ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 6 | Issue: 11 |November 2020 || Journal DOI: 10.36713/epra2013 || SJIF Impact Factor: 7.032 ||ISI Value: 1.188

COOLING SYSTEMS FOR PHOTOELECTRIC MODULES

Nigmatov Ulugbek Zhurakuzievich
Senior Teacher of the Department
"Production of Building Materials,
Products and Structures" of the Fergana Polytechnic Institute,
Fergana,
The Republic of Uzbekistan.

ANNOTATION

In this paper, the structural elements of the cooling of hybrid solar collectors (HSC) are considered. A comparative analysis of the energy characteristics of domestic and foreign structures has been carried out in order to increase the efficiency of similar installations.

KEY WORDS: ***renewable energy sources, solar energy, photovoltaic module, hybrid solar collector, efficiency, design, cooling, energy characteristics.***

INTRODUCTION

At the present time, there is an increase in energy consumption, at the same time, there is an increase in electricity prices and a decrease in reserves of traditional resources. In this regard, developments in the field of renewable energy sources (RES) are becoming relevant. Solar energy is one of the most promising and actively developing types of renewable energy sources. In this regard, it is necessary to stimulate further growth in the consumption of such types of energy as solar, wind, biogas and hydropower. Traditional sources of energy do not always allow to provide electricity, heat, and water supply to the population living in remote and hard-to-reach areas, as well as seasonal workers and scientific expeditions. As the operating temperature rises, each type of solar panel behaves differently. So, for silicon cells, the nominal power drops with each degree of excess of the nominal temperature by 0.43-0.47%, cadmium telluride solar cells lose only 0.25%. To solve the problem of overheating of solar panels, for a number of years, work continues on the development and improvement of existing hybrid designs for air, water cooling, heat removal from panels, with forced cooling [1-3].

HSC research is based on the works of V.V. Kharchenko, V.I. Vissarionova, P.V. Tikhonova, B.A. Nikitina and others.

Foreign scientists: H. Sondag, D. de Vrieux, W. van Helden, R. van Solengen, A. Stenhofen, T. Chow, H. Wei and others.

Currently, researchers and scientists are considering technologies, materials, methods and solutions for the effective use of HSC. Hybrid photovoltaic thermal systems are considered in [4-6]. Hybrid photovoltaic thermal (HPVT) systems are very promising devices for collecting clean energy, which can be used both as a stand-alone system and in conjunction with other systems. This article shows the historical stages in the development and improvement of hybrid photovoltaic thermal HPVT systems to date. The results of the initial studies of HPVT systems, depending on the formulation of the research objectives, formed the main criteria for eliminating the shortcomings of the developments. The article discusses the main and improved varieties of solar collectors, working fluids, analysis methods for assessing performance, thermodynamic approaches, optimization of design parameters and mass flow rates, methods for increasing productivity and comparison of research results. In particular, various studies on optimizing the performance of the HPVT system in relation to the selected parameters were comprehensively considered, including various types of absorbers, cooling schemes, types of working fluids, design solutions of various sections of the system. HPVT collectors: For the first time, in the late 1970s, the features of flat HPVT collectors were outlined in the work of Russell and Kern. By using the calculation base of solar thermal collectors, a fundamental theoretical model of HPVT was derived. Then the well-known Hottel-Villier model was revised and applied by Florschutz for thermal

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 6 | Issue: 11 |November 2020 || Journal DOI: 10.36713/epra2013 || SJIF Impact Factor: 7.032 ||ISI Value: 1.188

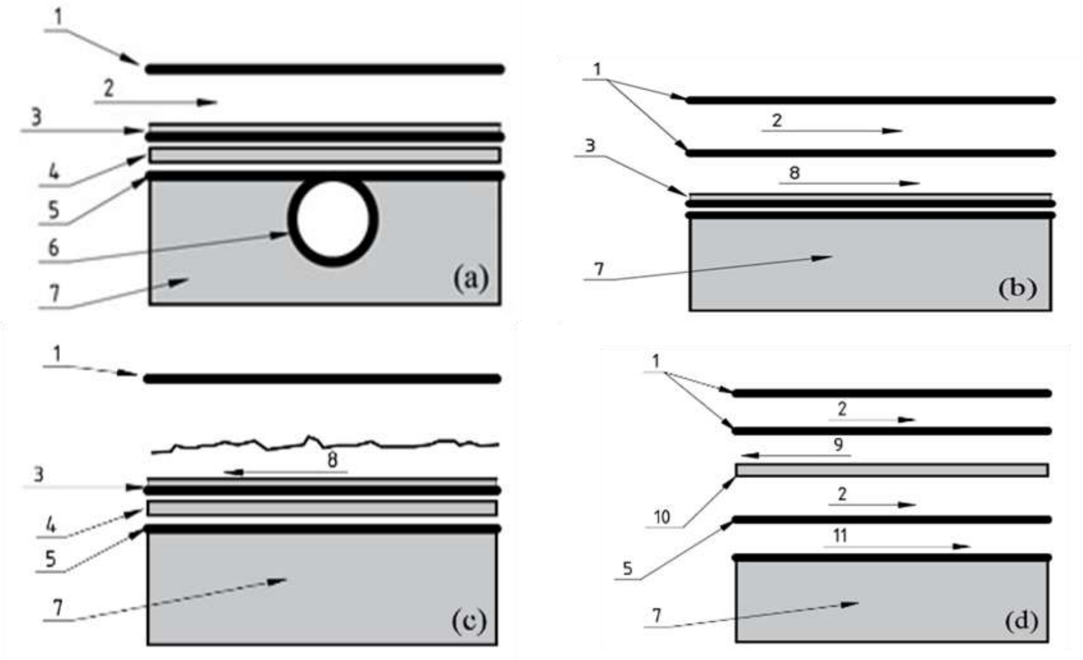
analysis of flat HPVT collectors. The new model assumes that the local electrical conversion efficiency is a linear function of the local temperature of the absorber.

The classification of flat HPVT collectors is carried out depending on the type of heat carrier, such as water, air, bifluid (water and air) and nanofluids. Sondtag studied the following types of HPVT collectors design: sheet-tube; channel; free flow; with a double absorber (fig. 1). The main structural element of the HPVT collector with a water coolant is shown in Fig. 1a, which consists of a conventional photovoltaic array embedded in a thermal collector module. It is noted that such designs have various disadvantages, for example, the scheme of a flat sheet-tube HPVT should be improved with a higher efficiency, and the heat exchange of the liquid in the channels of a flat HPVT of a collector should be carefully studied.

Moreover, it was shown that with a free flow of HPVT, the collector loses part of the accumulated heat due to evaporation. According to the research results, the best efficiency is achieved when using the circuit when the coolant channels are under a transparent photocell. It has been established that liquid HPVT collectors operate with a higher efficiency in comparison with an air coolant. Even if HPVT air collectors have lower costs, they are less preferable in the domestic environment. Flat HPVT collector units can be used as a stand-alone system or a system connected to the mains. Talavera showed that HPVT collectors connected to the main network are more profitable than stand-alone systems.

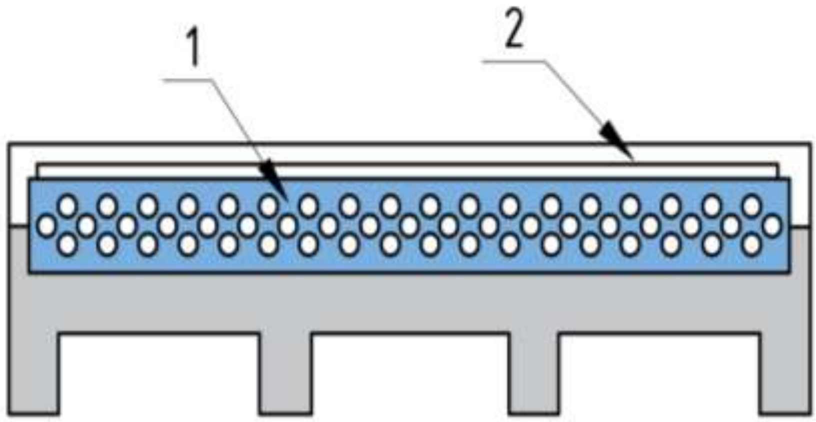
A comparative analysis was carried out to determine the capacity of the HPVT system of collectors and separately photovoltaic and thermal systems. Taking into account all the influencing factors, time-dependent mathematical models were built for the blocks of flat HPVT with the aim of using them in construction, and to demonstrate their superiority, the results were verified experimentally. The time-dependent mathematical model was found to successfully predict the performance of the three systems. The results confirm that HPVT collector systems perform best in urban environments. Even if a single thermal system has a competitive thermal efficiency, the HPVT collector system has the best performance due to the simultaneous generation of electricity. Accordingly, the change in daily solar radiation levels plays an important role in the overall efficiency of the system. Singh and his laboratory in 2016 developed a model of a two-channel semi-transparent hybrid photovoltaic thermal collector, in which the air flow passes simultaneously both on the front and back surfaces of the cells of the photovoltaic cells, i.e. through the upper and lower air channels. According to the results, the overall exergy efficiency and the overall thermal efficiency were 5.78% and 35.41%, respectively. Wats and Tiwari in 2012 evaluated the thermal and exegetical efficiency of a HPVT collector with crystalline silicon cells (CSi) for a 21 m3 room and concluded that only 33% of thermal energy is efficiently used. In 2015, Yazdanpanahi conducted an experiment on a plant consisting of a conventional HPVT collector. The test results are used to validate a one-dimensional stationary thermal model and a photovoltaic current model with four parameters. There is a slight error between the mathematical model and the experimental test results. In addition, they add the effects of several different exergy losses to equations by introducing additional parameters. In 2016, Khelifa experimentally and theoretically analyzed a sheet-tube HPVT collector, simulating the heat transfer mechanism at each node selected on different layers. Tiwari assessed the benefits of the potential use of the HPVT collector as a solar greenhouse dryer for the climatic conditions of India. The payback period for the drying system is estimated to range from 1.2 to 10 years in relation to the efficiency requirement. In 2014, as part of the development of the "Green House" concept implemented at the Technical University of Denmark, Kazanchi assessed the efficiency of using HPVT collectors in houses, the soil base of which is used as a heat sink.

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 6 | Issue: 11 |November 2020 || Journal DOI: 10.36713/epra2013 || SJIF Impact Factor: 7.032 ||ISI Value: 1.188



1– glazing; 2 - air, 3 - photovoltaic module; 4 - glue; 5 - absorber;
6 - water pipe; 7 - insulation; 8 - water; 9 - air-steam mixture;
10 - primary water channel; 11 - secondary water channel.
a) sheet-tube; b) channel; c) with free flow; d) with a double absorber.
Figure: 1. Longitudinal sections of various types of HPVT collectors.

The issue of optimized heat dissipation for thermo-photoelectric panels is considered in works [7]. Their work proposed an innovative hybrid solar panel that can be used as flooring or roofing. A special heat sink is used, which ensures the strength of the panel and increases the heat transfer efficiency in relation to the tube heat exchangers. The design of the heat sink used in the panel is optimized using a numerical model and algorithm. The article provides some examples of optimization, as well as the results of a study to determine the distribution of speed and temperature in the cross section of the heat sink. The presented hybrid panel allows up to 20% increase in electrical efficiency compared to a conventional photovoltaic panel. In addition, it can be used in any natural and climatic conditions, as the construction of the unit is waterproof.



1 - heat absorber; 2 - photovoltaic cells.
Figure: 2. Sections of a hybrid solar panel.

The proposed hybrid solar panel consists of a layer of highly efficient monocrystalline photovoltaic cells, which are placed on an aluminum absorber (Fig. 2). The cells of the photovoltaic cells are attached to each other and then mechanically connected to the heat sink using a special heat-conducting paste, which ensures a satisfactory thermal contact.

The absorber consists of an aluminum block with internal parallel channels, which are staggered (Fig. 2, 3). Inlet and outlet chambers are also created in the aluminum block. The water flow passes through the channels, absorbing the heat of the cells of the photocells.

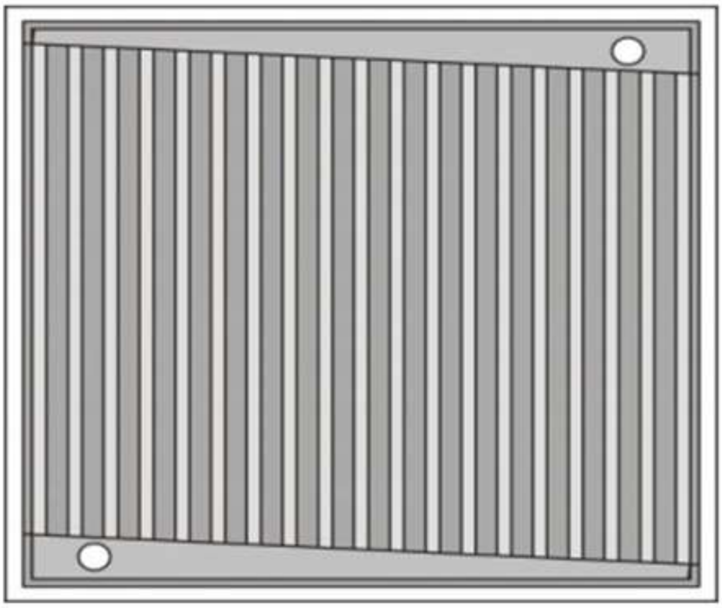


Figure: 3. Absorber sections.

The photovoltaic cells and the heat sink are bonded to the housing by cold curing epoxy resin. The upper coating of transparent resin allows the elements to be influenced by solar radiation, and the lower coating of the opaque resin prevents heat loss during radiation. Both resins provide good mechanical strength and thermal insulation for the entire hybrid panel. The absorber inlet and outlet are connected to connectors that provide a direct connection to the installation pipes.

Hydraulic and electrical connectors are integrated in the lower plastic housing. To study the characteristics of such a heat sink, a mathematical model was created that can reproduce the thermal and fluid dynamic changes caused by changes in the design and location of the channels.

The article by M. Abdelrahman et al. considers the issue of experimental research of various methods of cooling photovoltaic modules [8-9]. One of the most important problems in the use of photovoltaic systems is the low efficiency of energy conversion of photovoltaic cells, and, in addition, this efficiency decreases even more during the working period due to the increase in the temperature of the cells above the permissible limit.

To determine the efficiency of photovoltaic systems during operation, three cooling methods are used in experimental work: cooling with water under the film; direct contact cooling of the rear side of the photovoltaic system due to heat removal by water; a combination of the previous two methods. An infrared camera is used to obtain the temperature distribution on the surface of the module.

Experimental measurements for three cooling experiments show that the temperature of the cooled photovoltaic module is 16 °C lower for a module cooled with water under the film, by 18 °C for a module with direct contact cooling of the rear side of the photovoltaic system due to heat removal by water and by 25 °C for the module using the combined method, respectively, compared to the uncooled module. Lowering the surface temperature of the module results in higher output power and higher efficiency of the module. The results show that the daily power output of the cooled modules increased by up to 22%, 29.8% and 35%, respectively, compared to the non-cooled module.

Internal dimensions of the finned flat liquid heat sink (90 × 66 × 4 cm). It is made of 2 mm thick galvanized sheet metal and insulated with 25 mm glass wool, which is mounted on the rear side by a photovoltaic system to ensure direct contact between water and the rear surface of the module (Fig. 4, 5). The heat sink has ribs to increase the rate of heat transfer from the photovoltaic module to the moving fluid. A DC water pump connected to the battery (see Table 1) is used to pump water from the reservoir into the channels for the cooled module. Then the heated water flows back into the tank, and this cycle is periodically repeated.

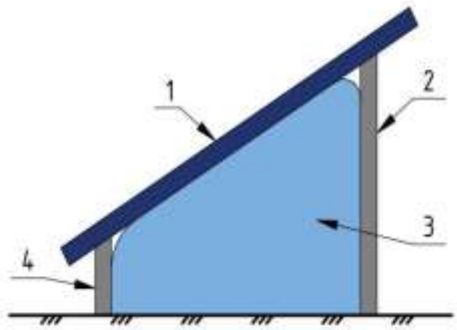
Table 1
Pump Specifications

Name	Characteristic/value
Power	4.3 W
Current and voltage	0.36 A and 12 V
Maximum flow rate	1.5 l/min

Also, in addition to the two previously considered methods, there is a third one, where simultaneous cooling of both the front and rear sides of the photovoltaic module is considered. The first pump is used to pump water through a perforated pipe installed on the top of the PV module in order to create a thin water film over the front of the module (Fig. 4), the second pump is used to recirculate water through a ribbed channel attached under the PV module (Fig. 5).

1 - perforated tube;
2 - microclimate; 3 - PVM; 4 - water film.

Figure: 4. Cooling of the PVM surface by creating a thin heat-removing film from water.

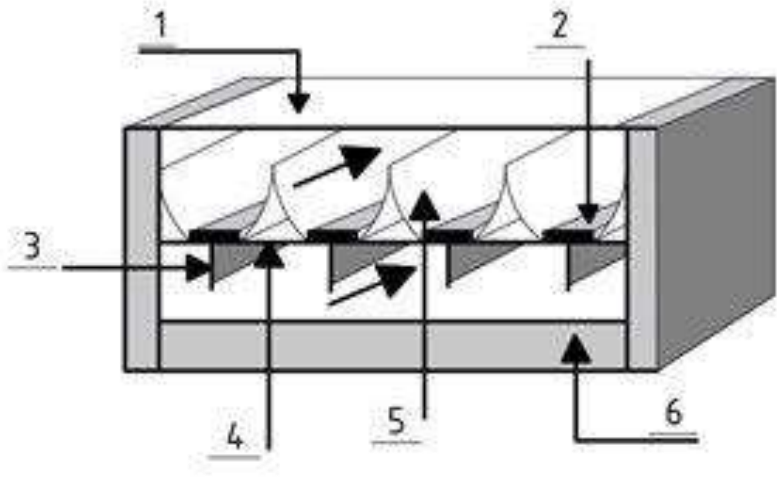


1 - PVM; 2, 4 - enclosing elements;
3 - flexible film; filled with water.

Figure: 5. Cooling of the rear side of the PVM by recirculating water through the ribbed channels.

In the article, B. Bhaskar et al. consider the issue of designing solar panel cooling systems in order to increase their electrical efficiency [10]. A photovoltaic solar cell generates electricity from solar radiation. The temperature of photovoltaic modules increases as they absorb solar radiation, resulting in reduced efficiency. This undesirable effect can be partially avoided by using a heat recovery unit with liquid circulation in a photovoltaic module. Such a block is called photovoltaic/thermal collector (PVTC).

Objective B. Bhaskar et al. Is to develop a solar battery cooling system to increase its electrical efficiency, as well as obtain thermal energy. A hybrid solar system is being studied, which simultaneously generates both electricity and thermal energy. This hybrid system consists of photovoltaic cells attached to the face of a T-shaped absorber. A simulation model of a single-pass finned solar collector was developed and performance curves were obtained. Performance analysis was performed using seven different gases to ensure maximum heat transfer with minimum mass flow and minimum number of fins. It was found that the most suitable gas is hydrogen. For hydrogen, the system requires a mass flow rate of 0.00275 kg / s, which is the lowest of all. The theoretical number of ribs required in this case is 3.46.



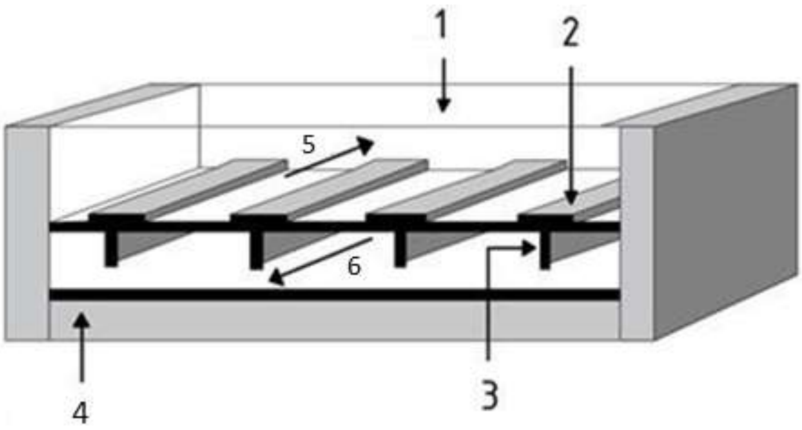
1 - glazing; 2 - solar battery; 3 - ribbing;
4 - absorber; 5 - parabolic concentrator; 6 - insulating material;

Figure: 6. Schematic model of a single-pass and two-pass solar collector.

A photovoltaic cell converts only a small part (less than about 20%) of the radiation into electrical energy.

Ibrahim Ali investigated a single pass solar air heater consisting of a photovoltaic cell with a parabolic collector and a finned heat sink as shown in Fig. 6. The experiments carried out have shown that the electric power of the collector increases with the radiation intensity.

Othman designed a two-pass, photovoltaic, thermal, solar air heater.



1 - glazing; 2 - solar battery; 3 - ribbing;
4 - insulating material; 5 - air inlet; 6 - air outlet.

Figure: 7. Ribbed, double-pass, photovoltaic, thermal, solar air heater.

In this system, the ribs are introduced into a second channel parallel to the length of the manifold, as shown in fig. 7. Ribs on the back of the photovoltaic panel increase heat transfer to the air and improve the efficiency of the system.

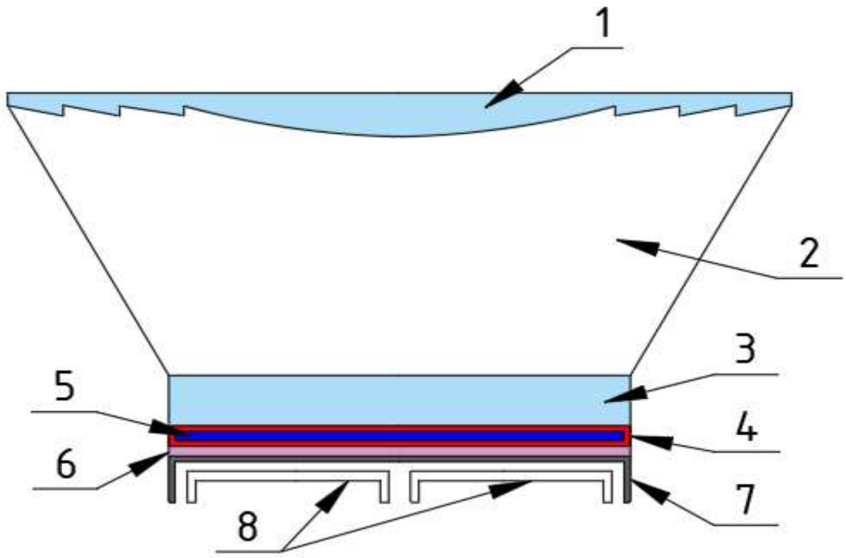
But the low thermal conductivity of the air leads to poor heat transfer between the panel and the air flow. Therefore, the efficiency of such a heater is low.

The article by Ali Radwan et al. Proposes an algorithm for controlling photovoltaic systems with concentrators based on the use of microchannel heat sinks with nanofluids [11]. The authors of the article proposed a new cooling method for a photovoltaic system with a concentrator, which uses a wide-channel heat sink with nanostructured fluids. The developed three-dimensional model of heat transfer of a nanofluid flow in a wide microchannel heat sink

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 6 | Issue: 11 |November 2020 || Journal DOI: 10.36713/epra2013 || SJIF Impact Factor: 7.032 ||ISI Value: 1.188

with a thermal model of a photovoltaic system with a concentrator. The model is verified using experimental and numerical data. The influence of the types of nanoparticles, volume fractions and the flow of the coolant in terms of the Reynolds number on the parameters of the solar battery is investigated. The results show that when using nanofluid (SiC), the chamber temperature is lower than when using nanofluid (Al_2O_3). An increase in the volume fraction of nanoparticles significantly reduces the temperature of the solar battery and increases their thermal and electrical efficiency. In addition, increasing the Reynolds number flow to a certain value significantly increases the electrical power. A further increase in the Reynolds number leads to a significant decrease in the power of the cells of the photocells. When using 4% nanofluid (SiC), the decrease in the maximum local temperature of the solar battery is in the range from 8 °C to 3 °C compared to water when the flux changes by Reynolds number from 12.5 to 250 and the solar energy concentration factor is 20 [12].

In the studies of the authors of the article, the characteristics of solar polycrystalline silicon under conditions of concentrated illumination equal to 20. Two different water-based nanofluids are used as coolants. Nanoparticles of aluminum oxide (Al_2O_3) and silicon carbide (SiC) with different volume fractions from 0 to 4%. It has been found that reducing the size of the nanoparticles improves the heat transfer characteristics. In addition, to achieve stability, a smaller nanoparticle size is required compared to a larger size. Thus, 20 nm nanoparticles are used in the simulation process. The selected nanoparticles are stable suspensions in water, since they have been comprehensively investigated in experimental works. Thus, these two nanofluids were chosen for modeling. The components of a photovoltaic system with a concentrator are shown in Fig. 8. In this system, a linear dual axis Fresnel lens is used to concentrate solar radiation on the target area of the solar cell.



1 - linear Fresnel lens; 2 - solar radiation falling at a right angle;
3 - glazing; 4 - photocell cell; 5 - silicon plate; 6 - calculated area; 7 - polyvinyl fluoride;
8 - inlet and outlet of nanofluid mixture.

Figure: 8. Schematic diagram of a photovoltaic system with a linear concentrator based on a solar Fresnel lens.

Commercially available polycrystalline solar cells consist of a 0.2 mm thick silicon layer coated with an antireflection layer. These two layers are embedded in a 0.5 mm transparent EVA liner above and below the silicon interlayer to anchor it and provide both electrical insulation and moisture resistance. In addition, polyvinyl fluoride is used, which is a photostable layer with a thickness of 0.3 mm. Finally, this design uses a more transparent 3mm thick tempered glass cover. A simple wide microchannel heat sink with a plan view of 127.2 mm by 127.2 mm is used as a heat sink. and a channel height of 100 μm. The flow of coolant in the middle of the solar cell comes in two directions. Aluminum is recommended as a heat sink material. A microchannel heat sink attaches to the back of the solar array to remove excess heat [13].

In the cell area, the size of the solar cell is 125 mm by 125 mm and the spacing between adjacent cells is 2.2 mm. Thus, the total size of the calculated area is 127.2 mm by 127.2 mm, including 1.1 mm EVA. To save computational time, especially in three-dimensional modeling of a two-phase flow, the effective area of the solar array is divided into two equal symmetrical regions with dimensions of 127.2 mm by 63.6 mm.

CONCLUSION

PVM cooling by means of water recirculation through finned channels has the following advantages over the above-considered analogs:

1. Possibility of simultaneous generation of electrical energy and heat treatment;
2. Using the energy of the base (soil) for cooling, based on the natural recirculation of water (heat agent), the rear part of the PVM;
3. Lack of additional energy costs to create the microclimate of the installation.

REFERENCES

1. *Radkevich M.V. Dostizheniya i perspektivy razvitiya ekologicheski chistoy energetiki v Uzbekistane // Universum: Tekhnicheskiye nauki: elektron. nauchn. zhurn. 2017. № 4(37). URL: http://7universum.com/ru/tech/archive/item/4665 (data obrashcheniya: 05.02.2020).*
2. *Zhurayeva Z.I. Obzornyy analiz osnovnykh vidov solnechnykh elementov i vyyavleniye putey povysheniya effektivnosti ikh raboty i primeneniya // Universum: Tekhnicheskiye nauki: elektron. nauchn. zhurn. 2018. № 10(55). URL: http://7universum.com/ru/tech/archive/item/6460 (data obrashcheniya: 05.02.2020).*
3. *Kuchkarov A. A., Muminov SH. A. U. Modelirovaniye i sozdaniye ploskogo frenelevskogo lineynogo zerkal'nogo solnechnogo kontsentratora //Universum: tekhnicheskiye nauki. – 2020. – №. 3-2 (72).*
4. *YU.D. Arbuzov, V.M. Yevdokimov. Osnovy fotoelektrichestva. M.: GNU VIESKH, 2007. p.292.*
5. *Erdem Cuce, Erman Kadir Oztekin, Pinar Mert Cuce. Hybrid Photovoltaic/Thermal (HPV/T) Systems: From Theory to Applications. Energy Research Journal. 2018, 9 (1). pp. 1-71.*
6. *V.P. Yefimov. Fotopreobrazovateli energii solnechnogo izlucheniya novogo pokoleniya. Fizicheskaya inzheneriya poverkhnosti. 2010. Vyp. 8. № 2. pp. 100-115;*
7. *Giampietro Fabbri, Matteo Greppi. An Optimized Heat Sink for ThermoPhotovoltaic Panels. Journal of Applied Research on Industrial Engineering. Vol. 5, No. 1 (2018). pp. 1-9*
8. *A.O. Miram. Tekhnicheskaya termodinamika. Teplomassoobmen. M.: ASV, 2011. – p. 352.*
9. *M. Abdelrahman, A. Eliwa, O.E. Abdellatif. Experimental Investigation of Different Cooling Methods for Photovoltaic Module. https://www.academia.edu*
10. *V.V Nashchekin. Tekhnicheskaya termodinamika i teploperedacha. ucheb. posobiye – 4-e izd., ster. – M.: Azbuk, 2008. – 469 p.*
11. *Bhaskar B. Gardas, M.V. Tendolkar. Design of Cooling System for Photovoltaic Panel for Increasing Its Electrical Efficiency. International Conference on Mechanical and Industrial Engineering. June 2012. pp. 144-149.*
12. *D.S. Strebkov, B.A. Nikitin, V.V. Kharchenko, V.A. Gusarov, P.V. Tikhonov. Vliyaniye temperatur v shirokom intervale znacheniy na parametry solnechnykh elementov. ELEKTRO. Elektrotekhnika, elektroenergetika, elektrotekhnicheskaya promyshlennost'. 2013. №4. pp. 46-48.*
13. *Ali Radwan, Mahmoud Ahmed. Thermal management of concentrator photovoltaic systems using microchannel heat sink with nanofluids. Solar Energy. 171 (2018). pp. 229-246.*