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Photovoltaic Thermal Module With Paraboloid Type Solar Concentrators

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ABSTRACT

The article presents the results of the development and research of the solar photovoltaic thermal module with paraboloid type solar radiation concentrators. The structure of the solar module includes a composite concentrator, which provides uniform illumination by concentrated solar radiation on the surface of the cylindrical photovoltaic thermal photoreceiver in the form of the aluminum radiator with photovoltaic converters. When exposed in concentrated solar radiation, the electrical efficiency of specially designed matrix photovoltaic converters increases, and the heat taken by the heat carrier increases the overall efficiency of the solar module. Uniform illumination of photovoltaic converters with concentrated solar radiation provides an optimal mode of operation. The consumer can use the received electric and thermal energy in an autonomous or parallel power supply with the existing power grid.

KEYWORDS

Current-Voltage Characteristics, Efficiency, Energy Supply, Finite Element Analysis System, Matrix Photovoltaic Converters, Paraboloid, Photovoltaic Thermal Module, Solar Concentrator, Solar Energy

INTRODUCTION

In recent decades, power plants based on the conversion of renewable energy sources, have significantly expanded their geography and technologies to increase their efficiency are developing at a faster pace (Adomavicius, Kharchenko, Valickas & Gusarov, 2013; Nikolaev, Nikolaev & Kharchenko, 2018; Kharchenko, Gusarov & Bolshev, 2019; Zharkov, 2014). Power plants based on converters of wind energy and solar energy have been developed to a greater degree and solar power plants have been more actively developing in recent years compared to other stations based on renewable energy (Ibrahim, Othman, Ruslan, Mat, & Sopian, 2011; Kharchenko, Nikitin, Tikhonov & Gusarov, 2013; Nesterenkov & Kharchenko, 2019; Panchenko 2018; Sevela, & Olesen, 2013; Zakharchenko, Licea-Jime'nez, Pe'rez-Garci'a, Vorobeiv, Dehesa Carrasco, Pe'rez-Robels, et al., 2004). The conversion of solar energy into heat and electricity is of interest not only to autonomous and remote consumers, but also to owners of solar power plants, which can be used to solve regional energy problems and global energy problems.

One of the methods for converting solar energy into electrical energy is the direct conversion method using planar and matrix photovoltaic converters (Panchenko, 2019; Panchenko, Izmailov,

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Kharchenko, & Lobachevskiy, 2020; Panchenko, 2020; Kharchenko, Nikitin, Tikhonov, Panchenko & Vasant, 2019). Currently existing photovoltaic converters can be classified by the number of *p-n* junctions – single-junction and multi-junction, as well as by the location of the *p-n* junction – planar and with vertical *p-n* junctions. Multi-junction photovoltaic converters include planar-cascade and photovoltaic converters with a vertical *p-n* junction (matrix photovoltaic converters). In solar energy, when using planar and matrix photovoltaic converters, two directions are distinguished – the photovoltaic conversion of non-concentrated and concentrated solar radiation. There are also two directions for reducing the cost of solar photovoltaic stations: improving the technical and economic characteristics of planar photovoltaic converters and creating stations with solar radiation concentrators. The use of concentrating systems reduces the number of photovoltaic converters.

The main features of matrix silicon photovoltaic converters developed at the All-Russian Research Institute of Electrification of Agriculture is the possibility of their use at high concentrations of solar radiation, in which there is an increase in their electrical efficiency (Kharchenko, Panchenko, Tikhonov & Vasant, 2018; Panchenko, 2019; Panchenko, Izmailov, Kharchenko, & Lobachevskiy, 2020). Using such photovoltaic converters, it is possible to create a combined installation for the production of electricity and heat. In such photovoltaic systems, the primary task is to remove heat from photovoltaic converters, where the design of solar modules can be both planar (Al Harbi, Eugenio, & Al Zahrani, 1998; Bergene, & Lovvik, 1995; Buonomano, Calise & Vicidimini, 2016; Dubey. & Tiwari, 2008; Hosseini, Hosseini & Khorasanizadeh, 2011; Ibrahim, Jin, Daghigh, Salleh, Othman, Ruslan, et al., 2009; Ji, Lu, Chow, He, & Pei, 2007; Kalogirou, 2001; Mourad, Rabah & Meerzouk, 2014; Othman, Ruslan, Sopian & Jin, 2009; Rawat, Debbarma, Saurabh Mehrotra et al., 2014; Sandnes & Rekstad, 2002; Tiwari & Sodha, 2006), and concentrator (Chen, Hsu, Lin & Su, 2011; Daliento, & Lancellotti, 2010; Fassbender, Ackermann, Battenhausen, Colburn, Löffler & Marks, 2011; Kemmoku, Araki & Oke, 2011; Rosell, Vallverdu, Lechon & Ibanez, 2005). Also in solar photovoltaic thermal installations, a large role is played the type of solar radiation concentrator and the shape of its working profile, as well as its design technique and manufacturing accuracy (Sinitsyn, Panchenko, Kharchenko & Vasant, 2020; Strebkov & Tveryanovich, 2007).

Thus, solar concentrator photovoltaic thermal installations have great potential for implementation, the concentrators of which can provide uniform illumination of the surface of photovoltaic converters, which are used as silicon matrix solar cells, during cooling of which the overall efficiency of the solar module increases significantly.

To create such installations, which are based on solar radiation concentrators, it is necessary to develop a method for calculating the working profile of a concentrator, which would ensure uniform illumination in the focal region and the choice of a manufacturing method for such a solar radiation concentrator.

The centrifugal method (Strebkov & Tveryanovich, 2007) allows obtaining parabolic surfaces using the property of a liquid to acquire a parabolic surface with uniform rotation. Liquids with different specific gravities form equipotential surfaces with uniform rotation, when a lighter material is poured onto a uniformly rotating liquid, which hardens during rotation. After curing, a convex original form is formed, which has a smooth surface of high purity formed on the separation of two liquids.

The method of electroforming (Strebkov & Tveryanovich, 2007) allows the manufacture of light metal concentrators of solar radiation with high accuracy and almost any size. In the manufacturing process, a conductive layer of silver is chemically deposited on a matrix that has the necessary configuration and high class of purity of the reflecting surface, on which a layer of metal (nickel, copper) is then electrochemically deposited, which has a given thickness. The stiffness frame is attached to the resulting copy, after which it is separated from the matrix.

The method of glass bending (Strebkov & Tveryanovich, 2007) consists in the deflection of sheet glass onto a metal matrix when heated to glass softening temperatures under the influence of a force of weight or vacuum. The matrix consists of a plate on which the rack tapes with rotary platforms

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