Chapter 13
Development and Research of PVT Modules in Computer-Aided Design and Finite Element Analysis Systems

Vladimir Panchenko
Russian University of Transport, Russia

Valeriy Kharchenko
https://orcid.org/0000-0003-3725-2976
Federal Scientific Agroengineering Center VIM, Russia

ABSTRACT

This chapter discusses the simulation of solar photovoltaic thermal modules of planar and concentrator structures in computer-aided design systems KOMPAS 3D and finite element analysis ANSYS. To create photovoltaic thermal modules, a method for designing their three-dimensional models in the computer-aided design system has been developed. To study the thermal regimes of the created three-dimensional models of modules, a method has been developed for visualizing thermal processes, coolant velocity, and flow lines of a cooling agent in a finite element analysis system. As a result of calculations in the finite element analysis system using the developed method, conclusions can be drawn about the feasibility of the design created with its further editing, visualization of thermal fields, and current lines of the radiator cooling agent. As an illustration of the simulation results, a three-dimensional model of a photovoltaic thermal planar roofing panel and an optimized three-dimensional model of a photodetector of a solar concentrator photovoltaic thermal module are presented.

DOI: 10.4018/978-1-5225-9420-8.ch013

INTRODUCTION

The principle of creating a single device that provides simultaneous generation of electrical and thermal energy is the creation of a photovoltaic thermal module (PVTM) (Kharchenko, Panchenko, Tikhonov & Vasant, 2018), where solar cells are placed on a heated absorbing surface of a flat solar collector. The absorber in this design performs a double function – firstly, it cools the photovoltaic panel, removing excess energy that is not involved in the generation of electricity, thereby increasing its efficiency, and secondly, it produces thermal energy.

The history of the development of this class of devices goes back several decades, where it is shown that such a combined system is a promising design for further development. In (Zharkov, 2014; Kamilov, Muminov & Tursunov, 2008), the authors studied the modules that heat water and air, identified key concepts and main priorities for the development of cogeneration systems of this type. Improving the efficiency of thermal conversion of solar radiation implies a high operating temperature, which at the same time reduces the efficiency of photoelectric conversion. It is not surprising that in the reviewed papers attention is paid to the development of the optimal design of the heat generating part of the PVTM, since the optimal design of such a module will ensure high efficiency of the photovoltaic plant and high thermal output.

Experimental studies (Hosseini, Hosseini & Khorasanizadeh, 2011; Rawat, Debbarma, Mehrotra et al., 2014; Buonomano, Calise & Vicidimini, 2016) showed that the overall efficiency of the combined module is greater than the efficiency of a conventional solar panel, where the daily thermal efficiency was 50.1%, and the total efficiency of the developed module exceeded 73%. Improving the design of the photovoltaic thermal module (Ibrahim, Jin, Daghigh, Salleh, Othman, Ruslan et al., 2009), where the absorber is made in the form of a rectangle in cross section, it is possible to manufacture an absorber in the form of a V-shaped triangle, which is presented in (Othman, Ruslan, Sopian & Jin, 2009), thereby reducing heat loss and improving heat removal. In (Sevela & Olesen, 2013), a photovoltaic thermal module with a tubular heat exchanger is presented, where the maximum efficiency of a liquid solar collector in the installation was 48% with photoelectric converters turned off, and with simultaneous production of electrical and thermal energy, its value decreased to 42%. A flat photoelectric thermal collector was considered in (Ibrahim, Othman, Ruslan, Mat & Sopian, 2011), in which the radiation receiver is a light-absorbing plate with photoelectric elements and under this plate are tubes with a circulating coolant. Studies (Dubey & Tay, 2012) have shown greater efficiency of a photovoltaic thermal module with rectangular coolant channels compared with a module with a tubular sheet heat exchanger. The disadvantages of photovoltaic thermal modules with tubular heat exchangers include the low efficiency of heat energy transfer due to insufficient thermal contact between the absorber and the substrate of the photovoltaic cells. To solve this problem, a photovoltaic thermal module is presented, in which the photodetector is mechanically pressed against the thermal collector without the aid of any mounting glue. Compared with a photoelectric thermal collector with a tubular radiator, this solution provides better thermal contact between the photoreceiver and the heat exchanger, which increases the efficiency of solar energy conversion, but this solution is problematic due to the fragility of the photoelectric converters and the need for a sealant to maintain high electrical characteristics.

Today, one of the most advanced designs in terms of optimization is the modules of Solimpeks (http://www.solimpeks.com) and Sunsystem (http://www.sunsystem.bg/en/fotovoltaika/PV-T/), which produce photovoltaic thermal modules with a tubular heat exchanger. However, even commercially manufactured modules are distinguished by high material consumption, mass, and, accordingly, cost. In addition, the