CFD Analysis of PV Panel Temperature Reduction via Cooling Methods under High Irradiance Conditions.

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INTRODUCTION

In the context of modern renewable energy development, solar panels play a key role in ensuring sustainable energy supply. However, one of the major factors limiting their efficiency is overheating. An increase in the temperature of photovoltaic (PV) cells leads to a decrease in their performance, which is especially relevant for hot climate regions such as Kazakhstan [1].

METHODOLOGY

This study applies a numerical simulation method combined with comparative analysis to investigate thermal processes occurring during the operation of solar panels under elevated temperature conditions. Ansys Fluent software was used as the main simulation tool.

The research methodology involved the creation of a 3D model of a solar panel using the Design Modeler tool within the Ansys Workbench environment. The developed 3D model had dimensions of 2094 mm × 1038 mm × 35 mm, with its surface exposed to solar radiation at an intensity of 786 W/m² and ambient temperature at 33 °C. To improve the accuracy of the simulation, the parameters of all layers of the photovoltaic module were taken into account, as they play a critical role in heat transfer processes (see Tab.1).

Table 1. PV panel layer properties [2]

Layer	Thickness	Thermal Conductivity	Specific Heat Capacity	Density
	cm	W/m°C	J/kg°C	kg/m^3
Glass	0.3	1.8	500	3000
EVA	0.05	0.35	2090	960
PV Cell	0.04	148	677	2330
Tedlar	0.01	0.2	1250	1200
Frame	2	204	996	2707

To ensure accurate calculations, a computational mesh is generated, which plays a critical role in the numerical analysis of temperature distribution within the solar panel.

In the first stage, baseline thermal behaviour is analysed by simulating the heating of the solar panel under defined ambient conditions and solar radiation intensity.

In the second stage, air cooling is applied to the rear side of the panel, as this area typically experiences poor ventilation due to rooftop installation constraints.

In the third stage, a combined cooling approach is implemented, which includes both air flow and water spraying to enhance heat dissipation.

RESULTS

Figure 1 presents the computational mesh of the 3D solar panel model. As shown, the mesh is uniformly structured into finite elements, which contributes to reducing numerical errors and improving the convergence of the solution.

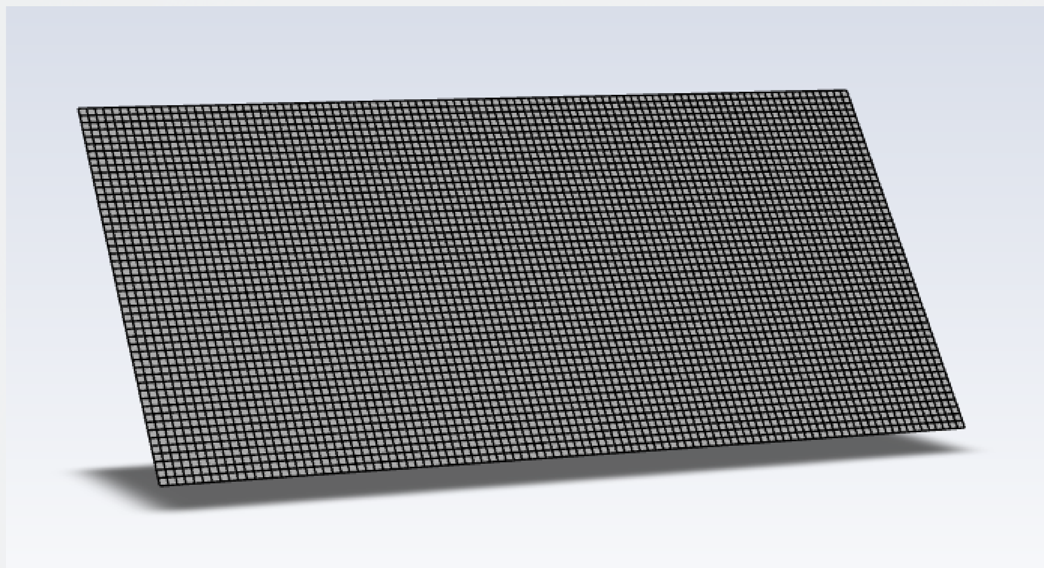

Fig.1. Computational mesh of the 3D solar panel model

Figure 2 shows the results of the thermal analysis of the solar panel under solar radiation of 786 W/m². According to the simulation data, the temperature distribution across the panel surface is relatively uniform, reaching values in the range of 50 to 51°C.

Fig.2. Solar panel heating

Figure 3 shows simulation of the cooling process of the solar panel using a directed airflow applied from the rear side in a top-down direction. According to the obtained data, the thermal performance of the panel improved significantly, with the maximum temperature reduced to 37.7 °C. However, the temperature distribution remained non-uniform, with values reaching up to 38.3 °C observed at the peripheral areas of the panel.

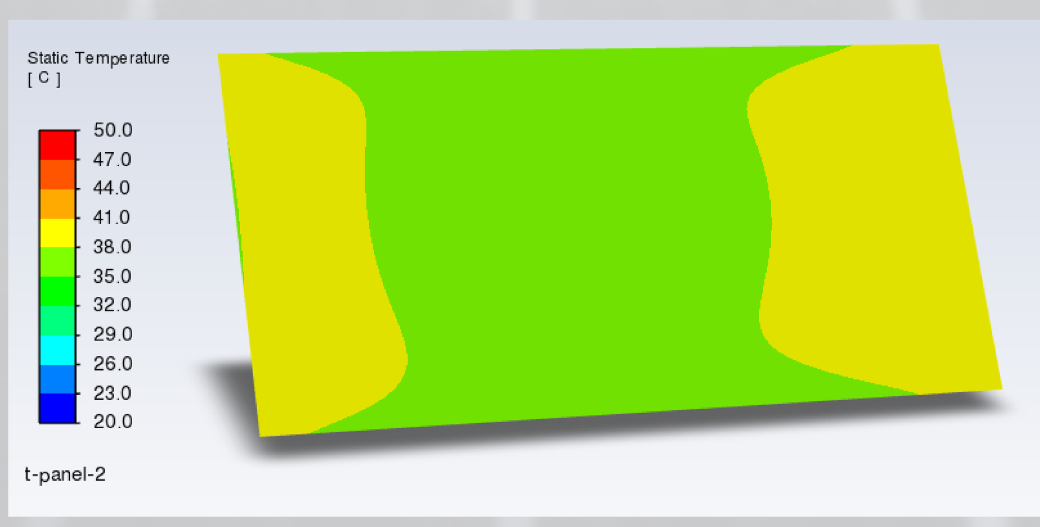

Fig.3. Air cooling of the solar panel

Figure 4 presents the results of combined cooling of the solar panel, implemented through a directed airflow in conjunction with water spraying. The application of this technique resulted in a surface temperature reduction to the range of 34–35 °C.

Fig.4. Combined (water+air) cooling of the solar panel

CONCLUSIONS

According to [3], for every degree above the STC, power output decreases by an average of 0.3%. This parameter is referred to as the temperature coefficient of power and is specified by the manufacturer in the technical documentation of the solar panel.

Based on the results of the numerical simulation, it was found that power losses amounted to approximately 7.5% at the first stage, 3.9% and 3% at the second and third stages, respectively. Thus, it can be concluded that the application of cooling methods significantly reduces the adverse effects of overheating, lowering power losses by nearly 2.5 times and thereby improving the overall efficiency of the system.

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