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(Research Article)

Development of 3d format photoelectric energy devices based on silicon solar cells

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Abstract

Today, the focus on electricity production is mainly on renewable energy sources. This is due to the depletion of traditional energy resources around the world and the negative environmental impact of their use. The most environmentally friendly and promising source of renewable energy is the energy generated by photovoltaic devices. In this research, we focus on the practical development of optimal designs for photovoltaic energy devices that are able to self-cool by rotating around their axis. These devices are technically adapted to various climates.

Keywords: Efficiency; Rotating; Climate; Photoelectric energy device; Solar cell; Cooling

1. Introduction

Every hour, 430 quintillion joules of energy is emitted by the Sun and reaches Earth. This is more energy than the entire planet uses in a year. With such a vast amount of clean energy available, it is inevitable that we will transition to solar power. Countries such as the United States, China, India, and Japan have all managed to make significant strides in this field and have been generating large amounts of energy from solar power for several years. In the coming years, most of the world is expected to use renewable energy sources as the primary source for electricity production [1]. One of the most environmentally friendly and promising forms of renewable energy is energy generated from photovoltaic devices [2]. Due to the increasing demand for energy, the number of solar photovoltaic installations has grown exponentially. Many companies are exploring the potential of solar power and making changes to their operations. Solar panels are installed in various parts of the world, so the efficiency of these panels differs from region to region [3]. There are several issues with solar panels, one of which is that when the outdoor temperature is high, their efficiency decreases due to the heating of the panel surface [4].

2. Materials and Methods

During the 8-minute experiment on July 6th, 2023, we observed that the surface temperature of the solar panel increased to 64 degrees Celsius (° C) when the external temperature was 41 degrees Celsius (° C). Over time, the coefficient of change in the temperature of the surface of the solar panel was determined by the following expression.

$$\beta = \frac{T_2 - T_1}{t_{time}} \qquad (1)$$

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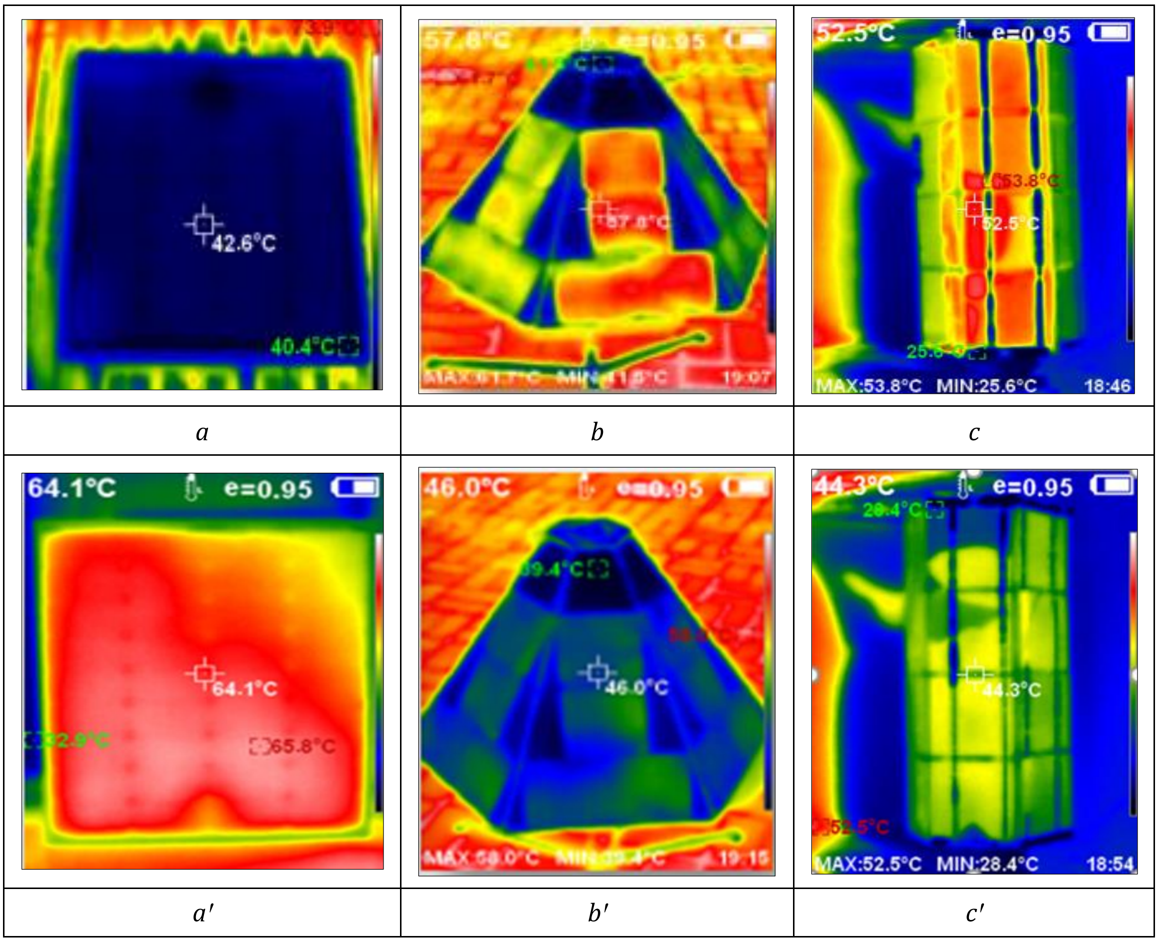

Figure 1 FLUS IR-892 thermal imaging shows that the surface temperature of a flat solar panel increases over time, while 3D photovoltaic devices have a surface temperature that decreases over time

In Fig. 1(a), we found in the experiment that the temperature coefficient of the flat-surface solar panel increased by $\beta = 0.046$ *°C/s* every second and by $\beta = 2.76$ *°C / min* every minute, resulting in a 30% decrease in output power.

Scientists around the world are conducting extensive research to improve the efficiency of their development of optimal solar panel and module devices [5].

To address this issue, we have designed a groundbreaking 3D photovoltaic energy device (PVED) that incorporates self-cooling capabilities and can adapt to various climatic conditions. The system features a pyramid-shaped vertical axis and a prism-shaped horizontal axis design. Through modeling, we have achieved optimal performance [2-3].

3. Results and discussion

In Fig. 1 (b, b') a prism-shaped photoelectric energy device rotating around a horizontal axis with an output power P_{max}=11W and (c, c') a pyramid-shaped photoelectric energetic device rotating around a vertical axis with an output power P_{max}=60 W. The temperature coefficient of PED was determined for the rotated state with ω = 4 rad/s. According to it, at (b, b') β_{prism} = - 0.0022 °C/sec= - 1.3 °C/min, and at (c, c') $\beta_{pyramid}$ = -0.00312 °C/sec= - 1.87 °C/minute was found to decrease.

In Fig. 1 (a, a'), a prism-shaped photoelectric energy device is rotating around a horizontal axis with an output power of Pmax = 11 W, and (b, b') is a pyramid-shaped photovoltaic energy device that rotates around a vertical axis and has an output power equal to Pmax =60 W. The temperature coefficient of the PED was determined for the rotated state at ω = 4 rad/s. Based on this, at (b, b') coefficient of Prism change was found to β_{prism} =-0.0022 °C/s = -1.3 °C/min and at (c, c') coefficient of Pyramid change was found to decrease by $\beta_{pyramid}$ =-0.312°C/second = -1.87°C per minute.

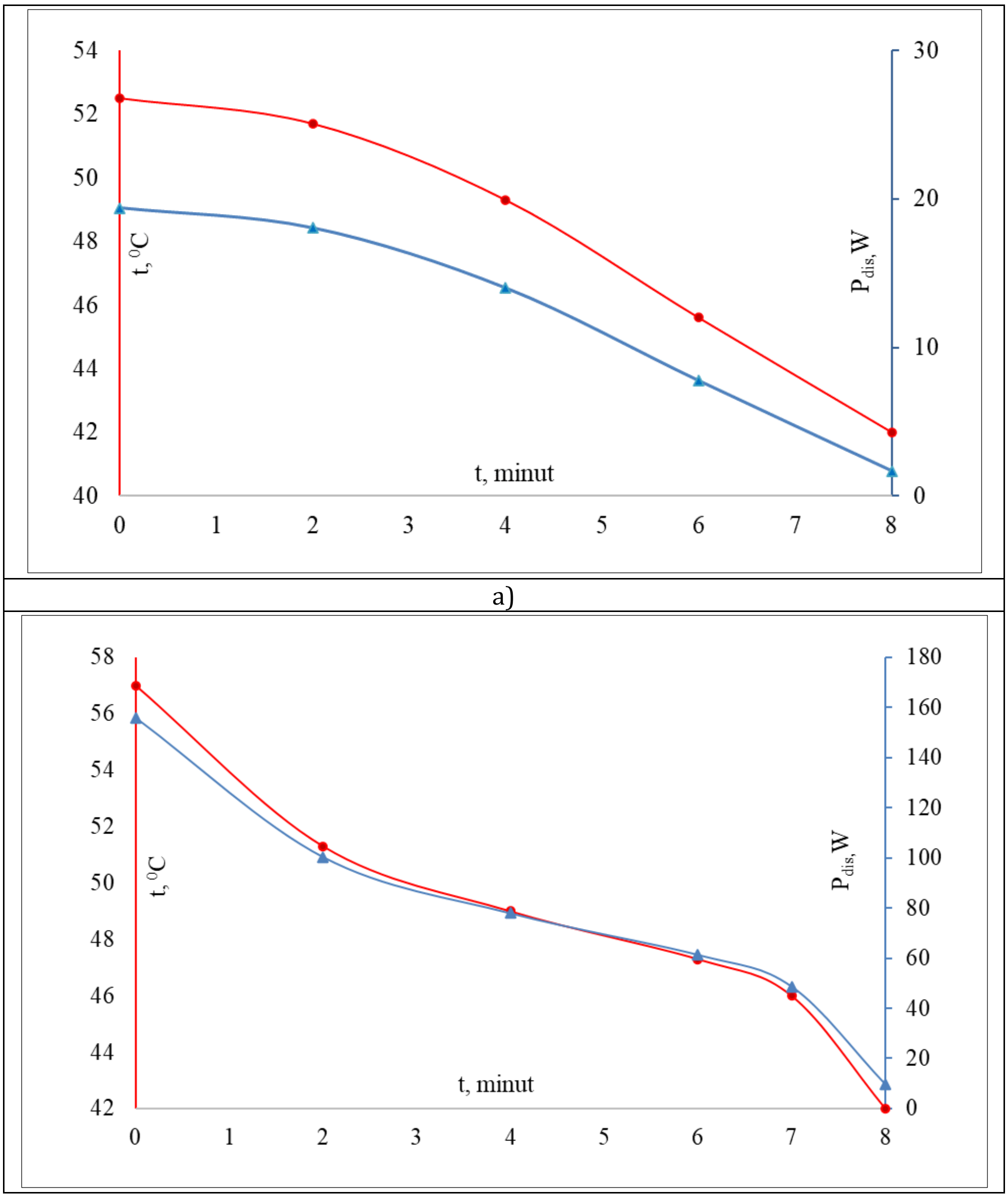

Figure 2 Changes in the surface temperature of solar panels due to heat loss through forced convection. In this case, —•— represents the surface temperature of the solar panel, while —▲— represents the energy emitted from the panel's surface.

Experimental samples of 3D-format photoelectric energy devices with prism and pyramid-shaped structures based on silicon solar cells were prepared and tested.

Table 1 The energy efficiency and payback period of the photoelectric modules under study

№	*Type of solar module*	$P_{avarage}$, *mW/sm²*	*Average annual energy, kW×s*	*Financial equivalent, k. UZS*	*Relative efficiency, %*	*Average cost and its growth $ / %*	*Payback period, year*
1	SP with a flat surface	16,8	100,8	100,8	100	90	10,7
2	3D PED without rotation	16,8	100,8	100,8	100	96 / 1,06	11,4

3	PED with rotating 3D format	23,7	142,5	142,5	142,5	99 / 1,1	8,3
4	Rotating 3D format PED+Sunlight Concentrator	24,3	146,1	146,1	146,1	105/1,16	8,6

Thus, the technical and economic characteristics of the introduction of photoelectric power modules in 3D format based on silicon solar cells have been determined. The relative efficiency of the wind-driven three-dimensional (3D) photovoltaic energy device developed is 42.5% greater than that of a conventional flat solar panel. The use of concentrators in these devices can increase their efficiency by up to 46.1%. At the same time, the average cost of a 3D rotating photovoltaic energy device is about 10% more expensive than a flat solar panel. When the concentrator is installed, the cost of the device is 16% higher than a flat solar panel (row 4).

4. Conclusion

It has been found that a photoelectric energy device in the shape of a pyramid cools the surface 1.42 times faster than one in the shape of a prism, due to its optimized design. New 3D format photoelectric energy devices have been shown to be 33% to 40% more efficient than flat-surface solar panels. Their technical and economic indicators have also been determined.

Compliance with ethical standards

Acknowledgement

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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