Air-cooling System for a Large Size Photovoltaic Panel

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Abstract: Under extreme climatic conditions, the temperature of a photovoltaic solar panel can increase considerably. This can alter its performance and contribute to its degradation. To overcome these inconveniences, we propose to cool this PV panel by the ambient air. To do this, we use fan which blows air on the underside of the PV panel. For a large size PV panel (commercialized panel) two fans are needed to ensure this cooling. The judicious arrangement of these two fans makes it possible to reduce the temperature gradient on the PV panel. At first approach, four cases of positions of the fans were considered. By determining the optimum position, the influence of the ambient air temperature (T_{air} = 25 and 50 ° C) and the intensity of the radiation (R_G = 400 W/m² and 1000 W/m²) was studied by varying the air mass flow rate from 200 to 400g/s. The results obtained show that the average temperature of the silicon varies slightly with the mass flow of air while it is sensitive to the air temperature and the solar radiation. Moreover, the maximum temperature gradient on the PV panel is only influenced by solar radiation.

1 INTRODUCTION

The use of renewable energies, especially solar photovoltaic energy, makes it possible to offset the depletion of fossil fuels and reduce global warming. The low efficiency of PV panels has led the research towards the design of new photoelectric materials (Sze, 1981), (Koch, Ito and Schubert, 2001) and (Yoann, 2014), while others are interested in the cooling of PV panels. (Hasanuzzaman et al, 2016) reviewed methods of cooling.

(Kaiser et al, 2014) studied the cooling of a PV panel integrated into the building. This system allows the cooling of the PV panel and the preheating of the ventilation air of the building. Another cooling system uses the ground to cool the ambient air before blowing it onto the PV panel (Sahay, Sethi and Tiwari, 2013). (Iqbala et al, 2016) studied the water cooling effect of a polycrystalline PV panel; this technique achieves an increase in conversion efficiency of 7 to 12%.

The homogenization of the temperature on a PV panel is a very important factor that must be taken into account to avoid power dissipation and possibly the degradation of the panel (Royne, Dey and Mills, 2005). (Baloch et al, 2015) analyzes the performance of a convergent channel heat exchanger to ensure uniform cooling of PV by water. This system ensures a temperature reduction of 57 and 32% for the days of June and December, respectively. (Bahaidarah, Baloch and Gandhidasan, 2014) designed a water jet cooling system in order to ensure a homogenization. (Al Tarabsheh et al, 2013) designed a water-cooling system to ensure low and uniform PV panel temperature.

(Amelia et al, 2016) investigated the air cooling which consists of fans that blows ambient air on the rear face of the PV panel. As main results, two fans were enough to reduce the PV panel temperature by 14°C. (D. Nebbali, R. Nebbali and Ouibrahim, 2018) optimised this cooling system. A new design which consists of a fan placed underside the PV panel ensures better cooling. Indeed, under extreme climatic conditions (50°C of ambient air temperature and 1000W.m⁻² of solar radiation), the efficiency improvement reached 29.52% while the PV panel temperature lowered by 39°C.

The objective of this work is precisely to propose an air-cooling system that allows a better cooling with a good homogenization of the temperature. It consists of use two fans that blow ambient air on the underside of a PV panel.

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2 PROBLEM POSITION

In figure 1 we describe the sketch of the PV panel cooling system. As the first step, the positions of the two fans must be determined to ensure a well cooling of the PV panel. For this purpose, four positions of the fans were considered (Figure 2 – Table 1). Then, under extreme climatic conditions of air temperature and solar radiation characterised by: T_{air}= 50°C and R_G=1000Wm^{-2}, we studied the influence of air flow, air temperature and the solar radiation is then considered to evaluate the efficiency of this cooling system.

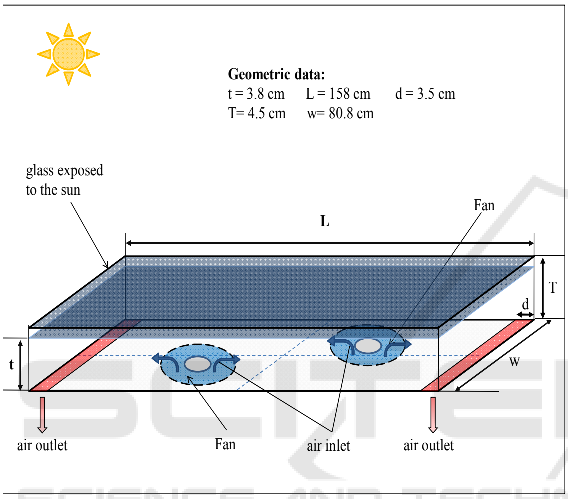

Figure 1: Sketch of the PV with the cooling system.

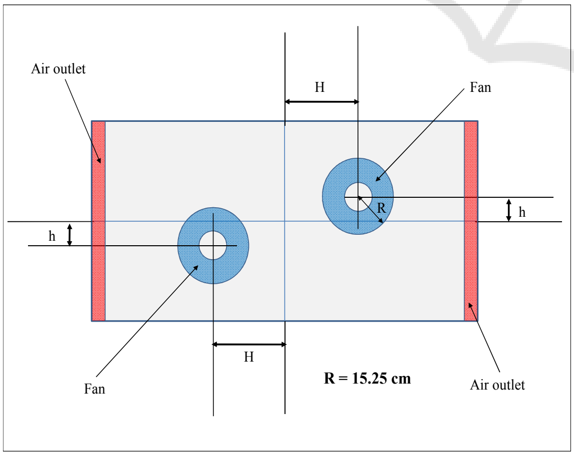

Figure 2: Bottom view of the cooled PV panel.

Table 1: Positions of the fans.

	H (cm)	h (cm)
Case 1	39.5	0
Case 2	39.5	10
Case 3	29.5	10
Case 4	19.5	10

Table 2: Material properties of a PV panel (Armstrong and Hurley, 2010).

Layer	e(mm)	λ(W/m.K)	ρ(kg/m³)	C_P(J/kg.K)	ε
Glass	3.2	1.8	3000	500	0.7
Silicon	0.3	148	2330	677	0.7

3 METHOD

3.1 Associated Equation

3.1.1 Thermal Balance of the Solar Panel

The thermal balances performed on the PV panel are expressed for the solid media of glass and silicon (Table 2), by:

$$\Delta T + Q / \lambda = 0 \qquad (1)$$

Where:

- heat source of the glass layer (W/m^3):

$$Q_g = [\alpha_g R_G - \varepsilon \sigma (T_p^4 - T_v^4)] / e_g \qquad (2)$$

Where:

$$T_v = 0.0552\ T_{air}^{1.5} \qquad (3)$$

- heat source of the silicon layer (W/m^3):

$$Q_{si} = \alpha_{si} \tau_g R_G / e_{si} \qquad (4)$$

Where T_p is the PV panel temperature; T_v the temperature of the sky; α_g the absorption coefficient of the glass; α_{si} is the absorption coefficient of the silicon; ε is the emissivity of the surface of the PV; σ is the Boltzmann constant and τ_g is the transmissivity of the glass.

3.1.2 Thermal Balance of the Cooling Fluid

As for the forced circulation air on the lower side of the panel, the distributions of the velocity and temperature field are determined by solving the coupled equations of continuity, momentum and energy. To do this, CFD-Fluent code was used.

3.1.3 Convective Exchange between the Panel and the Ambient Air

Moreover, the upper face of the panel exchanges, by natural convection, heat with the ambient environment. The convective exchange coefficient was evaluated by the following correlations (Holman, 1997).

$$N_u = 0.54\ (R_a)^{0.25} \quad \text{for } 10^4 < R_a < 10^6 \qquad (5)$$

$$N_u = 0.15\ (R_a)^{0.33} \quad \text{for } 10^6 < R_a < 10^{11} \qquad (6)$$

Where:
Nu and R_a are, respectively, the Nusselt and the Rayleigh numbers.

3.2 Boundary Conditions

3.2.1 Positions of the Fans

In order to determine the optimal position of the fans, four cases (Table 1) were considered under air temperature T_{air} = 50°C, solar radiation R_G=1000W/m² and air mass flow rate varying from 200 g/s, 300 g/s and 400 g/s.

3.2.2 Influence of the Air Temperature and the Intensity of the Solar Radiation

For the optimal position retained, we studied the influence of the variation of the temperature of the air (T_{air} = 25 and 50°C) associated with the variation of the intensity of solar radiation (R_G = 400 and 1000 W/m²).

4 RESULTS

4.1 Influence of Flow and Positions of Fans

The maximum temperature gradient ΔT prevailing on the PV panel highlight the influence of the fans positions. Indeed, as shown in figures 3, 4, 5 and 6, for an air flow of 400 g/s the distribution of the temperature field is almost homogeneous for case 3 with an average silicon temperature T_{si} = 69.1°C and a maximum gradient temperature ΔT = 13.3°C (Figures 3-6, Table 3).

4.2 Influence of Air Temperature and Global Radiation

By adopting the positions of the fans selected for the case 3, we studied the influence of T_{air} and R_G at different mass air flows.

It appears from Table 4 that the average silicon temperature increases significantly with T_{air} and R_G, whereas it varies slightly when the air flow increases from 200 to 400 g/s.

Moreover, the maximum temperature gradient remains only sensitive to variations in solar radiation (Table 5).

Table 3: Average silicon temperature and maximum temperature gradient on the panel.

	200g/s		300g/s		400g/s	
	***T**_{si}*	***ΔT***	***T**_{si}*	***ΔT***	***T**_{si}*	***ΔT***
Case 1	76,9	19,9	72,9	18,8	70,5	18
Case 2	75,9	18,4	72,7	17,4	70,3	16,6
Case 3	74,3	13,9	71,3	13,3	69,1	13,3
Case 4	76,9	16,3	73,2	15,3	70,5	14,9

Table 4: Average silicon temperature (°C).

	T_{air}=25°C		T_{air}=50°C	
	R_G=400 (W/m²)	R_G=1000 (W/m²)	R_G=400 (W/m²)	R_G=1000 (W/m²)
200g/s	33,7	48,9	59,8	74,3
300g/s	32,6	45,8	58,6	71,3
400g/s	31,7	43,5	57,6	69,1

Table 5: Maximum temperature gradient on the panel (°C).

	T_{air}=25°C		T_{air}=50°C	
	R_G=400 (W/m²)	R_G=1000 (W/m²)	R_G=400 (W/m²)	R_G=1000 (W/m²)
200g/s	5,5	14,3	5,9	13,9
300g/s	5,1	13,4	5,6	13,2
400g/s	5	13,2	5,6	13,3

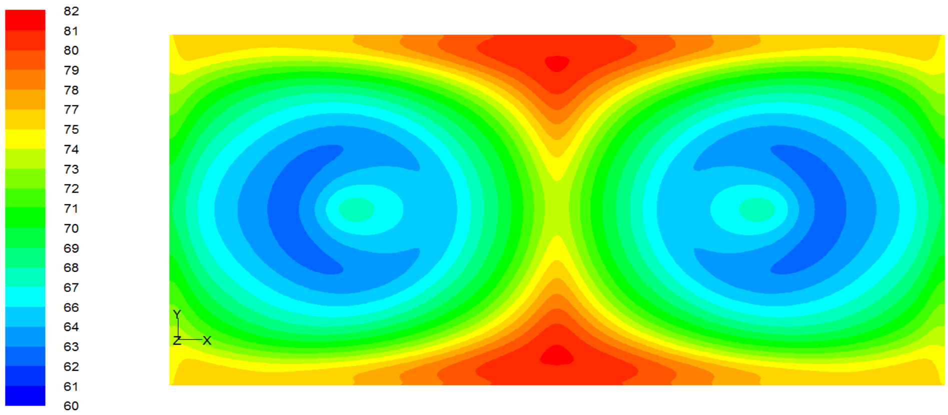

Figure 3: Temperature distribution on the PV panel (°C) at T_{air}=50°C, R_G=1000W/m^2 and 400g/s of air mass flow rate - Case 1.

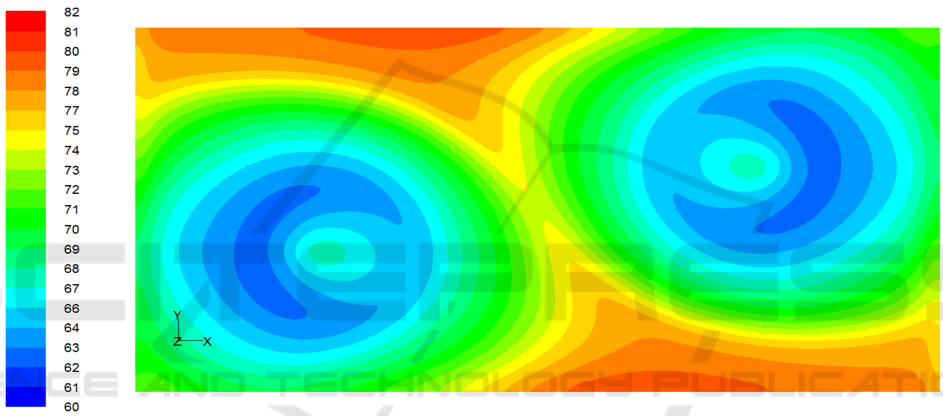

Figure 4: Temperature distribution on the PV panel (°C) at T_{air}=50°C, R_G=1000W/m^2 and 400g/s of air mass flow rate - Case 2.

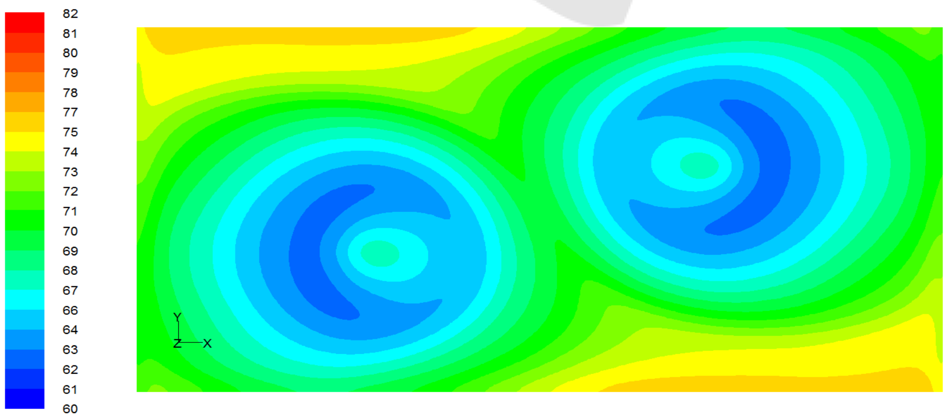

Figure 5: Temperature distribution on the PV panel (°C) at T_{air}=50°C, R_G=1000W/m^2 and 400g/s of air mass flow rate - Case 3.

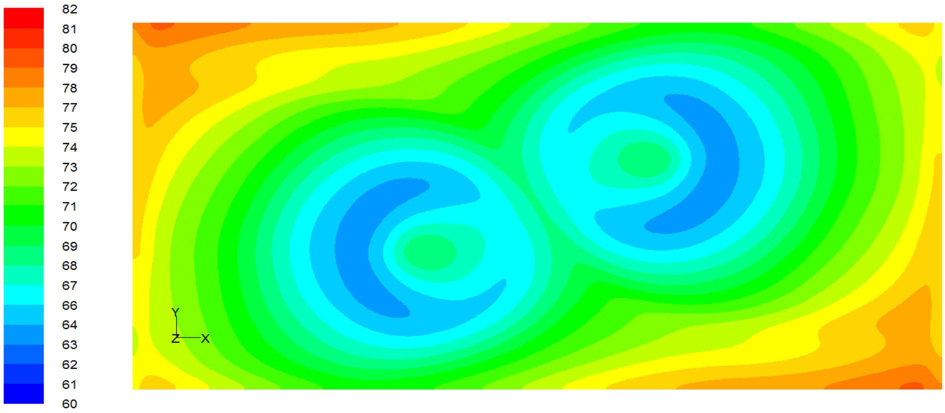

Figure 6: Temperature distribution on the PV panel (°C) at T_{air}=50°C, R_G=1000W/m^2 and 400g/s of air mass flow rate - Case 4.

5 CONCLUSION

This work proposes a new design of a PV panel cooling system. It consists of two fans that blow ambient air on the rear face of the PV panel. In order to ensure a good cooling of the PV panel with a better homogenization of the distributed temperature on the PV panel, it was necessary to determine the optimal position of these two fans.

By varying the air mass flow rate from 200 to 400g/s, we observed that:

- The PV panel temperature was very sensitive to changes in air temperature and solar radiation.
- The heterogeneity of the temperature field on the PV panel increases with the rise of solar radiation.

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