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COMPARATIVE STUDY OF WATER FILM HEAT EXCHANGERS FOR COOLING PHOTOVOLTAIC PANELS

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Abstract: *The paper presents a study of cooling photovoltaic (PV) panels for predefined external conditions. The efficiency of photovoltaic panels is evaluated from the point of view of its operating temperature. A numerical model is realized by using ANSYS-Fluent software and the solution proposed for cooling the PV panels consists of using a film heat exchanger, using water as heat transfer agent. The aim of the study consists in the comparative study of the heat exchanger efficiency when the thickness of the water film is varied. The results are evaluating the increase of the power produced by PV panels when a reduction of temperature is achieved.*

Key words: *photovoltaic panel, heat transfer, efficiency, water film.*

1. Introduction

The double skin facades are studied in literature [9] and their utility is also proven by the numerous buildings equipped with these systems.

The necessity of finding new solutions for reducing the energy consumption of buildings is determined by the important proportion that they hold in the global energy consumption [14].

One of the most comprehensive studies of these systems is presented in [10]. Therefore, the ventilated double skin façade represents an improvement of single glazing facades, obtained by placing an additional layer of glass at a certain distance towards exterior.

Ralph Evins et al. [5] investigated the importance of the optimization of double skin facades depending on destination and location.

A possible solution may consist in the integration of photovoltaic (PV) panels into the façades of the buildings, technology known as Building Integrated Photovoltaic (BIPV), creating an active wall or active façade.

The PV panels are replacing zones of the exterior or interior glazing, resulting cold or hot facades.

By using BIPV technique, the façade of buildings can be used, taking into account that in agglomerated zones, the buildings have an important tendency to grow on vertical.

In the same time, it is difficult to obtain a sufficient horizontal surface for placing PV

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panels.

An electron from the valence layer of a semiconductor material can become free and participate in conduction if it absorbs a certain quantity of energy. This energy has a particular value for each semiconductor [16].

The photons with high wavelength, with low kinetic energy, are detaching a small number of electrons from the valence layer and have a low efficiency in producing electric energy.

On the other hand, photons with low wavelength, rich in energy, will be absorbed at the surface of the cell, in an area that is unfavourable for electric energy production.

The extra energy is transformed into heat and determines a raise of material's temperature [2-4, 8]. Almost 80% of solar radiation that is not converted into electricity is transformed into heat [2, 3].

The dependence between the efficiency and the cells operating temperature is studied in literature [12]. Many of these studies consider a linear variation between them. The reduction of efficiency is approximately of 0.3%…0.5% for each degree of temperature rise over 25 °C.

Because it is more difficult to control solar radiation or modify inclination, one solution of increasing the efficiency could be the reducing of the operating temperature of the photovoltaic cell. For example, in the particular case of placing the photovoltaic panels on the buildings facades, that are vertical and immobile surfaces, the direction and intensity of the solar radiation are incontrollable values.

Skoplaki E. et al. [12] present different methods and relations for calculating the dependence between conversion efficiency and temperature of PV cells.

In literature are presented different strategies for cooling the photovoltaic panels and the most used solutions consist of using air cooling [6, 7] and water cooling [13].

An example for such a system is presented in [13] known in literature as photovoltaic thermal hybrid solar collector or PV/T. In this case the payback time is shorter than that of the common photovoltaic systems.

An example of modelling the heat transfer for photovoltaic panels in variable atmospheric conditions is presented by S. Armstrong et al [1].

2. Objectives

The study presents the variation of the temperature of photovoltaic panels depending on the width of the water film heat exchanger and temperature of the agent in the inlet section. The PV panel studied has an area of 0.25 m^2 (0.5m x 0.5m) and it is integrated in the ventilated double skin façade of a building.

The aim of the study is to determine the energetic efficiency for the PV panel in case of cooling. The cooling is realized by using a water film heat exchanger placed in the rear zone of the panel. The conversion efficiency is studied for different temperatures obtained.

The heat exchanger ensures the dissipation of thermal energy from the PV panel, and it is recommended that the contact zone between it and the photovoltaic panel to be realized from a high thermal conductive material as aluminium or copper. Dimensions of the water film heat exchanger are:

l = 0.5 m – length;

h = 0.5 m - height;

g = 0.003 m – width of the input and output sections.

3. Numerical Approach

The numerical simulation and the study of the photovoltaic panel temperature were realized using ANSYS-Fluent software.

The geometry and the mesh were created with ANSYS software, with Design Modeller and Design Meshing respectively. For simulating solar radiation, the Solar Ray Tracing model was used from Fluent software. The sketch of the studied model is presented in Fig. 1.

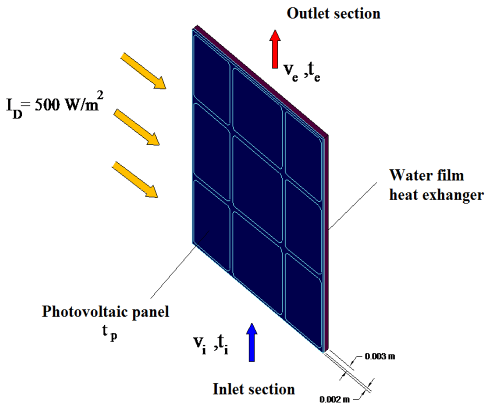

Fig. 1. *The model of PV panel and heat exchanger studied in ANSYS-Fluent*

I_D – intensity of solar radiation [W/m^2];

t_i, t_e – temperatures of agent for inlet and outlet sections [°C];

v_i, v_e – velocities of agent for inlet and outlet sections [m/s];

t_p – average temperature of the photovoltaic panel [°C].

The initial conditions used for simulations are the following:

- vertical position of the PV panel, placed on the façade of the building;
- constant solar radiation: 500 W/m^2;
- dimensions of water film heat exchanger: same as photovoltaic panel: 0.5 m x 0.5 m;
- thickness of the film: variable: g = 3 mm; 5 mm; 7 mm; 10 mm;
- inlet temperature of the heat transfer agent: variable: from 20 °C to 30 °C with 1 °C step.
- absorption coefficient of solar radiation for PV panel: α = 0,7 [11];
- inlet velocity of heat transfer agent: 0,001 m/s, corresponding to a flow rate of 0,09 l/min.

The output interest data are:

- average temperature of the photovoltaic panel;
- efficiency of the PV panel.

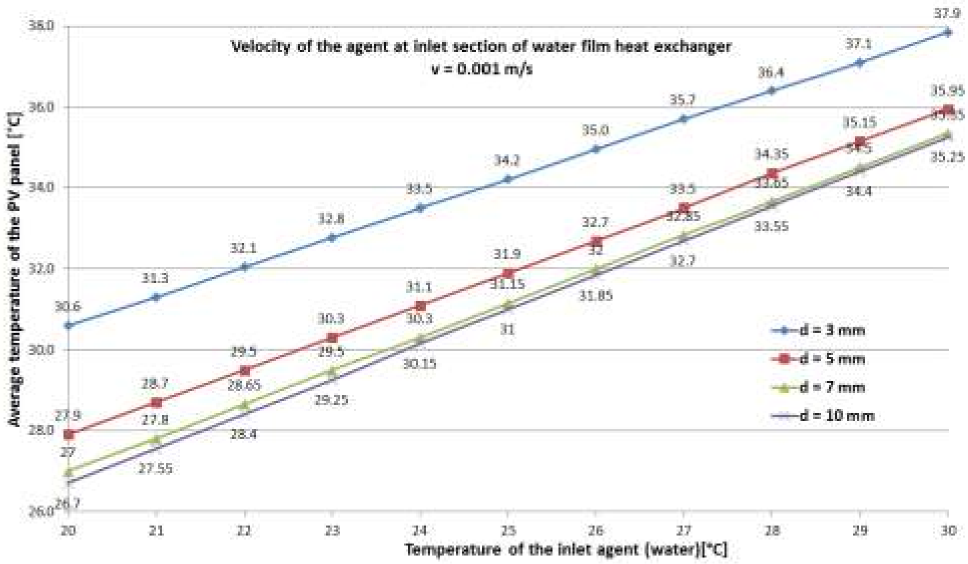

Fig. 2. *Variation of average temperature of the PV panel depending on the width of water film and inlet temperature of heat transfer agent*

Influence of PV temperature on the performance Table 1

Case	Water film width [mm]	t_p [°C]	*[%] from P_N	η	**P_{elspec} [W/m²]	S_p [m²]	P_{el} [W]	Increase over the base case [%]
Basic case***	-	60	84.25	0.1348	67.4	0.25	16.85	-
ti = 25 °C	3	34.2	95.85	0.1534	76.68	0.25	19.17	13.77
	5	31.9	96.9	0.155	77.52	0.25	19.38	15.01
	7	31.15	97.25	0.1556	77.8	0.25	19.45	15.43
	10	31	97.3	0.1557	77.84	0.25	19.46	15.49
Standard conditions****	-	25	100	0.16	80	0.25	20	18.69

4. Results and Discussions

In Fig. 2 are presented the results of simulations obtained in the conditions exposed previously.

* According to [15]

** Incident solar radiation: 500 W/m^2

*** Without cooling

**** STC (Standard Test Conditions) according to [17]

Where: t_p – average temperature of photovoltaic panel [°C];

P_N – electric power generated at 25 °C [W];

η – performance of PV panel;

$P_{elespec}$ – specific electric power [W/m^2];

S_p – surface of PV panel [m^2];

P_{el} – electrical power generated by the studied panel [W].

The cooling effect of the photovoltaic panel is proportional with the width of the water film heat exchanger and inversely proportional to its temperature, Fig. 2.

The temperature of the photovoltaic panel has an important drop when the inlet section width is raised from 3 mm to 7 mm, with average values between 3.9 °C and 2.55 °C, also being dependent on the inlet temperature.

This effect is insignificant once the inlet section is increased, determining a temperature difference under 1 °C.

The average temperature of photovoltaic panel, without heat exchanger, reaches values of about 60°C for the same solar radiation conditions [7]. Taking into account this value, there is determined the difference between the efficiency of the PV panel in the basic case and in case of using the water film heat exchanger.

In order to reduce the operating temperature of the PV panel and also the efficiency of conversion, a cooling at approximate 25°C was simulated. This temperature is known as the one used for defining the Standard Test Conditions for photovoltaic panels.

The influence of the average temperature of the panel on its performance is represented in Tab. 1, for the inlet temperature of water of 25 °C

5. Conclusions

The cooling of the photovoltaic panel may cause an increase of electrical power generated between 13.77 % and 15.49 %, comparing to the basic case, Tab. 1.

The drop of the performance considered in computation is about 0.45 % for each degree over the standard temperature of 25 °C.

Therefore, the cooling of the PV panels represents an advantageous solution for increasing the efficiency of conversion. The reduction of the operating temperature obtained by using water as heat transfer agent has multiple advantages. Hence, the cold water available in the sanitary installations it can be used. It has optimal parameters for extracting the heat from the photovoltaic panel and represents a cheap solution.

By using a water film heat exchanger for extracting the thermal energy combined with a storage or exploitation system, the energetic efficiency of the entire ensemble can be globally evaluated and it is higher than the efficiency of the independent photovoltaic system.

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