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Double glass PV cell efficiency in PV/T combination water and air heating flat plate collector system

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ABSTRACT: In this paper, an attempt is made to investigate the thermal and electrical performance of a solar photovoltaic thermal (PV/T) air collector. A detailed thermal and electrical model is developed to calculate the thermal and electrical parameters of a typical PV/T air collector, but here we want to notice this paper was just one part of our project that which has been completed. The thermal and electrical parameters of a PV/T air collector include solar cell temperature, inlet air temperature, outlet air temperature, open-circuit voltage; short-circuit current, maximum power voltage, maximum power current and air mass flow rate. Since some corrections have been down on thermal and electrical models, it is observed that the thermal and electrical simulation results obtained in this paper is more precise than the one given by the previous literature. It is also found that the thermal efficiency, electrical efficiency and overall energy efficiency of PV/T air collector is about 15.4%, 18%%, 18.3%, and 18.9% respectively, for an irradiane 350,500,650 and 800 W/m^2 operating and design parameters.

***Keywords*:** Photovoltaic thermal (PV/T), open-circuit voltage; short-circuit current, maximum power voltage, maximum power current.

INTRODUCTION

Renewable energies are starting to be a primary substitute for fossil fuels in the coming years for their clear and renewable nature. Solar energy is one of the most important renewable energy sources that the world needs. (Zondag . 2002 has developed 1D, 2D, and 3D dynamical models of a Combi-panel (PV/T). They have concluded that the simple1D steady-state model for computing daily yield from combi panel performs almost as well as more time consuming 2D and 3D dynamic models. (Infield .2004) has suggested cutting down the temperature of the PV module by flowing air between the PV module and the double glass wall for space heating. They have produced a steady state model to calculate an overall heat loss coefficient and the thermal gain factor. (Coventry.2005) has examined the performance of a concentrating PV/T collector and concluded that an overall thermal and electrical efficiency of concentrating PV/T system are 58% and 11%, respectively. This yields a total efficiency of the system at 69%. (Tiwari . 2006) have validated the theoretical and observational results for PV module integrated with air duct for the composite climate of India and concluded that an overall thermal efficiency of the PV / T system is significantly increased (18%) due to utilization of thermal energy from PV module. (Chow .2007) has done an experimental study of facade-integrated photovoltaic/thermal water-heating system and prove the thermal efficiency as 38.9% at zero reduced temperature and the corresponding electrical efficiency as 8.56% during the summer of 2006 (Hong Kong). They have compared both forced as well as a natural mode of water circulation and found that the latter is more preferable and suggested that the system can suffice as a water preheating system. (Dubey and Tiwari.2008) have developed a thermal model of a PV integrated solar water heater and validated the experimental results.(Dubey .2009) have derived the expression for temperature dependent electrical efficiency considering glass to glass and glass to tedlar type PV modules.

(Abdolzadeh and Ameri.2009) have looked into the possibility of amending the mental procedure of a photovoltaic water pumping system by spraying water over the front of PV array experiments. They have pointed out that the efficiency of PV array can be increased due to spraying water over the front end of the PV array.(Joshi . 2009) have produced a thermal manikin for the PV module integrated with solar air collector and validated it experimentally. They have indicated that PV module temperature can be controlled and brought low in consequence of altering the mass flow rate of air power in the solar collector and the efficiency of PV module can be increased. (Tiwari . 2009) have analyzed energy metrics (energy payback time, electricity production factor and life cycle conversion efficiency) of a PV/T air collector for the composite climate of New Delhi, India. They have reported that the energy payback time (EPBT) of a PV/T air collector is reduced by taking into account the growth in annual energy availability of the thermal energy in addition to the electrical energy. Chow.2010) has performed a review on PV/T hybrid solar technology, especially PV/T air collector systems. His article gives a review of the course of development of the technology, in particular the advancements in recent years and the future work required. (Chow . 2009) have investigated the performance rating of a glazed and unglazed PV/T water system in the terms of energy and exergy efficient for Hong Kong climates. They have read that in terms of the first law, a glazed PV/T system is desirable and in terms of the second law, an unglazed PV/T system is favorable. (Tiwari . 2009) have carried out the energy and exergy analysis of an integrated photovoltaic thermal solar (IPVTS) water heater. They have reported that the overall exergy and thermal efficiency of an IPVTS system is maximum at the hot water withdrawal flow rate of 0.006 kg/s. In this report, we would wish to make it clear that the quality of the PV solar cell type that's used in this work is transparent double glass PV solar cell model SPT-30M-80B. In this test we used two cells have linked in parallel within the system. The detailed of thermal and electrical performance will be produced to compute the thermal and electrical parameters of a typical PV/T air collector.

The major applications of solar energy can be classified into three categories: solar thermal system, which converts solar energy to thermal energy, and photovoltaic (PV) system, which converts solar energy to electrical energy and PV/T photovoltaic thermal (Tabook al. 2014). Normally, these schemes are practiced individually. In the solar thermal system, external electrical energy is required to circulate the working fluid through the system. On the other hand, in the PV system, the electrical efficiency of the system decreases rapidly as the PV module temperature increases. Therefore, in order to achieve higher electrical efficiency, the PV module should be cooled by removing the heat in some way. In order to eliminate an external electrical source and to cool the PV module, the PV module should be combined with the solar air/water heater collector. This type of system is called solar photovoltaic thermal (PV/T) collector. The PV/T collector produces thermal and electrical energy simultaneously.

The full schematic diagram of data acquisition for the PV/T combination flat plate collector water and air system as shown in figure 1.

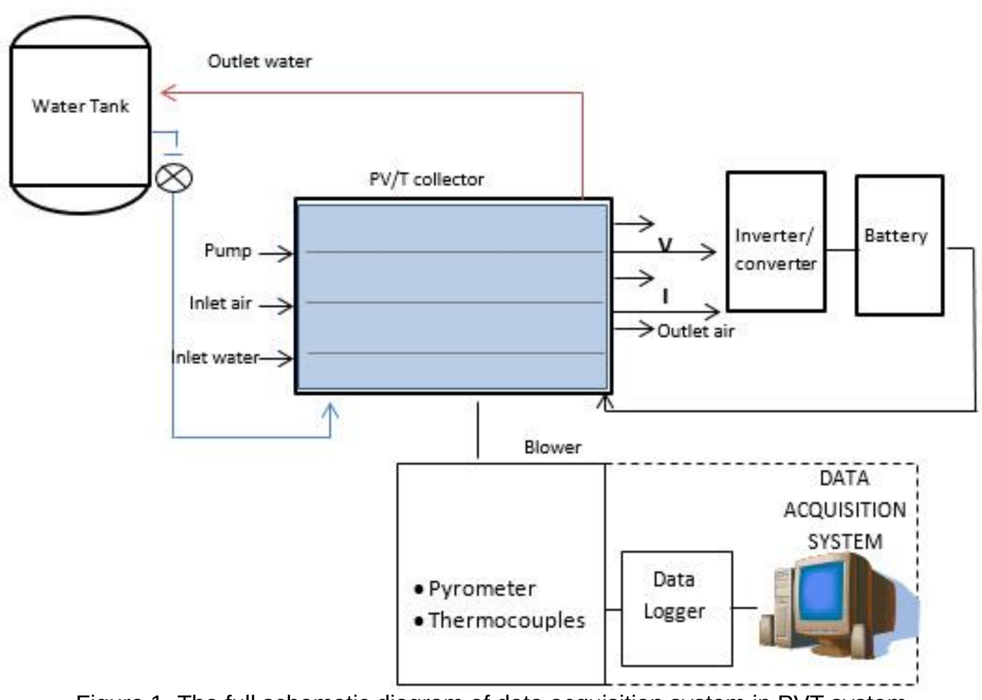

Figure 1. The full schematic diagram of data acquisition system in PVT system

ELECTRICAL ANALYSIS

The double glass transparent is the type of the PV solar cells that we used model SPT-30M-80B it made in China as we show in the figure 2.

Figure 2. The double glass transparent PV solar cell

The electrical power output from a photovoltaic panel depends on the incident solar radiation, the cell temperature, the solar incidence angle and the load resistance. Manufacturers typically provide only limited operational data for photovoltaic panels, such as the open circuit voltage (Voc), the short circuit current (Isc), the maximum power current (Imp) and voltage (Vmp), the temperature coefficients at open circuit voltage and short circuit current the characteristics of this event from the manufactory as shown in the table below.

Table 1. The Manufacturers typical characteristics

Rated Maximum Power (Pmax)	80W
Current at Pmax (Imp)	5.26A
Voltage at Pmax (Vmp)	15.2V
Short-circuit Current (Isc)	5.9A
Open-Circuit Voltage(Voc)	19.9V
Dimensions	1200mm*1000mm
Glass Thickness	3.2mm+3.2mm
Cell Nos.	30pcs
Weight	20kg
All technical data at standard test condition	AM= 1.5 ; E=1000W/m^2 ; Tc=25℃

THE CURRENT – VOLTAGE RELATIONSHIP OF PV DEVICE

The current and voltage functions at fixed cell temperature and solar radiation well known equivalent to the circuit as shown in figure 3 by (Duffie and Beckman.1991& Nelson. 2003).

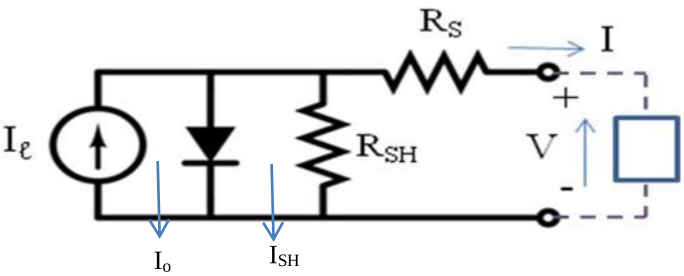

Figure 3. The Photovoltaic solar cell electrical circuit.

From the figure we conclude that there are five parameters must be known in order to determine the power delivered to the load. These five parameters are the light current (I_ℓ), the diode reverse saturation current (I_o), the series resistance (R_S), the shunt resistance (R_{SH}) and the modified ideality factor that defined in equation (1).

$$I = I_\ell - I_\circ \left(\exp^{\frac{q(V+IR_S)}{n.k.T}} - 1 \right) - \frac{V + IR_S}{R_{SH}} \rightarrow 1$$

To find these five parameters we needed of information at reference conditions as follows in the table below.

Table 2. The reference conditions of parameters

At short-circuit current	$I = I_{sc,ref}$, $V = 0$
At open-circuit voltage	$I = 0$, $V = V_{oc,ref}$
At the maximum power point	$I = I_{mp,ref}$, $V = V_{mp,ref}$
At the maximum power point	$[d(IV)/dV]_{mp} = 0$
At short circuit	$[dI/dV]_{sc} = -1/_{Rsh,ref}$

The electrical efficiency of our PV module in this paper can be defined as an equation (2):

$$\eta_{el} = \frac{V_{mp} I_{mp}}{GA} \rightarrow 2$$

Where G is the radiance of the simulator that we used in the test and A is the collector system area. Applying equation 2, we get the results shown in the following table.

Table 3. The results of double glass transparent PV solar cell efficiency

Solar Radiation (W/m^2)	Current(I)	Voltage(V)	Power	Efficiency(η_{th})
350	3.0	15.8	48.0	15.4%
500	5.0	17.0	85.0	18.0%
650	6.6	18.0	118.8	18.3%
800	8.4	19.0	159.6	18.9%

In this testing the two PV modules are connected together as shown in figure 4, the temperature is set to the room temperature and the radiation intensity by the simulator sets in ranging levels of 350, 500, 650 and 800 W/m^2.

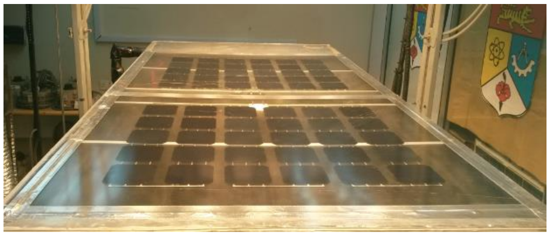

Figure 4. Two PV penal connected in parallel

The result show that the changes contain current and also the voltage that is because we used two panels of PV module that's connected together in parallel as shown in figure 4, so that means the change of the current is more than the change of voltage as we noted above about the connecting types and its properties. This show clearly with solar radiation ranging of 500 W/m^2 to 800 W/m^2 indicates a change of I_{sc} from 3 (A) to 8 (A). Meanwhile the V_{oc} also increases from 15.2 (V) to 19 (V) under the same conditions. The open circuit voltage (V_{oc}), and short circuit current (I_{sc}) were also measured as shown in figure 5.

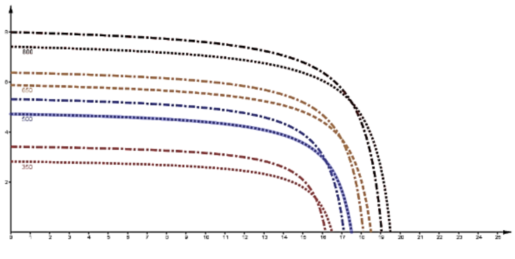

Figure 5. (I-V), (V_{oc}) and (I_{sc}) curves of PV modules under various solar radiations

PV/T COMBINATION WATER AND AIR HEATING SYSTEM DESIGN

The PV/T technology allows producing thermal and electrical energy at the same time through the direct conversion of solar radiation. The operating principle of PV/T collectors is the generation of thermal and electrical altogether at the same time is the transfer of the thermal energy absorbed by the photovoltaic solar cell to the fluid enabling its subsequent use as shown in figure 6.

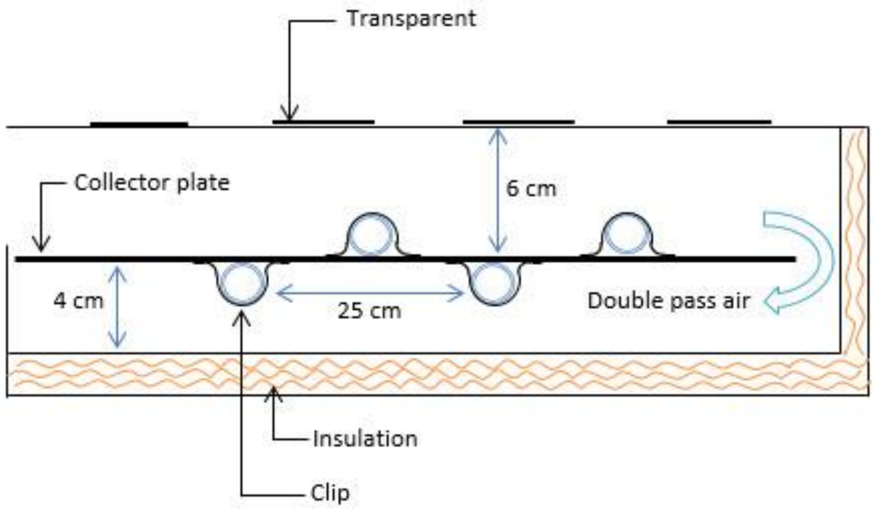

Figure 6. Diagram of PV/T combination flat plate collectors

CONCLUSION

In this case of PV/T technology, there are two important parameters as a key first the efficiency of PV cells by actively cooling the PV laminate or by removing the heat. Second the thermal efficiency of the fluid controlling by solar irradiance and fluid mass flow rate. Most of the work and research in this area uses glass as an outside cover for the system, some of them used one and some of the other uses more than one as a cover glass. Since the solar cells, transparent cover, we'll presume that it runs as a glass in terms of the universal characteristics of transmittance and absorption and reflection of solar irradiation. In aphotovaltic module the cells are generally tied in series in order to have higher output voltages and consequently lower ohmics losses. In fact the connection in series increasing the voltage whereas in parallel circuit the current value increases. With solar radiation ranging of 500 W/m^2 to 800 W/m^2 indicates a change of I_{sc} from 3 (A) to 8 (A). Meanwhile the V_{oc} also increases from 15.2 (V) to 19 (V) under the same conditions and this also open the gate to use more for application in one system.

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