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Performance Analysis of Photovoltaic Thermal (PVT) with and Without ∇-Groove Collector

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Abstract: In this study, experimental of PVT based air collector system has been conducted. It can produce electricity and heat at the same time. Fans are used to cool the PV panel and the ∇-groove used to improve the efficiency of the cooling process. During the study carried out on PVT air collectors without ∇-groove, air mass flow rate varied in ranges of 0.0069-0.0491 kg/sec and the radiation intensity halogen lamp at two different intensities of with an average of 820 and 522 W/m^2. The average PVT efficiency without collector is 59.07% in solar radiation 522 W/m^2 and the average PVT efficiency with collector is 66.49 W/m^2. It shows that ∇-groove collector used to improve the efficiency of PVT system.

Key words: Mathematical model, thermal, electrical, second law efficiency, ∇-collector, solar radiation

INTRODUCTION

Electrical energy can be generated using photovoltaic solar collectors and placed in the sun. But the amount of electricity produced by photovoltaic solar collectors will decrease as a result of increased heat on photovoltaic cells in the solar collectors. Solar energy absorbed through the surface of the photovoltaic panel is not everything can be converted into electrical energy. Partly, it converted into heat energy. Thus, the combined Photovoltaic-Thermal system (PVT) can generate heat and electricity simultaneously. The heat generated can be passed through a heat exchanger for other uses and at the same time can limit the temperature increase photovoltaic cell that can increase the efficiency of photovoltaic cells. The crucial idea about the hybrid Photovoltaic Thermal (PVT) that converted the absorbed solar irradiant into thermal and electrical energy has been introduced by Kern (1978). Mathematical model approach for photovoltaic thermal collector by using outdated thermal flat technique has been conducted by Hendrie. With the purpose of analyze the thermal performance of PVT collector; Florschuetz had presented the generally known extension of Hottel-Whillier Model (Florschuetz, 1979).

In the last few years, an amount of experimental and theoretical studies have been informed on PVT systems. In the case of heat absorption and lower production costs, a new design developed for PVT system collector and compared it with other designs (Touafek *et al*., 2014).

The applications and different forms of Flat-plat PVT collector have been conducted by Zondag *et al*. The experimental analysis has been done on PVT system with ferro-fluids as a coolant to increase the whole productivity system by Kamthania *et al*. (2011). Using thermal modeling for space heating has been developed by energy balance calculation of PVT system with semitransparent double pass module (Ghadiri *et al*., 2015). The different types of collectors like with glazed and without glazed PVT tiles and conventional hybrid PVT collector have been compared by Agrawal and Tiwari (2013). A new design of a dynamic model of air based PVT system has been offered by Sohel *et al*. (2014) The performance analysis of and new design of PVT system for low attentiveness PV panel has been conducted (Fernandez *et al*., 2014).

The use of fins and v-groove design in solar collector has a higher thermal efficiency in previous literatures (Karim and Hawlader, 2006ab; Karim *et al*., 2014). Performance and cost benefits analysis of double-pass solar collector with and without fins have been conducted by Fudholi *et al*. (2013, 2014). Investigation with The structures that were designed nearer with double-channel parallel flow bare plate (Ong, 1995), single-channel cross-corrugate (Lin *et al*., 2006), double-channel flow ∇-groove (El-Sebaii *et al*., 2011) and two-channel counter flow bare plate (Sopian *et al*., 2002). Thermal conductivity depends on the surface area of the two materials touch. The contact surface of the

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∇-groove with the back of photovoltaic are few because only vertices each ∇-groove only to be touched by the photovoltaic panel. This study uses the ∇-collector. Using ∇-collector can touch the whole backside photovoltaic panel. It is very urgency to know performance of PV/T system with ∇-collector with experimental investigation. In this study, the objective of this study is exergy analysis of PVT system with and without ∇-collector with different of solar radiation and mass flow rate.

MATERIALS AND METHODS

Design ∇-groove collector: This study use of ∇-collector is produced in the form of a bar. There is a total of 13 unit ∇-collector produced. Wide of ∇-groove that touches the back is measuring 3.4 cm the length of each ∇-groove is 114 cm (10 bars) and 100 cm (3 bars because of wire rod of photovoltaic panel). Each vertex angle is 60°. The length of each side is 3.45 cm and height is 3 cm. Figure 1 shows the ∇-collector which has been produced to fit behind the photovoltaic panel.

Performance analysis: Performances of PVT with ∇-collectors are characterized by their air temperature rice, thermal and electrical efficiency. The electrical efficiency of PV panel depends on its temperature which corresponding to the cooling performance. Cooling is a feature that distinguishes PV panel from PVT collector. Normally, performances of PVT air collector is presented by thermal, electrical and combined efficiencies which are functions of parameters such as solar radiation, mass flow rate, ambient, inlet, outlet temperatures. For electrical efficiency (Skoplaki and Palyvos, 2009):

$$\eta_{pv} = \eta_{ref}\left[1-\beta_{ref}\left(T_{pv}-T_{ref}\right)\right] \tag{1}$$

For the temperature coefficient β_{ref} can be written as Agarwal and Garg (1994) :

$$\beta_{ref} = \frac{1}{\left(T_O-T_{ref}\right)} \tag{2}$$

For thermal efficiency by following (Chow, 2010):

$$\eta_{th} = \dot{m}C\left(T_O-T_i\right)/IA \tag{3}$$

For the Photovoltaic Thermal (PVT) efficiency is:

$$\eta_{pvt} = \eta_{pv}+\eta_{th} \tag{4}$$

Fig. 1: ∇-collector collector to fit behind photovoltaic panel

Fig. 2: Photograph of PVT air with ∇-groove under solar simulator

Experimental investigation: The PVT with ∇-collector consists of a PV panel, ∇-collector, fan and insulator. Ducting used to connect a fan to the PVT with ∇-collector. The tunnel bars was placed at the back surface of PV panel. The 100 W PV panel was insulated with monocrysthalene. The PVT with ∇-collector evaluated using a specially constructed solar simulator in the laboratory as shown in Fig. 2. Solar simulator built using 45 halogen lamps with 500 W each lamp. Regulators were used to control the solar radiation or brightness of solar simulator. The experiments were conducted under solar radiation of 522 and 820 W/m^2, also with five different mass flow rates from 0.0069-0.0491 kg/sec. Electronic load was used to collect data voltage and current with model 8500 from BK precision. An air flow DTA 4000 anemometer was used to determine the air flow velocity. A pyranometer to determine solar radiation and J-type thermocouples connected to multimeter were used. Using ADAM-4019 to record temperature data used computer software automatically made in Solar Energy Research Institute (SERI), the National University of Malaysia.

RESULTS AND DISCUSSION

The experimental results were conducted at laboratory in National University of Malaysia. Results indicated that effects of solar radiation and mass flow rate on the temperature different were obtained. The temperature distribution of PVT with and without ∇-groove collector was gained from the experimental result. The result shows that by lowering the temperatures T_{pv}, T_o simultaneously the increasing the mass flow rate as shown in Fig. 3-6. The maximum outlet temperature is 54.59°C with collector and the minimum outlet temperature is 46.77°C without collector at solar radiation 820 W/m^2. For solar radiation 522 W/m^2 the maximum outlet temperature with collector is 44.97°C and the minimum outlet temperature without collector is 44.17°C.

Figure 7 and 8 show mass flow rate versus Photovoltaic Thermal (PVT) efficiency of with and without ∇-groove collector. For the mass flow rate from 0.0069-0.0491 kg/sec, the PVT efficiency maximum at solar intensity of 820 W/m^2 79.17% with ∇-groove collector and the minimum PVT efficiency at intensity of 522 W/m^2 is 30.54% without collector. When mass flow rate value is decrease PVT efficiency follow it. This situation can be concluded that the higher mas flow rate, the higher PVT efficiency.

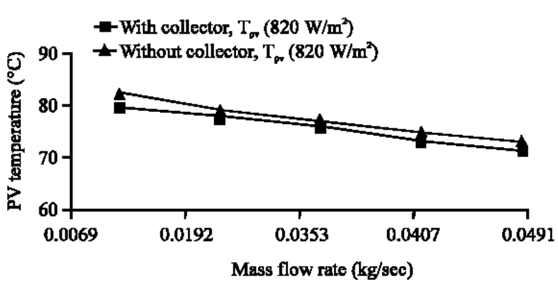

Fig. 3: Mass flow rate versus Photovoltaic panel Temperature (T_{pv}) of PVT with ∇-collectors for solar radiation of 820 W/m^2

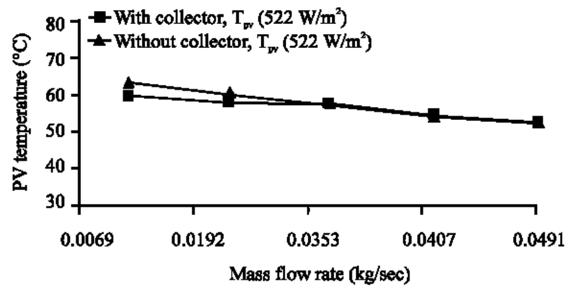

Fig. 4: Mass flow rate versus photovoltaic panel Temperature (T_{pv}) for solar radiation of 522 W/m^2

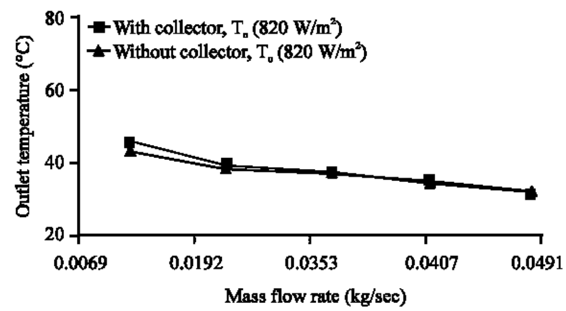

Fig. 5: Mass flow rate versus outlet Temperature (T_o) for solar radiation of 820 W/m^2

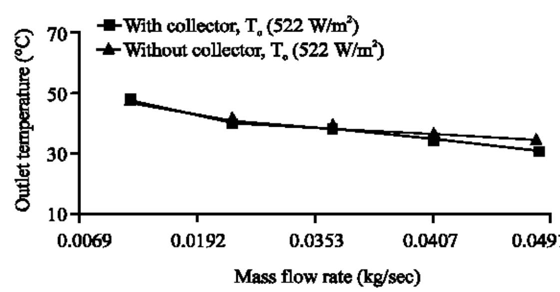

Fig. 6: Mass flow rate versus outlet Temperature (T_o) for solar radiation of 522 W/m^2

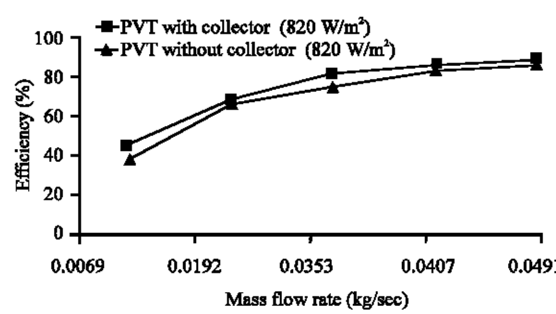

Fig. 7: Mass flow rate versus PVT efficiency for 820 W/m^2

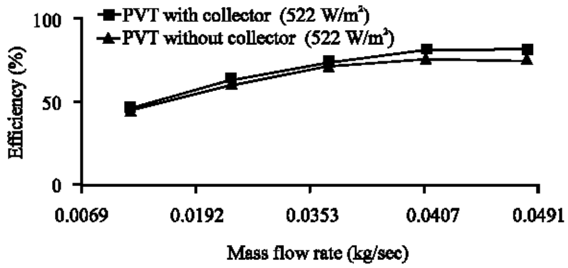

Fig. 8: Mass flow rate versus PVT efficiency for 522 W/m^2

CONCLUSION

Experimental study was conducted and performance of PVT based air with and without V-groove collector was evaluated. On the basis of present study, the results of these studies may be decided as follow:

The result of outlet temperature and PV temperature from experimental study shows that by lowering the temperatures T_{pv}, T_o simultaneously the increasing the mass flow rate. The maximum PVT efficiency is 79.17% with collector in solar radiation 820 W/m^2 and the minimum PVT efficiency is 30.54% without collector in solar radiation 522 W/m^2.

The average PVT efficiency with collector is 59.07% in solar radiation 522 W/m^2 and the average PVT efficiency without collector is 66.49 W/m^2. It shows that V-groove collector used to improve the efficiency of the cooling process.

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