Experiment Study on Single-pass Photovoltaic-Thermal (PV/T) Air Collector with Absorber

GOH LI JIN, HAFIDZ RUSLAN, SOHIF MAT, MOHD. YUSOF OTHMAN, AZAMI ZAHARIM AND KAMARUZZAMAN SOPYAN
Solar Energy Research Institute,
University Kebangsaan Malaysia,
43600 UKM Bangi,Selangor Darul Ehsan,
MALAYSIA
Email : hafidz@ukm.my,sohif@ukm.my,myho@ukm.my,
azami.zaharim@gmail.com,ksopian@eng.ukm.my

Abstract: - Problem statement: Solar cell received heat from solar irradiance as well and this will reduce the efficiency of the solar cell. The heat trap at the solar photovoltaic panel becomes waste energy. Approach: The solution for this was by adding a cooling system to the photovoltaic panel. The purpose of this study was to cool the solar cell in order to increase its electrical efficiency and also to produce heat energy in the form of hot air. Hot air can be used for drying applications. A single pass PVT with rectangle tunnel absorber has been developed. The rectangle tunnel acted as an absorber and was located at the back side of a standard photovoltaic panel. The rectangle tunnel was connected in parallel. The PVT collector has been tested using a solar simulator. Results: Electrical efficiency increased when the solar cell was cool by air flow. Solar photovoltaic thermal collector with rectangle tunnel absorber has better electrical and thermal efficiency compared to solar collector without rectangle tunnel absorber. Photovoltaic, thermal and combined photovoltaic thermal efficiency of 10.02, 54.70 and 64.72% at solar irradiance of 817.4 W m$^{-2}$, mass flow rate of 0.0287 kg sec$^{-1}$ at ambient temperature of 25°C respectively has been obtained. Conclusion: The hybrid photovoltaic and thermal with rectangle tunnel as heat absorber shows higher performance compared to conventional PV/T system.

Key words: Photovoltaic thermal, rectangle tunnel absorber, thermal efficiency, air collector

1 Introduction
Efficiency of solar cell will drop when the temperature of it increases. Air can be used to cool the surface temperature of the photovoltaic panel. The air will pick up the surface heat and can be used for domestic of application including drying and other industrial process heat application. A special type of solar collectors was design to collect electric energy and thermal energy simultaneously known as Photovoltaic-Thermal (PV/T) solar collector.

Single pass solar collector with open channel absorber has been studied by earlier researcher (Sopian et al., 1996; Prakash, 1994). The double pass solar collector with upper and lower channels has been fabricated by other researchers (Garg et al., 1991; Cox and Raghuraman, 1985). Comparison of single pass and double pass collector has been done and double pass solar collector shows better performance (Hegazy, 1999). Further research has been conducted by combining heat conductor into solar collector such as v-groove, porous media and fins (Othman et al., 2006; 2007).

2 PV/T Design
Purpose of adding heat conductor into solar collector was to enhance the heat extraction of collector and thus increase the efficiency of the collector. In this study, rectangle tunnel absorber is added into the photovoltaic thermal collector as heat conductor. A PV/T solar collector by combining photovoltaic panel and rectangle tunnel absorber as heat conductor was fabricate and tested in this experiment. Using single pass system instead of double pass system was to avoid using large amount of area. This design was to maintain the electrical efficiency of the solar panel and to produce hot air by extract heat from solar panel.

Figure 1 shows the single-pass PV/T collector with rectangle tunnels. Figure 2 shows the system connecting blower, ducting and PV/T collector. Table 1 shows other research on various design of single-pass and double-pass PV/T collector.
3 Results and Discussion

The purpose of this experiment was to improve the cooling system by carrying out as much heat as possible from solar photovoltaic PVT collector made for this experiment. So, this experiment was to increase both the electrical and thermal efficiency. Air flow mass can be calculated from the equation below:

\[ m = \rho AV_{av} \]  

(1)

Air flow mass, m was needed to calculate the thermal efficiency of the PVT system. Density, \( \rho \), area of air drain input, A was standard value in this experiment. \( I_m \) and \( V_m \) were from power maximum, \( P_m \). Power, \( P = I_m \times V_m \):

(2)

Performance of the system PVT can be seen from electrical and thermal efficiency. Electrical efficiency, \( \eta_{el} \) and thermal efficiency, \( \eta_{th} \) was shown as below:

\[ \eta_{el} = \frac{I_m \times V_m}{A_c \times S} \times 100\% \]  

(3)

\[ \eta_{th} = \frac{mC_p(T_o-T_i)}{A_p \times S} \times 100\% \]  

(4)

Table 1 Result of various PV/T air collectors

<table>
<thead>
<tr>
<th>Source</th>
<th>Solar Irradiance ((\text{W/m}^2))</th>
<th>Air Flow Rate ((\text{m/s}))</th>
<th>Electrical Efficiency (%)</th>
<th>Thermal Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sarhaddi (2010)</td>
<td>1000</td>
<td>1 m/s</td>
<td>10.01</td>
<td>17.18</td>
</tr>
<tr>
<td>Othman (2005)</td>
<td>500</td>
<td>0.015 kg/s</td>
<td>4</td>
<td>69</td>
</tr>
<tr>
<td>Tonui (2008)</td>
<td>800</td>
<td>0.05 kg/s/m^2</td>
<td>9-10</td>
<td>52</td>
</tr>
<tr>
<td>Shahsavar (2010)</td>
<td>820-900</td>
<td>0.13 kg/s</td>
<td>9.5</td>
<td>50</td>
</tr>
<tr>
<td>Sopian (1996)(single-pass)</td>
<td>n/a</td>
<td>200-300 kg/h</td>
<td>6-7</td>
<td>24-28</td>
</tr>
<tr>
<td>Sopian (1996)(double-pass)</td>
<td>n/a</td>
<td>200-300 kg/h</td>
<td>8-9</td>
<td>32-34</td>
</tr>
<tr>
<td>Solanki (2009)</td>
<td>600</td>
<td>0.1 kg/s</td>
<td>8.4</td>
<td>42</td>
</tr>
</tbody>
</table>
Figure 3 shows the temperature comparison of solar PV/T collector with and without rectangle tunnels. The result shows collectors with absorber have lower temperature with proved to be better performance.

Figure 4 and 5 shows the thermal and electric efficiency of the PV/T collector developed in this study. Figure 4 and 5 shows comparison of thermal efficiency and electric efficiency for 2 different solar collectors. Compare to electric efficiency, thermal efficiency shows big different between solar collector with and without rectangle tunnels.

The error for mass flow rate was 0.0052 kg sec⁻¹ for example (754±52)×10⁻⁴ kg sec⁻¹. Error for electrical efficiency around 4.04-4.43% and for thermal efficiency was around 0.28-0.49%. Error for thermal efficiency was lower than electrical efficiency and it’s because the mass flow rate used in thermal calculation had smaller error compare to current and voltage used in electrical.

4 Conclusion
Solar cells generate more electricity when receive more solar radiation but the efficiency drops when temperature of solar cells increase. Hybrid photovoltaic and thermal collector can solve the problem. Photovoltaic thermal collector with tunnel shows better performance in cooling, electrical and thermal efficiency. Efficiency of the collector will increase with the increase of mass flow rate or the air flow velocity. The efficiency archived steady stage when reach to certain mass flow rate or can be said that the system reach maximum performance. At mass flow rate of 0.0754 kg sec⁻¹, electric efficiency can archive 10.06% and thermal efficiency was 75.16%. Errors in Fig. 8 and 9 were because of the rheostat used in the experiment was inconsistent.

Recommendations for this experiment were that minimize the error of the apparatus used. The solar collector can be change to double pass collector to compare its performance with single pass system. Rectangle tunnel absorber can be change to fin or porous media to compare the performance. System collecting data using computer called data logger can be used to collect data like for more precise data.

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[7] Desalination, 209: 43-49. DOI:


