg/min mass flow rate is 10.72% and at 0.66 kg/min mass flow rate is 12.90% as compared to conventional PV panel.

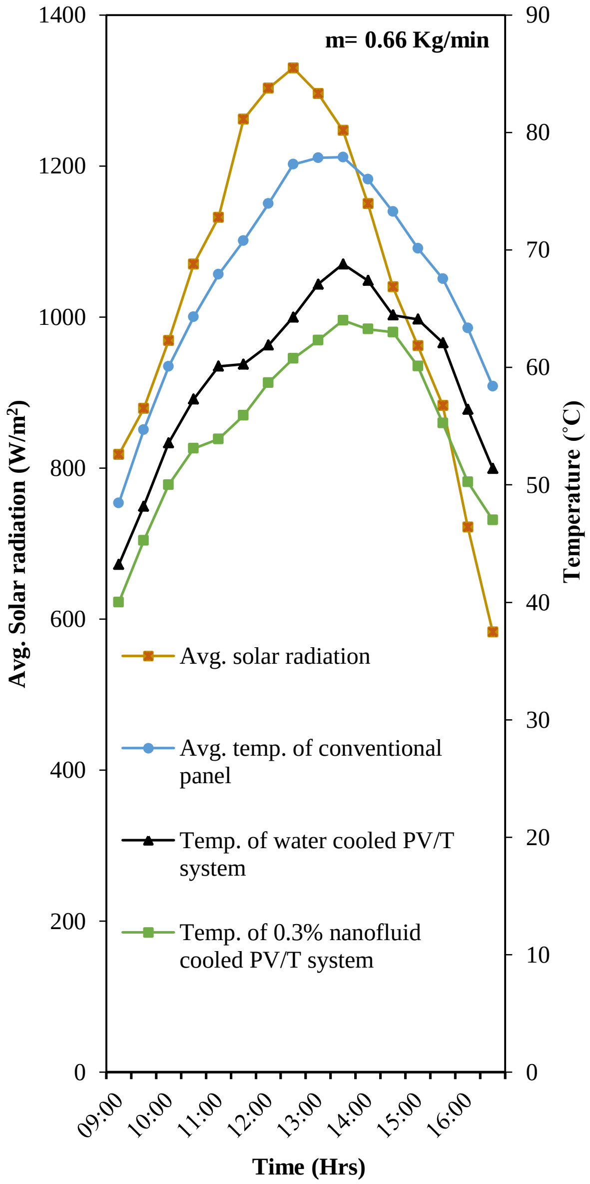


Fig. 6: Variation of PV module temperature with time under different operating conditions at maximum mass flow rate.

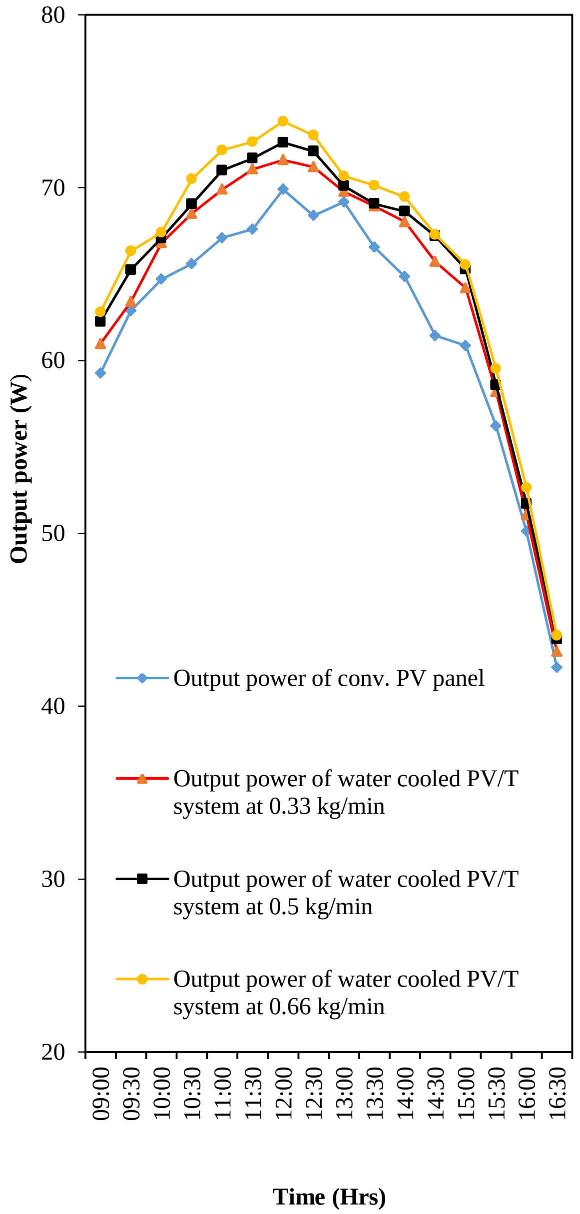


Fig.7: Variation of output power of nanofluid cooled PV/T system and conventional panel with time at different mass flow rates.

Fig. 8 shows variation of output power of conventional panel, water cooled photovoltaic thermal system and 0.3% vol. concentration of $CuO\text{-}H_2O$ nanofluid cooled photovoltaic thermal system at 0.66 kg/min (max.) mass flow rate. The maximum increment of average output power of water cooled PV/T system is 6.8% and with 0.3% volume concentration of $CuO\text{-}H_2O$ nanofluid is 12.90% as compared to conventional PV panel.

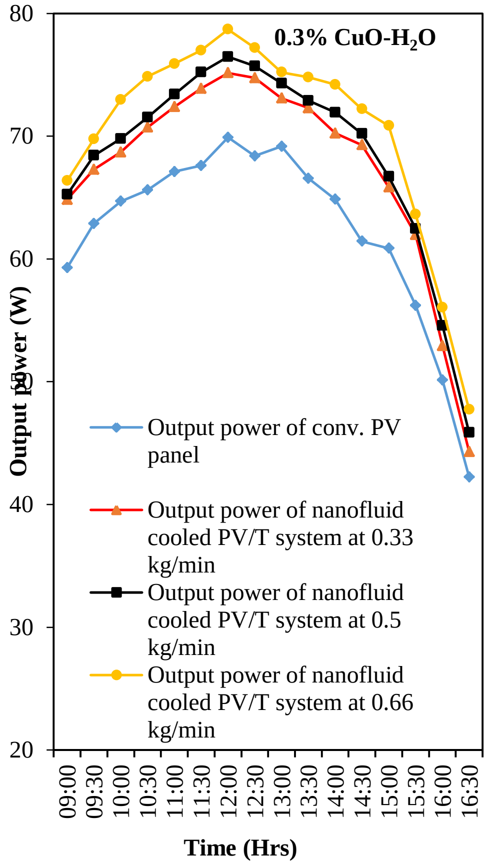


Fig. 8: Variation of output power of PV/T system, cooled based PV/T system and conventional panel with time at maximum mass flow rate.

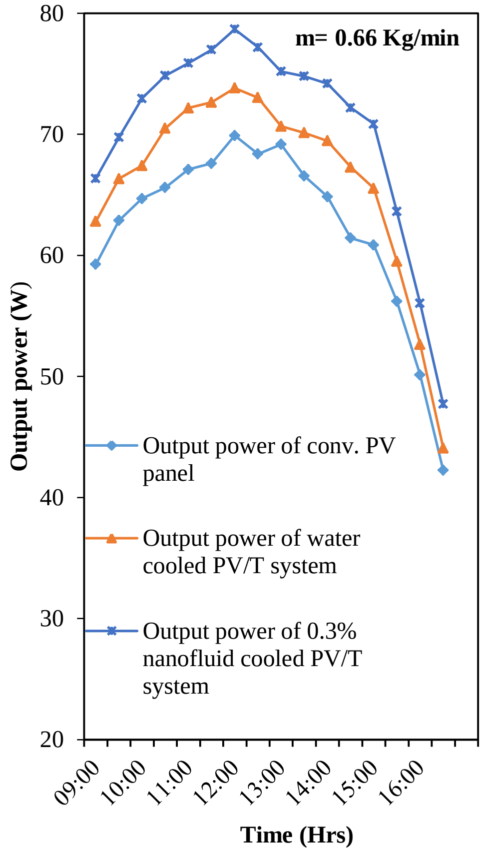


Fig. 9: Variation of output power of PV/T system, cooled based PV/T system and conventional panel with time at maximum mass flow rate.

4.5 Variation of Electrical efficiency with time

Fig. 9 shows variation of electrical efficiency of conventional panel and water cooled photovoltaic thermal system at different mass flow rates. It has been found that the electrical efficiency of water cooled photovoltaic thermal system is higher than conventional photovoltaic module. The average increment of electrical efficiency at 0.33 kg/min mass flow rate is 8.99%, at 0.5 kg/min mass flow rate is 11.83% and at 0.66 kg/min mass flow rate is 15.46% as compared to conventional PV panel.

Fig. 10 shows variation of electrical efficiency of conventional panel and photovoltaic thermal system with 0.3% vol. concentration of $CuO\text{-}H_2O$ nanofluid at different mass flow rates. It has been found that the electrical efficiency of photovoltaic thermal system with 0.3% volume concentration nanofluid is higher than conventional photovoltaic module. The average increment of electrical efficiency at 0.33 kg/min mass flow rate is 18.29%, at 0.5 kg/min mass flow rate is 20.82% and at 0.66 kg/min mass flow rate is 23.19% as compared to conventional PV panel.

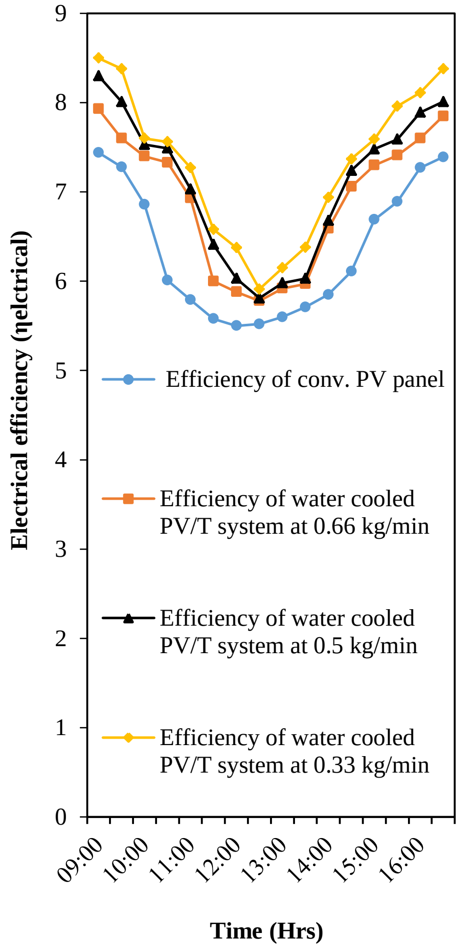


Fig. 10: Variation of output power of PV/T system, cooled based PV/T system and conventional panel with time at maximum mass flow rate.

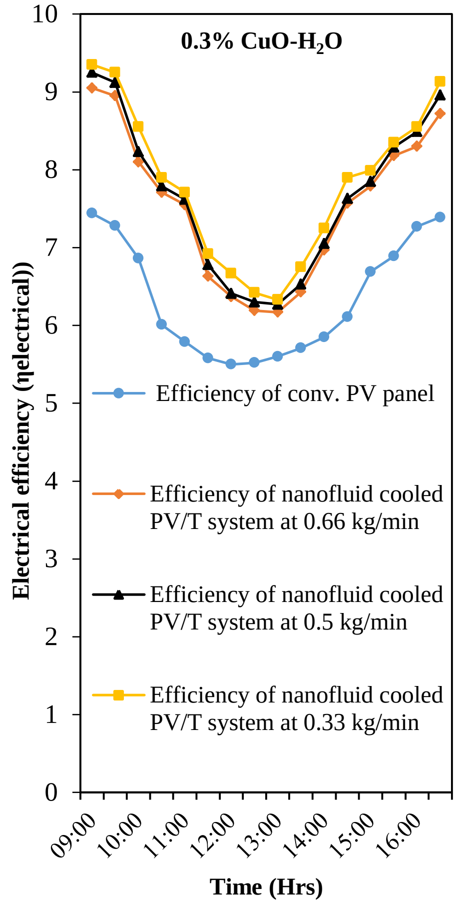


Fig. 11: Variation of output power of PV/T system, cooled based PV/T system and conventional panel with time at maximum mass flow rate.

Fig. 11 shows variation of electrical efficiency of conventional panel, water cooled photovoltaic thermal system and 0.3% vol. concentration of CuO-H_2O nanofluid cooled photovoltaic thermal system at 0.66 kg/min (maximum.) mass flow rate. The maximum increment of average electrical efficiency of water cooled PV/T system is 15.46% and with 0.3% volume concentration of CuO-H_2O nanofluid is 23.19% as compared to conventional PV panel.

4.6 THERMAL EFFICIENCY

Fig. 5.12 shows variation of thermal efficiency of water cooled photovoltaic thermal system and 0.3% vol. concentration of CuO-H_2O nanofluid cooled photovoltaic thermal system during days at maximum mass flow rate of fluid i.e. 0.66 kg/min mass flow rate. The average thermal efficiency of water cooled photovoltaic thermal system is 41.99%, and 0.3% nanofluid cooled photovoltaic thermal system is 58.04%. Heat transfer properties of nanofluids are responsible for further increment in thermal efficiency as reported by Moghadam et al. [13].

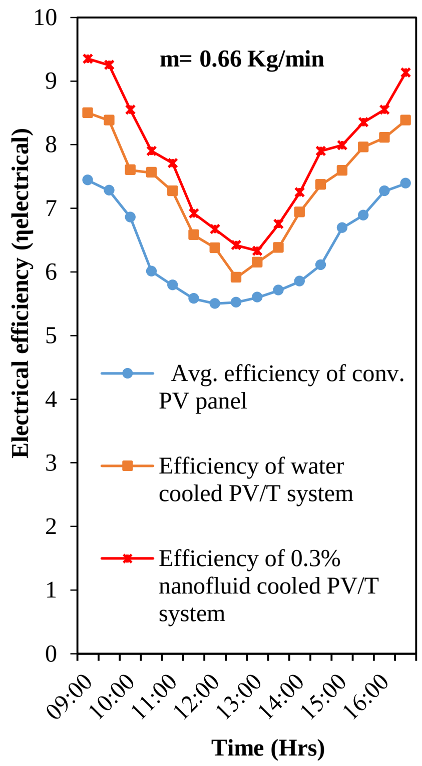


Fig. 12: Variation of output power of PV/T system, cooled based PV/T system and conventional panel with time at maximum mass flow rate.

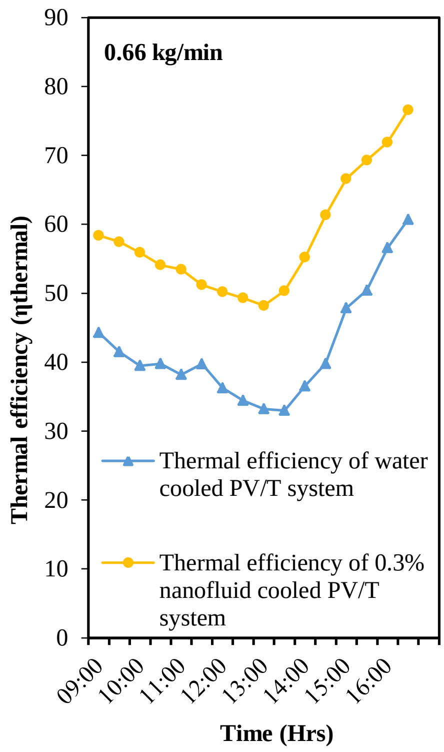


Fig. 13: Variation of thermal efficiency of PV/T system, nanofluid cooled PV/T system and conventional panel with time at maximum mass flow rate.

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)	nm	nanoparticles
V_{oc}	open circuit voltage (Volt)		

V. CONCLUSION

From this paper, it is concluded that the maximum temperature reduction with water cooled PV/T system is 16.3% and with 0.3% volume concentration of CuO-H_2O nanofluid is 21.61% at maximum mass flow rate as compared to conventional PV panel. The maximum increment of average electrical efficiency of water cooled PV/T system is 15.46% and with 0.1% volume concentration of CuO-H_2O nanofluid is 23.19% at maximum mass flow rate as compared to conventional PV panel. The average thermal efficiency of water cooled PV/T system is 41.99% and 0.3% nanofluid cooled PV/T system is 58.04%.

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] A. Ibrahim, MY. Othman, MH. Ruslan, S. Mat and K. Sopian, "Recent advances in flat plate photovoltaic/thermal (PV/T) solar collectors," Renew Sustain Energy Rev, vol.15, pp.352-365, January 2011.

[2] T. Yousefi, F. Veysi, E. Shojaeizadeh, and S. Zinadini, "An experimental investigation on the effect of Al_2O_3-H_2O nanofluid on the efficiency of Flat-plate solar collectors," Renewable Energy, Vol. 39, pp.293-298, 2011.

[3] C. Yun and Z. Qunzhi, "Study of photovoltaic/thermal systems with MgO/water nanofluids flowing over silicon solar cells", Power and Energy Engineering Conference (APPEEC), Asia-Pacific 2012.

[4] C. Chien, C. Kung, C .Chang, W. Lee, C. Jwo and S. Chen, "Theoretical and experimental investigations of a two-phase thermosyphon solar water heater", Vol. 36, pp. 415–423, January 2011.

[5] Y. Hwang, H. Park, J. Lee, and W. Jung, "Thermal conductivity and lubrication characteristics of nanofluids", Department of Mechanical Engineering, Pusan National University, San 30, Jangjeon-Dong, Kumjung-Ku, Busan, Republic of Korea Vol. 6, pp. e67–e71, August 2006.

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

[5] E. Erdil, M. Ilkan, and F. Egelioglu, "An experimental study on energy generation with a photovoltaic (PV)–solar thermal hybrid system", Energy, Vol. 33, pp.1241-1245, 2008.

[6] M. Elmir, R. Mehdaoui and A. Mojtabi, "Numerical simulation of cooling a solar cell by forced convection in the presence of a nanofluid", Energy Procedia, Vol. 18, pp. 594-603, 2012.

[7] 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.

[8] N. Karami and M. Rahimi, "Heat transfer enhancement in a PV cell using Boehmite nanofluid", Energy Conservation and Management, Vol. 86, pp. 275-285, 2014.

[9] M. Sardarbadi, M.P. Fard, and S.Z. Heris, "Experimental investigation of the effects of silica/water nanofluid on PVT", Energy, Vol. 66, 264-272, 2014.

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

[11] J. Michael and S. Iniyan, "Performance analysis of a copper sheet laminated photovoltaic thermal collector using copper oxide-water nanofluid", Institute for Energy Studies, Department of Mechanical Engineering, Anna University, Chennai 600 025, India, Solar Energy, pp.439–45, 2015.

[12] A. Wei, J. Zhang, T. Zhu and N. Gao, "Investigation on a spectral splitting PV/T system based on Polypyrrole nanofluid", Renewable Energy, Vol. 86, pp.633-642, 2015.

[12] M. Sardarabadi and M. Passandideh-Fard, "Experimental and numerical study of metal oxides/water nanofluids as coolant in photovoltaic thermal system (PV/T)," Department of Mechanical Engineering, Ferdowsi University of Mashhad, Mashhad, Iran, Solar Energy Materials & Solar Cells, Vol.157, pp.533–542, 2016.

[13] A. Moghadam, M. Gord, M. Sajadi, and M. Zadeh, "The effects of CuO/water nanofluid on the efficiency of a flat-plate solar collector", Experimental Thermal and Fluid Science, Vol.58, 2014.