Parametric study and energy evaluation of the effect of double glazing on the efficiency of a solar panel

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Abstract. The type of glazing used in the design of solar panels is considered one of the key technical aspects that can have a significant impact on the energy performance of the photovoltaic systems. The present study focuses on clarifying the impact of double-glazing on the efficiency of a photovoltaic module, by evaluating the variation in the thickness of the air space between the two layers of glazing that constitute the examined solar configuration . A comparative analysis of three different air space thicknesses was carried out to determine their effect on energy efficiency. An energy balance incorporating various energy parameters was employed, taking into account the influence of external meteorological parameters. The results demonstrate a significant sensitivity between the thickness of the air space in the double glazing and the electrical performance of the photovoltaic module. An average electrical efficiency of 16.02% is obtained for a thickness of 3 *mm*, and 15.76% for a thickness of 2 *cm*. In addition, average operating temperatures reached 39.1°C and 42.4°C for these thicknesses respectively.

1 Introduction

As global demand for energy grows, renewable energy sources are becoming increasingly important. Solar panels are one of the most effective ways of producing clean and sustainable energy. The key to advancing the technology of these panels is to find effective solutions to maximize their energy efficiency, hence the importance of researching the effects of various technical considerations on their performance. For crystalline silicon photovoltaic cells, efficiency decreases by around 0.45% for each degree of rise in operating temperature [1, 2]; for amorphous silicon cells, the percentage decrease is around 0.25% for every degree of increase in temperature [3–5].

In order to optimize the energy yield of solar panels, a number of studies have identified this target as an essential purpose; A comparative study was carried out by Wang et al. [6] concerning the overall efficiency of double-skin PV under the effect of five different Chinese climates, they performed experimental tests aimed at comparing the thermal performance and energy production of the considered system. Another study was realized by Al Shehri et al. [7] to find out the effect of dust on the transmission rate of radiation received by the

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glass, they also investigated the influence of dry cleaning on the optical characteristics of the glazing. In the study [8], six different types of dust were examined in terms of their impact on the temperature of the solar panel, the researchers noted a negative effect on the transmission properties of the glass; additionally, in the case of salt dust, a decrease in the temperature of the dusty solar panel was detected. Operating conditions can be considered an essential factor affecting the efficiency of photovoltaic cells and their lifetime [9]; in the manufacturing process of the various components that compose a photovoltaic module, it is preferable to take into consideration that these components are able to resist meteorological conditions [10]. Also, the differences in the types of solar radiation received by the surface of solar panels can lead to damage to solar cells, especially from ultraviolet solar radiation [11].

The main objective of the present paper is to comprehensively analyze the impact of varying the thickness of the air space between the two layers of glass in a double-glazing PV system on the productivity of solar panels. Based on a parametric evaluation, this research aims to understand how changes in this specific thickness directly influence the efficiency and performance of solar panels.

2 Overview of the examined PV module

The solar system presented in this work is primarily based on the use of a monocrystalline photovoltaic panel. The solar system under consideration consists essentially of five components (see Figure 1):

- A first layer presenting the top glazing;
- A closed space between the two glazing layers contains confined air;
- A third layer representing the lower glazing;
- The solar cell layer directly in contact with the lower glazing;
- A protective adhesive layer below the photovoltaic cells.

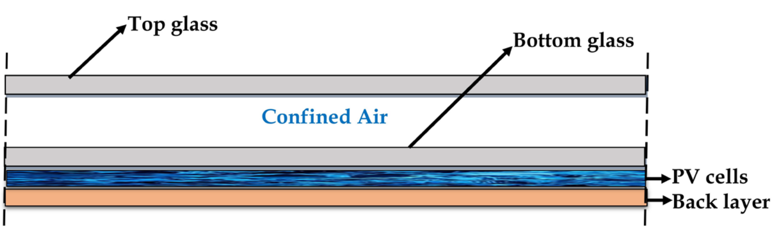

Fig. 1. Schematic view of the investigated double-glazed PV solar module.

The main geometric parameters and intrinsic characteristics of the solar system under investigation are listed in Table 1.

Table 1. Main parameters of the studied solar system [12].

Parameter	Value	Unit
Module Length, L	1.485	m
Module surface, S_m	0.992	m^2
Cells number, N	72	-
Maximum Power at STC, P_m	175	W
Reference efficiency, η_{ref}	17.6	%
Open-circuit voltage , V_{oc}	23.7	V
Short-circuit current , I_{sc}	9.89	A
Temperature coefficient, β_T	0.0045	/K
Packing factor, β	88	%
Output tolerance	+/-3	%
Temperature range	(-40,+85)	$^{\circ}C$
Emissivity of glass, ε_g	0.93	-
Absorptivity of glass, α_g	0.06	-
Absorptivity of PV cells, α_c	0.85	-
Absorptivity of Tedlar, α_t	0.8	-

3 Numerical modeling

In the order of modeling the energy performance of the solar configuration under study, and to clarify the effect of double glazing on the productivity of the investigated system; a number of assumptions are used during numerical modeling:

- Each layer's temperature is considered to be uniform;
- The solar system is impacted by two meteorological parameters (ambient temperature, solar irradiance);
- The impact of temperature on thermophysical properties is neglected.

3.1 Mathematical formulation

To provide an overview of how the use of a PV module with double layers of glass affects the energy yield and determine their effects on energy efficiency, an energy balance is applied that describes the heat exchange among the different components of the solar configuration under study.

For the top glazing:

$$\frac{dT_{tg}}{dt} = \frac{1}{m_{tg}Cp_{tg}}\Big(S_m\Big(\alpha_g G - h_{r,tg-k}(T_{tg} - T_k) - h_{r,tg-bg}(T_{tg} - T_{bg}) - h_{v,a}(T_{tg} - T_a) - h_{cv}(T_{tg} - T_{ca})\Big)\Big) \tag{1}$$

where:
$h_{r,tg-k}$ and $h_{r,tg-bg}$ represent the radiative transfer parameters between the upper glazing layer and the sky, and between the upper and lower glazing layers, respectively; while $h_{v,a}$ indicates the convection parameter due to wind velocity; and h_{cv} shows the parameter for

convective heat exchange in the closed air space between the two layers of glazing.

For the bottom glazing:

$$\frac{dT_{bg}}{dt} = \frac{1}{m_{bg}Cp_{bg}}\Big(S_m\Big(\alpha_g^2 G - h_{r,tg-bg}(T_{bg} - T_{tg}) - h_{cv}(T_{bg} - T_{ca}) - h_{cd}(T_{bg} - T_c)\Big)\Big) \quad (2)$$

where:
$h_{con,cg}$ and $h_{con,ct}$ present the heat transfer coefficients between two layers by the conduction mode [13]:

- Between the glazing and the photovoltaic cells [13, 14]:

$$h_{con,cg} = \frac{1}{(\frac{l_c}{\lambda_c}) + (\frac{l_g}{\lambda_g})} \quad (3)$$

- Between the PV cells and the tedlar layer [13, 14]:

$$h_{con,ct} = \frac{1}{(\frac{l_c}{\lambda_c}) + (\frac{l_t}{\lambda_t})} \quad (4)$$

λ and l correspond respectively to the thermal conductivity and the depth of the component.

To specify the energy performance of the studied system, we need to calculate several electrical parameters such as (electrical efficiency, electrical power). The electrical efficiency can be represented as follows [15–17]:

$$\eta_{el} = \eta_{ref} \cdot \Big(1 - \beta_p(T_c - T_{c,ref})\Big) \quad (5)$$

where:
T_c represents the PV cells temperature, η_{ref} is reference electrical efficiency; and ($T_{c,ref} = 25°C$) at "Standard test conditions".

To measure the electrical power generated by the examined PV module, we can use the following formula [17–19]:

$$P_{el} = \Big(\eta_{ref} \cdot \Big(1 - \beta_p(T_c - T_{c,ref})\Big)\Big) \cdot G \quad (6)$$

3.2 Weather parameters

The numerical simulation was carried out using climatic data for a Moroccan region distinguished by a semi-arid climate, for a sunny day during the summer period.

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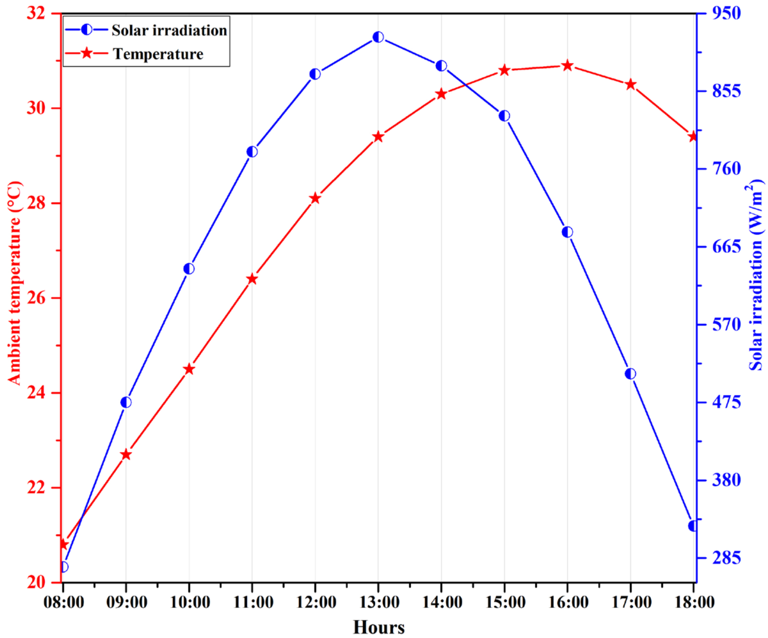

Fig. 2. Hourly variations in the meteorological parameters used in this study.

The climatic data used in this study comprise two main parameters: solar irradiance and ambient temperature (see Figure 2); it should be noted that wind speed was also taken into account, with an average of 3 m/s.

4 Results and discussion

In this section, a parametric analysis is presented to determine the effects of varying the thickness of the closed space containing the air on the energy performance of the solar configuration under investigation, with a view to understanding the effect of this parameter on the performance of solar energy systems.

4.1 Impact of thickness on glass temperature

The effect of the variation in the thickness of the confined air on the temperature of each glazing is shown in Figure 3, where it can be clearly seen that the difference between the temporal variations in temperature of each glazing varies according to the day. The bottom glazing has an average temperature of $41.3°C$, higher than the average temperature of the top glazing, which does not exceed $30.4°C$, therefore, we can note that the temperature difference peaks at 13h00 with a value of $14.65°C$.

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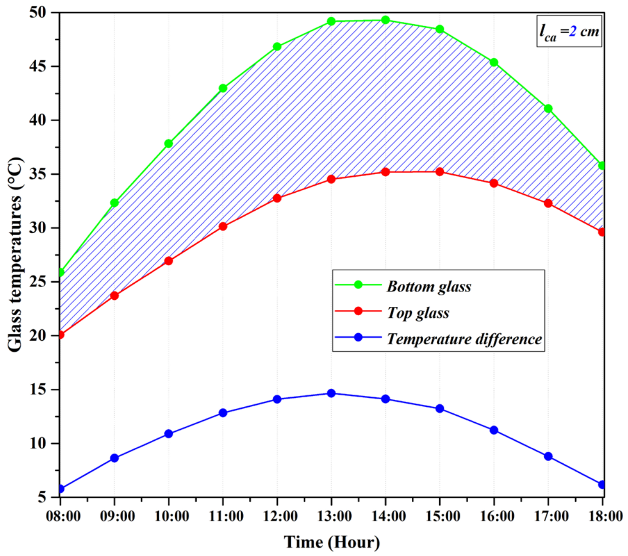

Fig. 3. The influence of the thickness of the confined air layer on glass temperature.

4.2 Impact of thickness on operating temperature

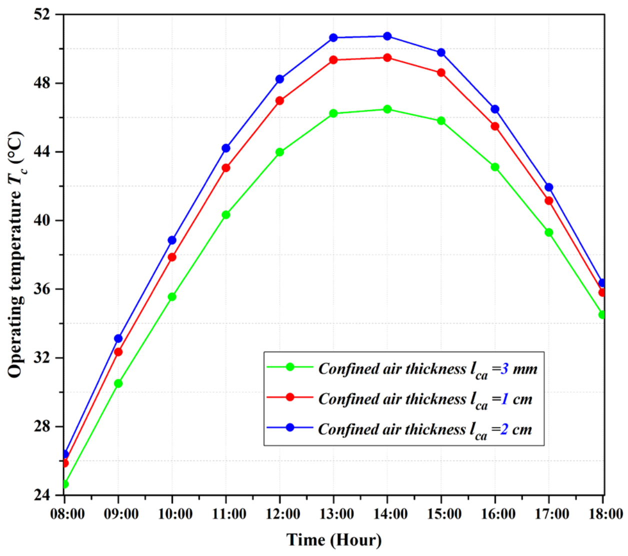

Fig. 4. The effect of the thickness of the confined air layer on operating temperature.

Figure 4 shows how the variation in confined air thickness affects the operating temperature of the solar system under investigation. It is clear that this thickness plays a crucial role in the operation of the solar system studied, as the operating temperature rises slightly with increasing thickness. The investigations were carried out for three different thickness values in order to assess their impact on energy performance, average operating temperatures are 39.1°*C*, 41.4°*C* and 42.4°*C* for thicknesses of 3 *mm*, 1 *cm* and 2 *cm* respectively. Compared with other thicknesses, the 2 *cm* thickness shows a temperature that remains much higher than that observed at the other two thickness values over the entire test day.

4.3 Impact of thickness on electrical efficiency

Figure 5 illustrates the impact of the thickness of the confined air on the daily fluctuation of the electrical efficiency characterizing the solar configuration studied. It is noticeable that this efficiency is influenced by variations in this thickness. The margins of variation in electrical efficiency are 15.45-16.3% and 15.78-16.48% for thicknesses of 2 *cm* and 3 *mm* respectively. By comparing the results obtained, we can conclude that electrical efficiency improves with the reduction in the thickness of the air confined between the two layers of glazing.

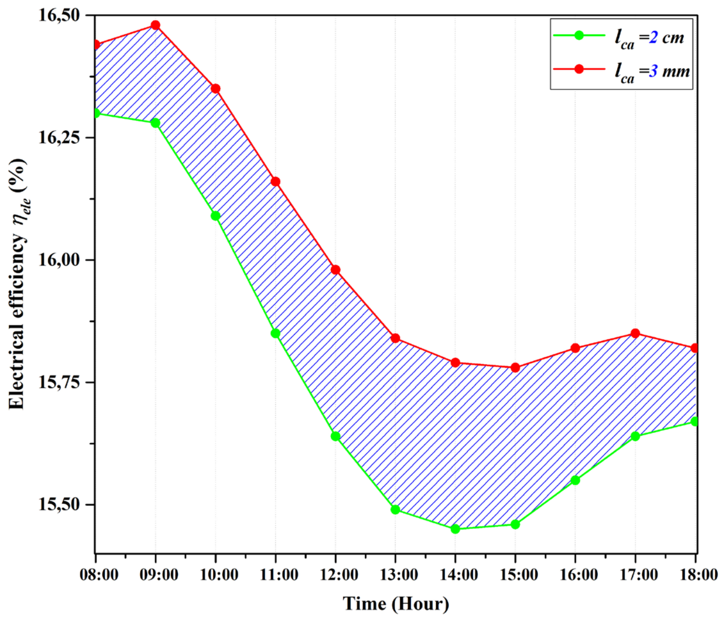

Fig. 5. The effect of the thickness of the confined air layer on electrical efficiency.

5 Conclusion

In this study, the impact of double glazing on the energy performance of a solar panel was carefully investigated. The air-containing space between the two layers of glazing was the main focus of investigation, with an exhaustive analysis of its influence on the productive characteristics of the solar configuration studied.

The results obtained show a significant relationship between the thickness of the space containing the confined air and the energy parameters of the solar panel. The following are the basic notions that can be cited from the present study:

- Increasing the thickness of the space enclosing the confined air resulted in a rise in the operating temperature of the solar configuration studied. The maximum operating temperature for a 2 *cm* thickness reaches 50.7°C, while it remains below 46.4°C for a 3 *mm* thickness.

- During the test day, the temperature of the bottom glazing remains higher than that of the top glazing, reaching a maximum difference of 14.65°C between the two glazing layers at 13h00.

- From the results, it can be concluded that a reduction in the thickness of the air space has significantly improved the performance of the solar configuration studied. In fact, for a thickness of 3 *mm*, the electrical efficiency reached an average of 16.02%, whereas it did not exceed 15.76% for a thickness of 2 *cm*.

6 References

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