SECTION 5. ELECTRIC POWER ENGINEERING, ELECTRIC ENGINEERING AND ELECTROMECHANICS

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SUBSTANTIATION OF DESIGN AND TECHNOLOGICAL SOLUTIONS FOR THE DEVELOPMENT OF COGENERATION PHOTOVOLTAIC MODULES

ОБҐРУНТУВАННЯ КОНСТРУКТИВНИХ І ТЕХНОЛОГІЧНИХ РІШЕНЬ ДЛЯ РОЗРОБКИ КОГЕНЕРАЦІЙНИХ ФОТОЕЛЕКТРИЧНИХ МОДУЛІВ

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Relevance of the Study. In the context of rising electricity costs and the need to meet energy efficiency standards for industrial and residential facilities, the development and implementation of advanced solutions, particularly in the field of renewable energy conversion (RES), especially solar energy, to improve the conversion efficiency of solar radiation, becomes critical. Thus, the development and study of new designs for photovoltaic devices aimed at enhancing the efficiency of converting solar insolation into electrical, thermal, and other forms of energy is a **relevant task.**

Given the above, **the aim of this study** is to substantiate the constructive and technological solutions for photovoltaic modules (PVMs) to enhance the efficiency of solar insolation conversion.

Main Research Materials. To improve the efficiency of solar insolation conversion, it is proposed to replace traditional flat solar panels with cylindrical cogeneration photovoltaic modules (CCPVMs) with liquid cooling. This is a promising and innovative approach to enhancing the efficiency of converting solar insolation into electrical, thermal, and other types of energy [1, 2].

One of the key elements ensuring high performance of such modules is the use of a cylindrical shape, which significantly optimizes the process of solar radiation absorption. This is explained by the fact that the cylindrical design allows for the utilization of direct, reflected, and refracted sunlight, contributing to the overall efficiency of the module. This design of PVMs increases the efficiency of solar radiation conversion even with changing incident angles throughout the day. Unlike traditional flat panels, CCPVM-based panels demonstrate higher solar radiation conversion efficiency, making them a promising solution for decentralized energy systems [3].

One of the prospective engineering solutions to enhance solar energy conversion efficiency is the development and implementation of hybrid photovoltaic panels with liquid cooling (e.g., Solar Collector Excell 540 W by Solimpeks, Solarus PowerCollector Hybrid PC2S, DualSun) [4–6].

A particular research interest lies in substantiating the parameters of an energy-efficient operating mode for an electrical complex in a local network based on CCPVMs. This includes the development and improvement of mathematical models that describe the constructive and technological parameters of the cylindrical photovoltaic converter – a key element of PVMs. Mathematical modeling of such modules' parameters is one of the main stages of their development, addressing the optimization of design factors such as tube diameter and length, absorber surface area, and peak daily solar radiation density.

The analysis of PVM models facilitates the development of optimal technical characteristics for maximum performance. In practice, ensuring their optimality and efficiency requires the adoption of advanced software tools (MATLAB/Simulink, ANSYS, OpenFOAM, PVsyst, AutoDesk Fusion 360, SolidWorks, etc.), which enable the optimization of constructive and technological solutions. These tools help simulate, analyze, and optimize module parameters under various operational conditions. Integrating multiple software solutions allows for a comprehensive approach to PVM design and analysis. For example, 3D modeling in SolidWorks can be supplemented with thermal analysis in ANSYS or OpenFOAM, and the results can be used to optimize energy efficiency in MATLAB/Simulink.

Thus, to describe the optimal operating mode of CCPVMs, models are utilized that include parameters for calculating predicted power, temperature fluctuations, and the use of battery storage for excess energy produced during periods of high solar activity. This approach reduces dynamic variations in peak daily specific power density of solar radiation, ensuring a more precise system operation for subsequent experimental research. Figure 1 shows the experimental setup of a CCPVM-based panel with liquid cooling for simultaneous electrical and thermal energy generation.

In addition, monitoring the key characteristics of PVMs under real-world conditions, such as changing insolation, temperature regimes, and other climatic factors, becomes necessary.

Fig. 1. Experimental CCPVM setup with liquid cooling for simultaneous electrical and thermal energy generation

The unique feature of the proposed CCPVM-based panel design is its potential application in the promising field of agrivoltaics (Agri-PV). This involves integrating such panels into agricultural lands to simultaneously utilize the land for livestock grazing, electricity production, and water heating for irrigating crops grown under the panels. The technology envisions installing solar modules at a height that allows for agricultural activities underneath. A wide range of technical solutions, agronomic techniques, and organizational forms of agricultural activity intersecting various technologies makes agrivoltaics a distinct economic sector.

It is worth noting that CCPVMs also hold potential for application in transportation, particularly for charging electric vehicles. Implementing such solutions at existing charging stations not only reduces environmental impact but also creates conditions for efficiently utilizing available energy.

CCPVMs demonstrate significant potential in sustainable energy supply, combining high efficiency, versatility, and adaptability to diverse operating conditions. The implementation of such designs will promote the development of renewable energy, enhance energy efficiency in local networks, and contribute to sustainable development in the energy sector.

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