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## INTRODUCTION

Solar energy technologies are a fundamental component of sustainable energy development. However, the efficiency of PV modules is strongly influenced by temperature conditions. Increased operating temperatures lead to a decline in PV efficiency, especially in regions characterized by high ambient temperatures [1].

## METHODOLOGY

This study presents an experimental investigation and comparative analysis of the thermal performance of PV panels using different cooling methods. The experiments were carried out on a rooftop PV module prototype to simulate real operating conditions. The work extends previous numerical research [2] by providing experimental validation of the proposed cooling methods.

The research methodology involved the development of a mobile rooftop test platform (see Fig.1), on which the PV panel was mounted. This configuration was specifically designed to simulate real-world installation conditions typical of residential rooftop systems, thereby ensuring the practical relevance of the obtained results.

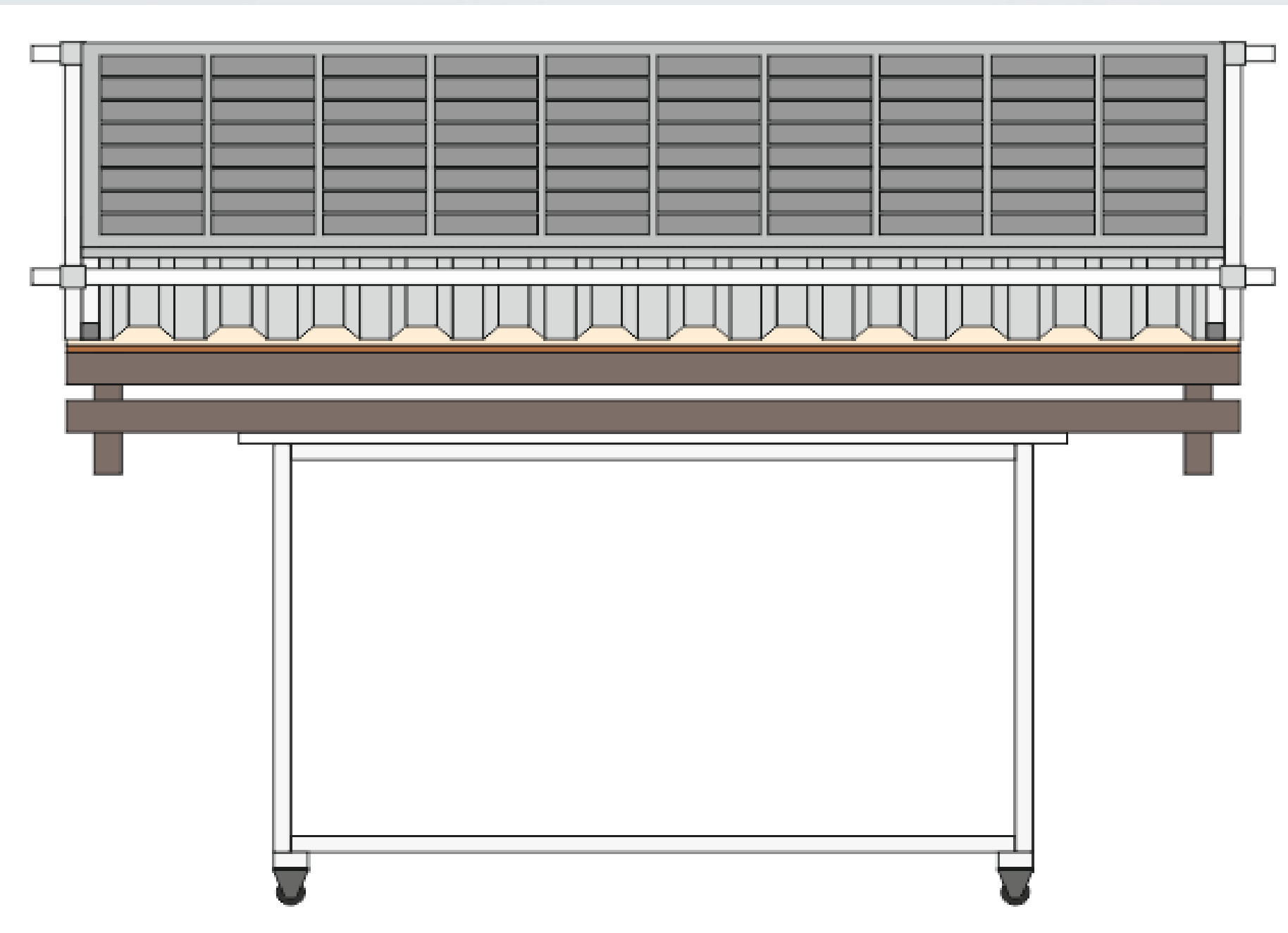
To investigate cooling performance, two types of cooling systems were implemented (see Fig.2). For air cooling, a total of 12 fans were installed on the supporting frame of the panel. These fans were arranged to provide a continuous airflow along the rear surface of the PV module, where heat accumulation is typically most significant.

For water cooling, a system consisting of 9 spray nozzles was used. The nozzles were connected to a pump that circulated water from a storage tank, enabling uniform spraying of water onto the rear side of the panel to enhance heat dissipation.

The experimental procedure consisted of three stages: baseline analysis without cooling, air cooling, and combined air-water cooling.

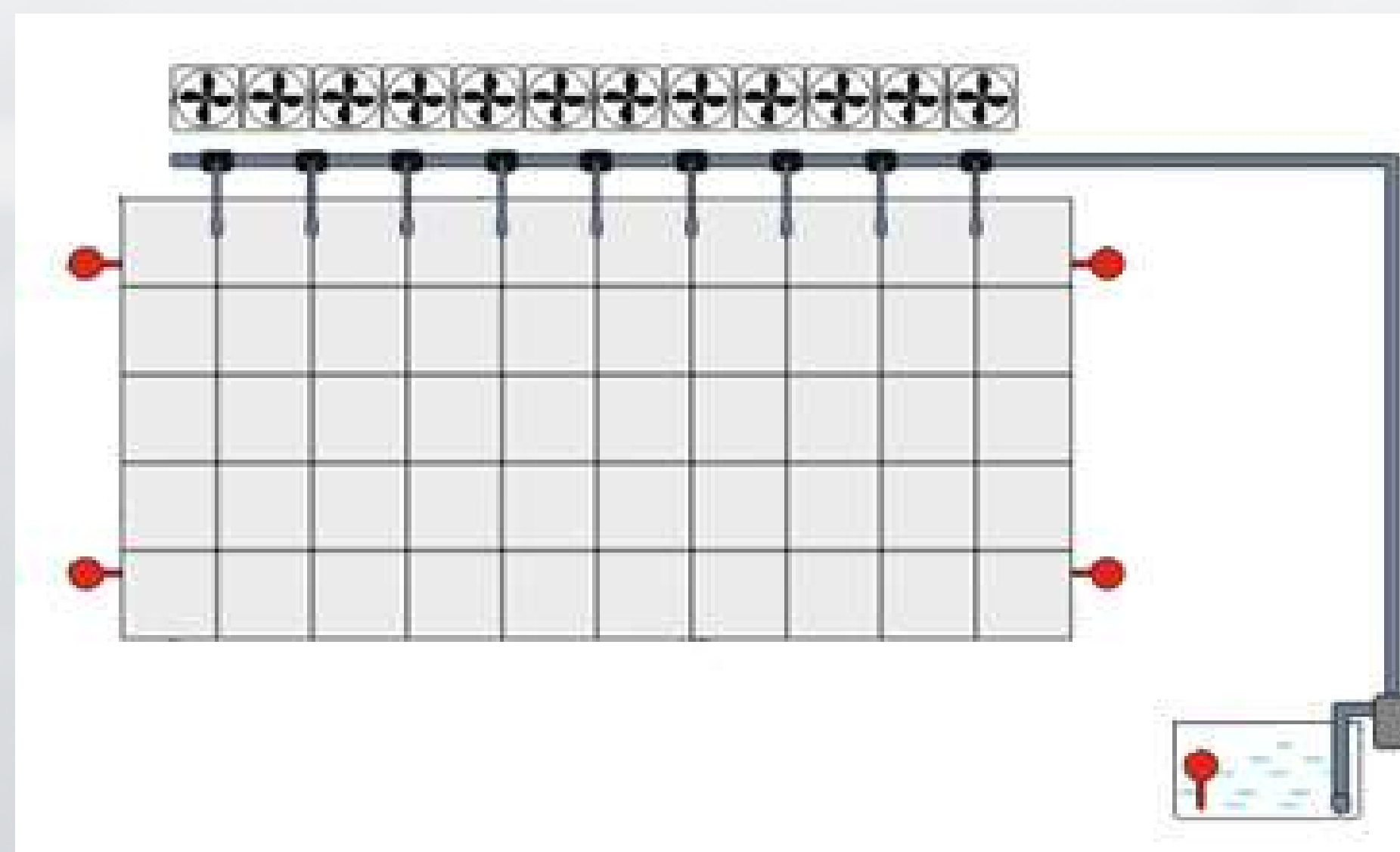
The cooling system is automatically controlled by a PLC installed within the control panel, which also provides real-time temperature monitoring. Temperature measurements are

obtained from four different points on the surface of the photovoltaic panel to ensure accurate assessment of its thermal state.



**Fig.1.** Rooftop PV module prototype model

In addition, the temperature of the water in the storage tank is continuously monitored as shown in Fig.2. The control panel also houses essential electrical components, including protective devices and a power inverter, ensuring safe and stable operation of the system.



**Fig.2.** Schematic of the cooling system for a rooftop PV panel

## RESULTS

Figures 3 and 4 illustrate the assembled mobile prototype of the rooftop PV panel integrated with the cooling system. The experiment was conducted on the rear side of the panel, and the results are summarized in Table 1 and presented in Figure 5.



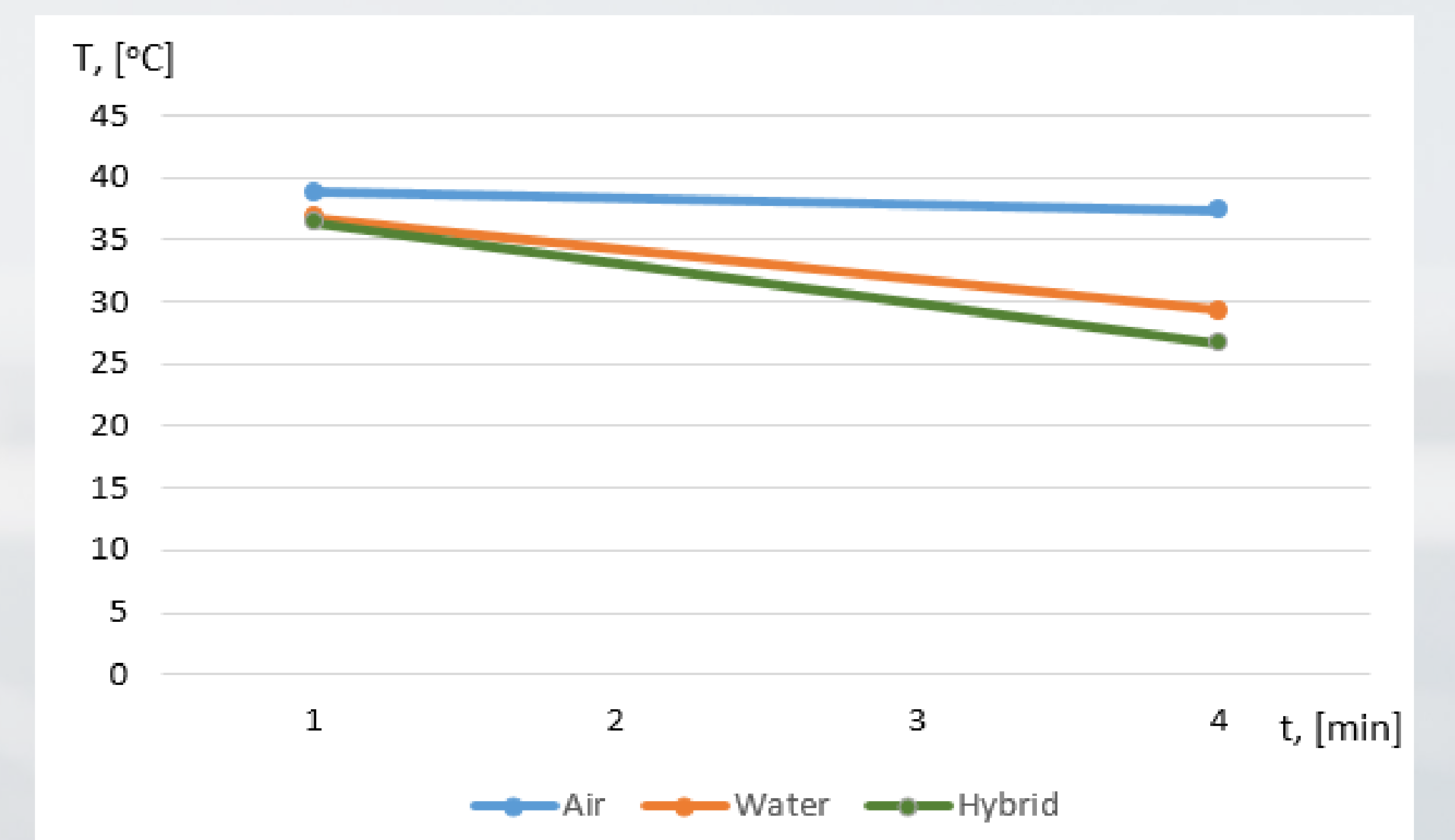
**Fig.3.** PV panel prototype



**Fig.4.** PV panel cooling system

**Table 1.** Initial experimental data

Category	Parameter	Value	Unit
Climatic Conditions	Illuminance	70,500	lx
	Ambient temperature	19	°C
	Wind speed	7	km/h
Technical Conditions	Tank volume	16	L
	DC voltage	28.3	V
	DC current	1	A
	AC voltage	223	V
	AC current	0.2	A



**Fig.5.** Temperature reduction under different cooling methods

## CONCLUSIONS

The results show that the combined air-water cooling method was the most effective, reducing the panel temperature by about 10°C. Water cooling alone also provided a noticeable improvement, lowering the temperature by around 6°C. In contrast, air cooling was the least effective, with a temperature reduction of only 1-2°C. In addition, it took about 2-3 minutes after activation before any cooling effect became noticeable.

## REFERENCES

- [1] S. Minazhova, M. Kurrat, B. Ongar, A. Geargiev. Deploying a rooftop PV panels in the southern regions of Kazakhstan. *Energy* 320, 135205 (2025).
- [2] S. Minazhova, N. Nalibayev, A. Geargiev, A. Bekbayev, Y. Sarsenbayev. CFD analysis of PV panel temperature reduction via cooling methods under high irradiance conditions. *Energy* 351, 140831 (2026).