ANALYSIS OF THE EFFICIENCY OF HYBRID ENERGY SYSTEMS COMBINING THERMOELECTRIC GENERATORS AND SOLAR PHOTOVOLTAIC INSTALLATIONS

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Abstract. This article examines hybrid energy systems integrating thermoelectric generators and solar photovoltaic installations. An analysis of the operating principles and efficiency of such systems is carried out, and the possibilities of increasing electricity generation through the utilization of thermal energy generated during the heating of solar panels are investigated. The main factors affecting the performance of the hybrid system, including solar radiation intensity, temperature conditions, and the characteristics of thermoelectric materials, are considered. The obtained results demonstrate that the combined use of thermoelectric generators and photovoltaic modules contributes to an increase in the overall efficiency of the system and ensures more effective utilization of renewable energy sources.

Keywords: hybrid energy system, thermoelectric generator, solar photovoltaic installation, renewable energy sources, solar energy, efficiency, energy conversion efficiency, thermoelectric materials, photovoltaic modules, energy saving.

Introduction.In the context of growing global energy consumption and the need to reduce greenhouse gas emissions, special attention is being paid to the development and implementation of renewable energy sources. Among them, solar energy occupies a leading position due to the availability of solar radiation, environmental friendliness, and the continuous improvement of photovoltaic technologies. However, the efficiency of conventional solar photovoltaic systems is limited by several factors, one of which is the heating of photovoltaic modules during operation.

It is well known that only a portion of the incident solar energy is converted into electrical energy, while a significant share is transformed into thermal energy, causing an increase in the temperature of solar panels. The rise in the temperature of photovoltaic cells leads to a reduction in their conversion efficiency and a decrease in electricity generation. Therefore, the effective utilization of excess thermal energy generated during the operation of solar systems has become an important research challenge.

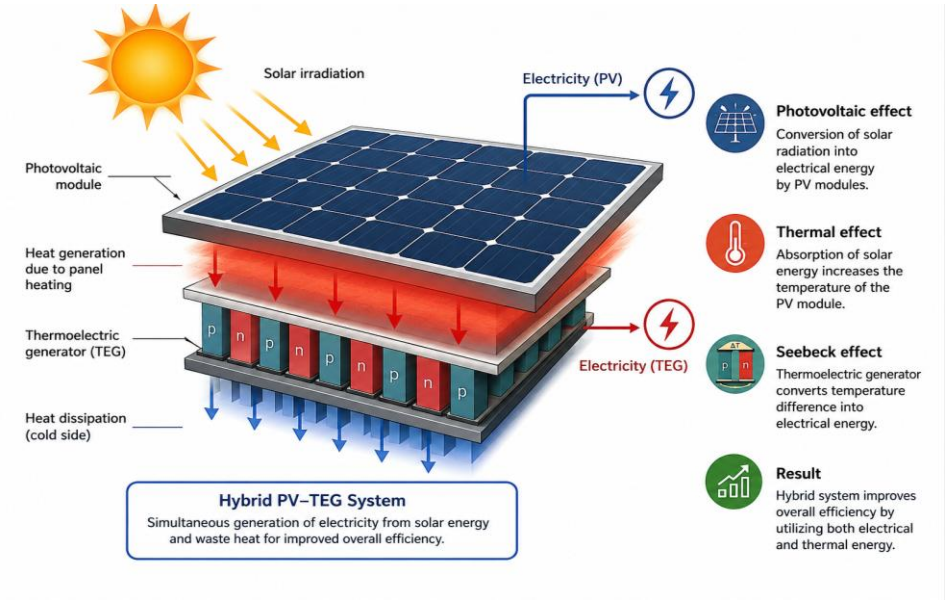

Figure 1. Operating Principle of a Hybrid Solar Photovoltaic and Thermoelectric Generation System

One of the most promising solutions is the integration of thermoelectric generators with solar photovoltaic systems. Thermoelectric generators are capable of directly converting temperature differences into electrical energy based on the Seebeck effect. The combined use of photovoltaic modules and thermoelectric generators makes it possible not only to increase the overall efficiency of the energy system but also to ensure a more rational utilization of solar energy.

In recent years, hybrid photovoltaic–thermoelectric systems have attracted increasing attention from researchers due to their potential to enhance energy efficiency and improve the reliability of power supply. Despite the progress achieved, issues related to the optimization of system design, the selection of efficient thermoelectric materials, and the assessment of the influence of operating parameters on system performance remain highly relevant.

The aim of this study is to analyze the efficiency of hybrid energy systems combining thermoelectric generators and solar photovoltaic installations, as well as to investigate the factors affecting their energy performance and prospects for practical application.

Methods.In this study, an analysis of the efficiency of a hybrid energy system combining a solar photovoltaic installation and a thermoelectric generator was carried out. The fundamental operating principle of the system is based on the simultaneous conversion of solar energy into electrical energy by photovoltaic modules and the utilization of thermal energy generated as a result of solar panel heating for additional electricity production through thermoelectric generators.

The investigated system consists of a silicon photovoltaic module and a thermoelectric generator mounted on the rear side of the solar panel. The thermoelectric generator operates based on the Seebeck effect and converts thermal energy into electrical energy through a temperature difference between its hot and cold sides.

To evaluate the energy performance of the system, data on solar irradiance, ambient temperature, and the surface temperature of the photovoltaic module were used. The analysis

was conducted under various levels of solar radiation intensity and temperature conditions typical of regions with high solar energy potential.

During the study, the main parameters affecting the efficiency of the hybrid system were investigated, including solar radiation intensity, the operating temperature regime of photovoltaic modules, and the properties of thermoelectric materials. Particular attention was paid to the influence of solar panel heating on the overall system performance and the possibility of utilizing the generated thermal energy for additional electricity production.

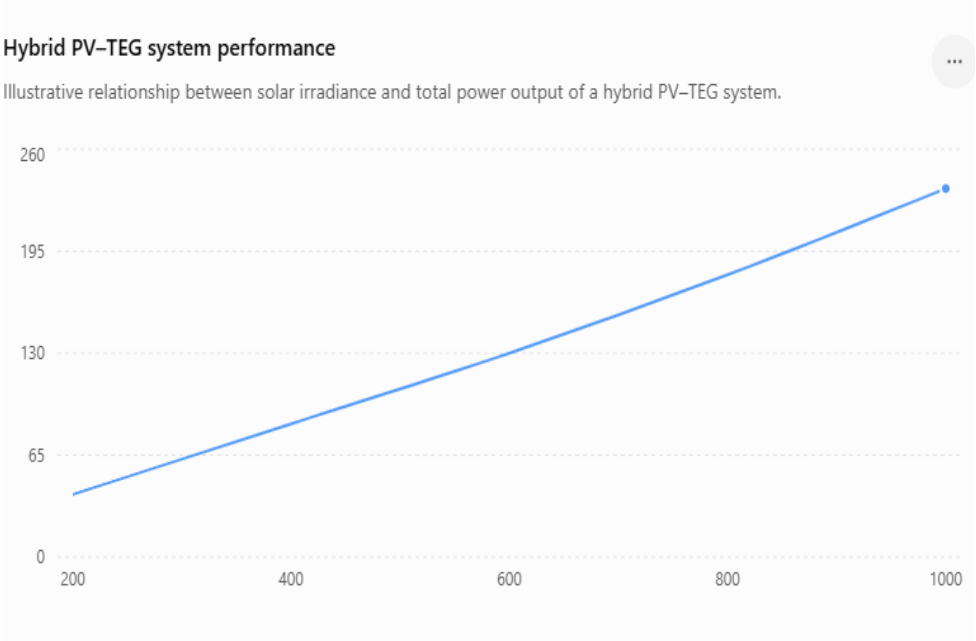

Figure 2. Dependence of the total power output of the hybrid photovoltaic–thermoelectric (PV–TEG) system on solar irradiance.

The processing and analysis of the obtained data were performed using comparative analysis and mathematical modeling methods. The research results are presented in the form of tables and graphs illustrating the dependence of the hybrid system's energy characteristics on operating conditions and environmental parameters.

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