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Modelling and experimental studies of heat transfer for a new active cooling system for photovoltaic modules

One of the greatest economic challenges today is the shift from fossil fuels to a zero-emissions economy. To this end, the EU has taken several initiatives to ensure a clean and fair energy transition in all economic areas. Launched in 2016, the Clean Energy for All Europeans package is described as the most ambitious set of energy proposals. One of the areas covered by the package is taking the global leader in the use of renewable energy sources, which in practice means reaching the target of 32% renewable energy by 2030. The second area is energy efficiency and aims to achieve at least 32.5 % of energy efficiency level.

Currently, more than half of the energy in the European Union is imported, in particular oil and gas. In Poland, coal is still the main energy pillar. The share of this raw material in electricity production in 2019 was 73.6%. On the other hand, the import of fuels in our country has increased by 60% over the last decade. It is estimated that in 2030, lignite deposits in Poland will start to run out. It is, therefore, necessary to look for alternatives that will meet the increasingly growing needs for energy consumption. The solution is to invest in renewable energy sources, which have been developing dynamically in recent years thanks to technological progress. In 2018, renewable energy accounted for 21.1% of total energy consumption for heating and cooling.

The main sources of renewable energy are wind, sun and solid biofuels. Solar energy, unlike wind energy, is not so strongly dependent on climatic conditions, so it can be used regardless of location. In 2018, the photovoltaic industry produced approximately 113 GWp of photovoltaic modules. However, despite the growing interest in photovoltaic technology and the drop in module prices, the solar-to-electricity conversion is still relatively low. The problem of excessive overheating of the panels and the decrease in their efficiency has also not been solved. The conducted literature analysis showed several solutions aimed at solving this problem, however, no solution was found that would allow obtaining satisfactory results and would be characterized by the simplicity of the solution and universality.

In this paper, an attempt was made to develop a mathematical model for the cooling system of PV panels, which would allow predicting the yields of electricity and heat from the system in changing climatic conditions. Simulations were carried out to select the best arrangement of cooling pipes responsible for effective heat collection from the installation, and then numerical calculations

were validated based on data from the test installation. For research on the active cooling system of PV panels, a research stand developed and implemented within the framework was used: "High-performance hybrid solar system for generation of thermal and electrical energy applied for buildings" is a project financed by The National Centre for Research and Development within the framework of the II Competition Polish-German Cooperation for Sustainable Development – STAIR. The stand is located on the campus of the Faculty of Mechanical Engineering of the Cracow University of Technology.

The first part of the work covers the characteristics of solar radiation as an energy source, description of solar radiation and the method of solar energy conversion using the photovoltaic effect. The photovoltaic technologies currently available on the market were also characterized.

Chapters 3 - 5 describe the basic parameters characterizing photovoltaic cells and the influence of external factors on the operation of the cells. Next, Chapter 6 presents ways to increase electricity production from PV panels. Solar tracking systems are discussed and the current state of knowledge on cooling systems for solar panels is presented. The active and passive cooling systems and working factors most often used to lower the temperature of the panels were characterized. The conducted literature analysis was aimed at organizing the existing knowledge in this field

The main achievement of the work has been described in chapters 8 - 11 and concerns the development of a numerical model of the proposed cooling system for PV panels, its experimental validation and optimization of the number and arrangement of pipes in the heat sink. First, the energy transport equations are presented, assuming a three-dimensional temperature distribution in individual layers of a PV panel: in glass, protective foil, PV panel, aluminium base and cooling tubes, and one-dimensional temperature distribution of the coolant. Then a model for cooling PV was developed, which allowed designing the cooling system in such a way that the best possible heat collection from PV panels was possible. The developed cooling system was verified by comparing the obtained simulation results with the tests carried out on the existing test stand.

The last part of the work contains a summary, analysis of the results and conclusions resulting from the experimental research.