Experimental Study on a New Thermal Photovoltaic Hybrid air Heating Collector: Study of Three Configurations

K.Touafek, M. Haddadi and A. Malek

Abstract—Hybrid solar collectors (PVT) produce simultaneously electricity and heat. Indeed electricity is produced by the solar cells and heat is extracted from these cells by the thermal system, primarily made up by a channel where air can circulate. In this paper the experimental study of three configurations of new thermal photovoltaic hybrid collector is presented (PVT). The study is carried out on the collector not covered with a glass, then covered with one and finally with two additional glass. The parameters affecting PV/T performance, such as covered versus uncovered PVT collectors, absorber to air thermal conductance and configuration design types are extensively discussed. Based on an energy analysis, it was reported that the coverless PVT collector produces the largest available total (electrical and thermal) energy.

Index Terms— photovoltaic, thermal, collector, Hybrid, Uncovered, Temperature, Glass

I. Introduction

Photovoltaic panels absorb energy and convert it to electricity. Not all this energy is converted to electricity since the panels are not 100% efficient.

From the literature review, it is clear that PVT collectors are very promising devices and further work should be carried out aiming at improving their efficiency and reducing their cost, making them more competitive and thus aid towards global expansion and utilization of this environmentally friendly renewable energy device.

Over the years, a large amount of hybrid photovoltaic thermal (PVT) collectors research has been carried out, originating from several independent developments that all resulted in the idea of integrating PV and thermal into one module.

A number of inventories have been made of PVT research and products, such as presented in the work by Touafek et al. [1-6], Bazilian et al. [7-8], the report on the IEA PVPS task 7 workpackage 2.5 on PVT collectors [9], Bosanac et al. [10], Charalambous et al. [11-12] and the PVT roadmap [13].

The first PVT-air facility was the 'Solar One' house that was built in 1973 / 1974 at the University of Delaware by Professor Boer [14], who by that time had done a large amount of work on PV.

At the Brown University, in 1982 a building was realized with a 33.5 m2 PVT-air collector [15-16]. However, the financing stopped before the building could be taken into use [13].

At the University of Patras, research was done on an unglazed PVT collector with both liquid and air heat extraction [17]. The optimal performance was found to be with the PV in direct contact with the sheet-and-tube absorber, while an air flow through the air spacing underneath the sheet-and-tube absorber could provide air heating as well. Furthermore, the thermal optimization of a PVT air collector by locating a thin metal sheet in the air channel was studied both experimentally [18-22] and numerically [23-26].

In the USA, at the University of Miami, PhD research on double pass PVT air collectors was carried out by Sopian [27-28], who continued this work at the University Kebangsaan Malaysia [29]. In addition, he investigated a low-concentrating double pass PV-air collector [30].

In Egypt, a simulation study comparing several PVT-air collector designs was carried out by Hegazy [31], in which the efficiency of the double pass collector was underscored.

In India, research was carried out at the Indian Institute of Technology on PVT air heaters for solar drying [32-33]. In addition, a parametric study for glazed and unglazed PVT air-collectors was carried out by Tiwari and Sodha [34-35], who found that the glazing almost doubled the useful thermal output, while the electrical efficiency dropped from 10% to 9% due to the glazing, while Prakash [36] did a numerical sensitivity study on the effects of duct depth and flow rate in a PVT collector.

II. Uncovered Hybrid Air Heating Collector

The uncovered hybrid prototype of photovoltaic thermal (PVT) collector will allow us the simultaneous production of the electric power and thermal energy.

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Figure 1 shows the influence of the temperature on the current and the tension according to the temperature of the cell of the hybrid PVT not covered and non-ventilated.

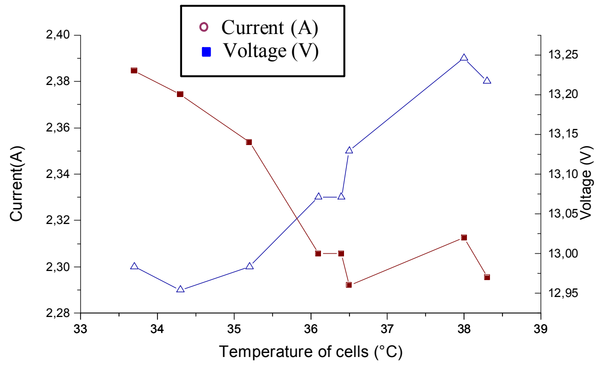


Fig.1. Current and tension according to the temperature

We notice that the short-circuit current increases slightly (from 2.30 A to 2.38 A) for an increase in temperature of (34.5 °C to 38.5°C). At the same time the open circuit tension decreases from 13.25 V to 13 V.

If the temperature of the cell increases the photo current also increases. This is due mainly to the reduction in the prohibited bandwidth of material. This increase is about 0, 1% per °C degree. The forward current of the junction increases also, but much more quickly and involving a reduction in the open circuit tension by about 2 mV per cell. The reduction in the provided power is estimated at approximately of 0, 5% per degree.

Figure 2 shows us the effect of ventilation. On the right of the figure i.e. for the collector without ventilation one notice that one obtain output temperatures of about 40-45 °C for inlet 20°C.

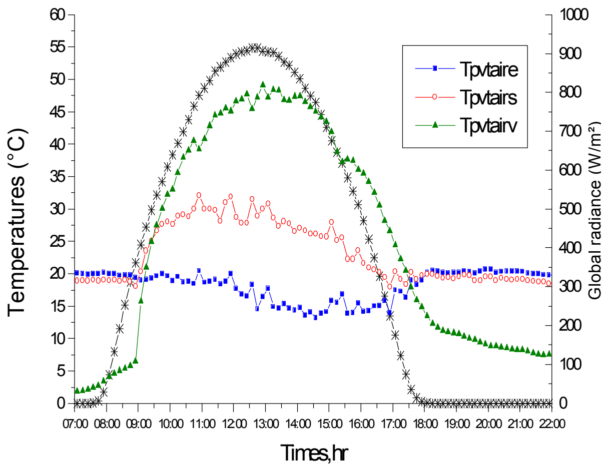


Fig.2. Temperature for uncovered PVT collector

The forced circulation decreases the variation in temperature between output and input of PVT collector for the same solar radiation. This is explained by the fact of the increase in the air flow caused by the ventilator. At the same time one should not too much thus increase the flow; it is necessary to seek the optimum. In digital simulation we found an optimum of 0.022Kg/s of masse flow rate.

Figure 3 shows the input and output temperature variation of hybrid PVT not covered and non-ventilated.

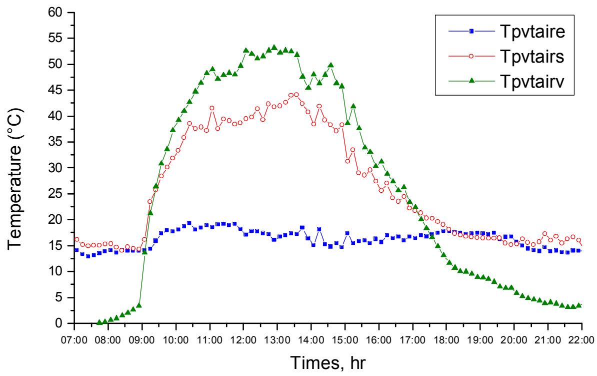


Fig.3. Uncovered hybrid PVT air heating collector without ventilation for the day of 03-02-2008

We obtained output temperatures of 45°c for an input of 15°c and 55°C for the external layer of the collector.

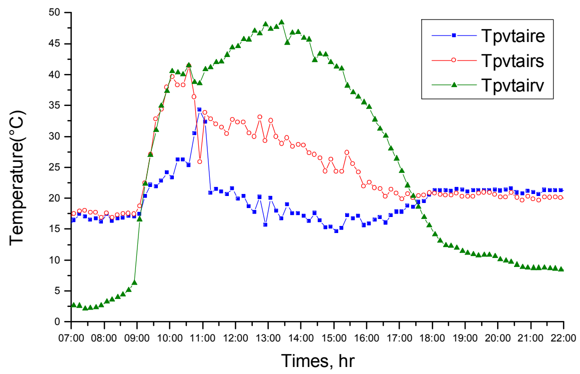


Fig.4.Uncovered hybrid PVT air heating collector with ventilator from 11: 30 for the day of 05-02-2008

Input and output temperature variation of uncovered hybrid PVT air heating collector with ventilator is shown on figure 4. Starting from 11:30 pm, we notice that from, the difference in temperature between decreased.

The use of the ventilator to decrease the difference in temperature confirms the results found by simulation.

Figure 5 and 6 show the characteristics current voltage of the uncovered hybrid PVT air heating collector without and with ventilator successively. Maximum power generated by the first and slightly higher than the second (31.2W without ventilator against 30.9 V with ventilator).

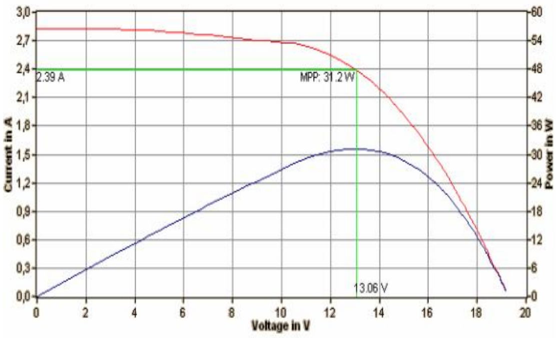


Fig.5. PVT without ventilator (G=1025w/m ²)

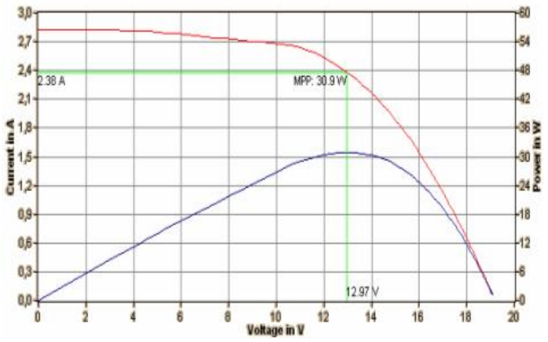


Fig.6. PVT with ventilator (G=1026w/m ²)

One notes that the ventilator (with a flow of 0.05 kg/s) slightly decreased the electric and performances of the hybrid collector. This does not want to say that the natural circulation is the ideal, but this is due with a too large flow that the ventilator used provided.

III. COVERED HYBRID PVT COLLECTOR

We added an additional glass to sensor PVT with air (figure 7).

Fig.7. Photograph of the Prototype of covered PVT collector at URAER Unity, Ghardaïa

We studied primarily two configurations, the covered hybrid collector with a natural circulation (without ventilation) and ventilated. The thermal study enabled us to trace the cartography of the temperature in different layers.

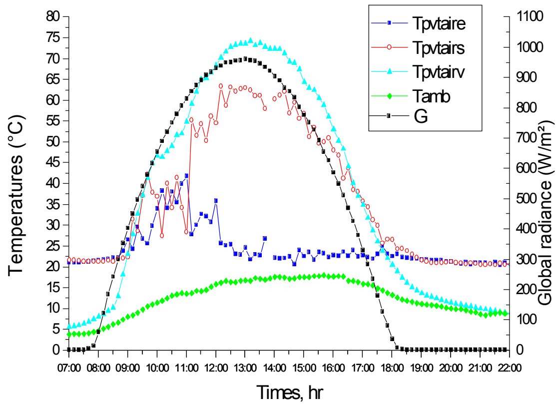


Fig.8. Covered without ventilation

Such as: Tpvtaire: input temperature of air in PVT collector; Tpvtairs: output temperature of air in PVT collector; Tpvtairv: temperature of glass, Tamb: ambient temperature; G: global radiance (W/m ²).

For an input temperature of 30°Cm one has 60°C in output.

For an input temperature of 20°C we had at exit 40°C and the temperature of the glass equalizes 60°C.

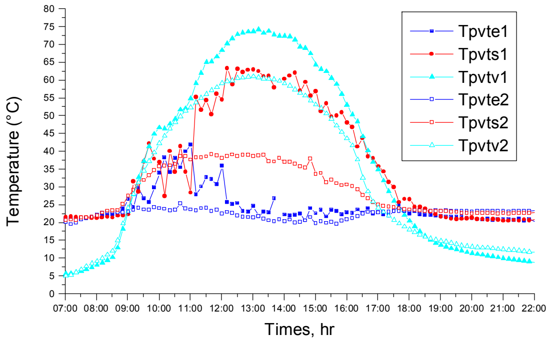


Fig.9. covered PVT with ventilator (2) and without ventilator (1)

The use of the ventilator made fall the level of temperature operating, this can be explained by the fact that for a small surface of the collector used (0.42 m ²), the increase in the air flow generates a fast circulation of this last to the lower part of the collector and a fast dissipation of heat towards the outside and thus a reduction of the temperature level.

IV. Double Glazing Hybrid PVT Collector

The raison of addition of a second glass to on top of the thermal photovoltaic hybrid air heating collector is to increase its thermal performances. Experimental measurements were taken during the day of April 7, 2008.

The variation in the temperature of input and output is shown on figure 10.

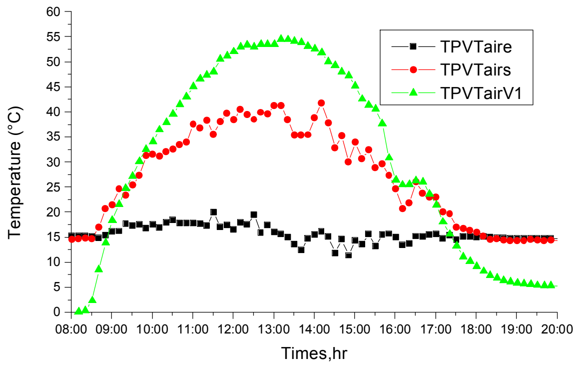


Fig.10. Temperature of the double glazing hybrid collector

The input temperature varies between 15°C and 20°C so the output temperature varies between 35°C and 40°C. This is explained by the effect of generated heat between the two glasses. In order to see the consequences of this increase in temperature on the electric performances of the double glass hybrid collector, we compared the output voltage of the sensor at the boundaries of an electric charge with the voltage delivered by a traditional photovoltaic module outputting on a similar load and we obtained the variation shown on figure 11.

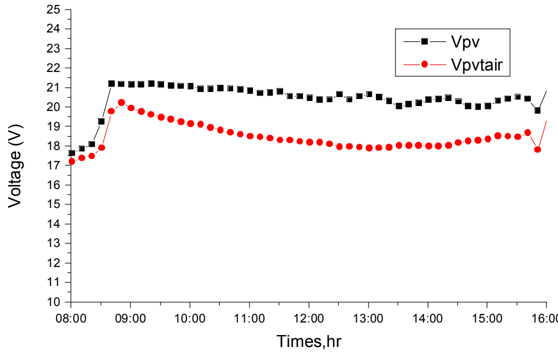
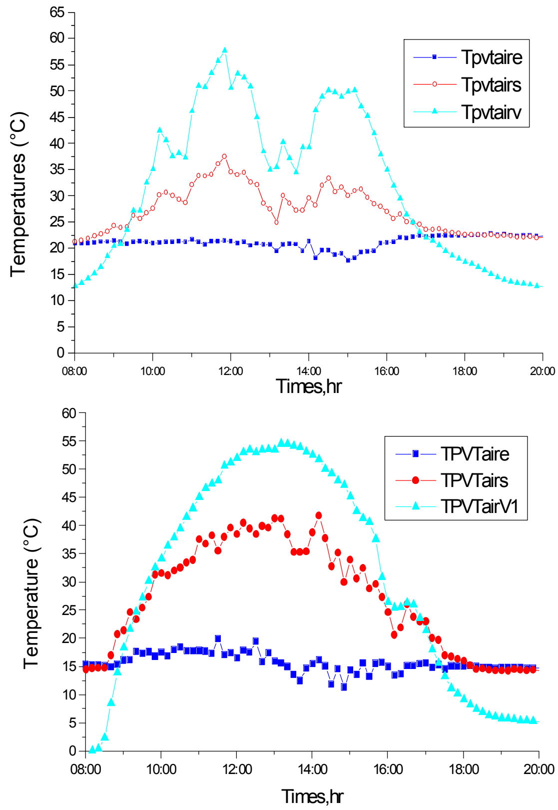


Fig.11. Tension delivered by the hybrid sensor double glazing and the pilot sensor

The voltage varies between 20V and 18V. It is appreciably lower than that at the boundaries of the load connected to the traditional photovoltaic module which remains constant in the vicinity of 21 V, this is explained by the fact that the addition of glass made increased the temperature of the solar cells constituting the collector and by increasing there the speed of recombination of the loads (electron-proton pairs) and thus the tension goes fallen.

4.2. Comparison with the collector with simple glazing

Figure 12 shows a comparison between the input and output distribution temperature of the thermal photovoltaic hybrid



collector covered with one glass (a) and with two glass (b).

(a)

(b)

Fig 12.Comparaison between the hybrid PVT simple and double glazing

One notice that the difference in temperature between the entry and the exit of the double glass covered hybrid reaches the 25°C while this difference is about 15°C in the case of the hybrid collector covered with only one additional glass.

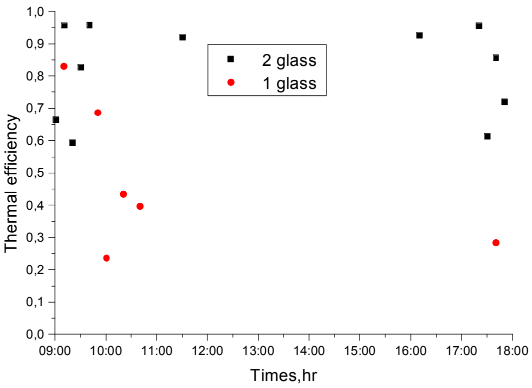


Fig.13.Comparisons of the thermal efficiencies

For the thermal efficiency (figure 13), the double glazing hybrid collector has an instantaneous thermal efficiency higher than the covered with one alone glass.

V. CONCLUSION

The interesting configurations are hybrid PVT air heating collector not covered and the collector covered with one glass. The addition of one or two glass increases the thermal performances and thus characteristics of hybrid sensor PVT compared to the not covered collector. But for the electric performances, the increase too high causes a considerable reduction in the electric output of the collector. The choice thus is clear, it is necessary to optimize the configuration for the applications which one wants, electric or thermal load, by taking account of the influence of the flow and the additional glass.

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