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AUTOMATED INSTALLATION FOR INCREASING THE EFFICIENCY OF FLAT SOLAR COLLECTORS WITH THE ORGANIZATION OF THERMAL INSULATION

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ABSTRACT:
This article presents the development of a new automated design to improve the efficiency of flat solar collectors (FSC) with the organization of thermal insulation on the absorber of thermal FSC at night. The technology of an automated design, a schematic diagram of the automatic functioning of the system and the results of experimental studies are presented.

Keywords: thermal flat solar collector, photovoltaic module, heat losses, receiver, relay, sensor, check valve.

INTRODUCTION:

After the global energy crisis in the 70s of the last century, the development of unconventional and renewable energy began. Currently, the total capacity of operating power plants based on renewable energy sources is about 600 GW, which is almost twice the capacity of all operating nuclear power plants in the world. [1].

On the territory of the Central Asian region, the priority areas of research in the field of solar energy are:

1. Improvement of solar power plants (SPP), allowing to generate electrical and thermal power on an energetically significant scale without negative impact on the ecological environment [2];
2. Experimental research and practical application of solar parabolic cylindrical power plants [3];
3. Developments for the widespread use of heat pipes as a heat sink for solar parabolic cylindrical installations [4];
4. Research to improve the efficiency of photoelectric conversion (solar flux, ambient temperature, wind speed, optimal system load matching) [5];
5. Development and improvement of existing hybrid structures for air, water cooling, heat removal from panels, with forced cooling [6].

In the automated systems for measuring the energy indicators of the above solar systems, certain structures and algorithms are formed, which consist of the following main parts:

– object of research - solar energy system;
– sensor;
– secondary, microprocessor device;
– actuating mechanism;
– experimental data logger.

The measuring system of experimental data consists of functionally combined measures, measuring instruments, measuring transducers, computers, other hardware and software modules installed to measure one or more energy quantities. The main task of measuring systems is to generate measuring information signals in a form most convenient for automatic processing and control, transmission and use in registration systems [7, 8].

According to the statements and recommendations of experts, in alternative energy, the traditional use of solar energy is carried out in three main areas:

– generation of electrical energy using solar cells, from commutated modules and batteries;
– thermal energy production using solar heating units;
– heat production by parabolic-cylindrical concentrating plants.

Solar energy is one of the most promising rapidly developing areas among renewable energy sources. It develops and is used in many countries of the world, and in a number of countries it is already capable of becoming a serious competitor to traditional energy [9]. In a world with the use of solar energy, it has a positive effect on climate change, the creation of new economic opportunities and the provision of energy when traditional energy sources are depleted.

Every year since 2000, the total installed capacity of all working solar panels in the world has been increasing. For example, in 2004, the total installed capacity of all working solar panels in the world was 2.6 GW, in 2019 - 635 GW, in 2020 - 760 GW. In 2019, all working solar panels on Earth produced 2.7% of the world's electricity [10, 11].

Our research is devoted to the development of modern thermal flat solar collectors (FSC) combined with a photovoltaic module (PVM).

A solar collector (SC) is a device that absorbs the sun's radiant energy and converts it into thermal energy from the environment (usually water or air) used for hot water supply or heating.

There are various types of SC, among which it should be noted:

– flat;
– vacuum;
– using hubs.

The principle of operation of such an SC is based on the property of glass to transmit short-wavelength sunlight and trap long-wavelength radiation of a heated surface (absorber) - a phenomenon called the "greenhouse effect". As a result of this selective transmission, solar radiation is absorbed by the absorber panel, which, when heated, begins to emit long-wave radiation. And, due to the ability of glass to trap long-wave radiation, there is a significant increase in temperature inside the space limited by the glass. The textured surface and the reduction in the composition of the iron material help to improve the transmission properties of glass, and additionally applied selective coatings help to trap long-wave radiation. The multi-layer translucent coating of the collector also allows to reduce heat losses.

Usually the absorber panel is made of a material with high thermal conductivity (copper, aluminum) and painted or coated with a black material that has a high solar energy absorption coefficient. The prospects and advantages of PVM and SC, as well as the search for ways to reduce the cost, led to the integration of photovoltaic converters into flat SC and the creation on their basis of a new type of installations, the so-called cogeneration photovoltaic thermal modules (PVTM) [12].

PVTM (Fig. 1), as a rule, consists of a photovoltaic battery (PVB), on the back side of which there is a plate of a tubular absorber – a device that absorbs and removes heat. An PVB with varying efficiency, depending on the type of photovoltaic converter used, converts solar radiation into electricity, the rest of the energy is potentially converted into heat. The absorber in this design has a double function. Firstly, it cools the PVB, removing excess energy that is not involved in the generation of electricity, and thereby increasing its efficiency, and secondly, it produces thermal energy.

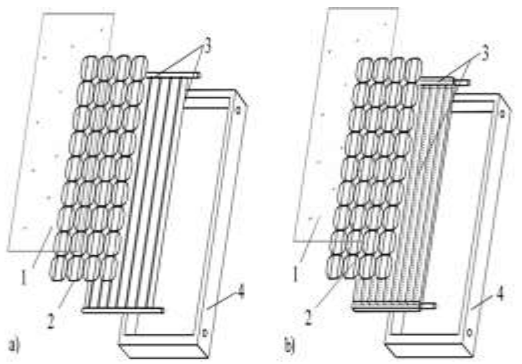

Fig. 1. The most common solar cogeneration module designs [12]: a) with a sheet-tube heat absorber; b) with a heat absorber made of vertical rectangular channels; 1 – transparent insulation (glazing); 2 – PVB; 3 – heat absorbing element (absorber); 4 – heat-insulating body.

Thus, hybrid PVTM are devices that simultaneously convert solar energy into electricity and heat [12].

To improve the efficiency of combined thermal FSC, specialists have carried out a number of studies to reduce the heat losses of the combined installation through the use of various design solutions and modern heat-insulating materials. For example, a heat-insulating paint based on "Izofull" aluminoborosilicate microspheres, which is used to cover the surface of the back side of thermal FSC. The results of theoretical and experimental studies on the problems of daily heat losses in FSC absorbers are described in the works of a number of researchers [13].

An empirical equation for calculating the coefficient of heat loss through the front surface of the FSC panel to the environment U_t, which is approximated by the dependencies U_t at average panel temperatures ranging from ambient temperature to 200 °C, with an error of W/(m^2 ·°C) has the following form:

$$U = \left(\frac{N}{\frac{C}{T_{pm}}\left[\frac{T_{pm}-T_a}{N+f}\right]^{e}} + \frac{1}{h_w} \right)^{-1} + \frac{\sigma(T_{pm}+T_a)(T_{pm}^2+T_a^2)}{\frac{1}{\varepsilon_p+0,00591Nh_w}+\frac{2N+f-0,133\varepsilon_p}{\varepsilon_g}-N}, \quad (1)$$

where,

N – number of glass coatings;

$f = (1+0,089h_w - 0,11h_w\varepsilon_p)(1+0,07866N)$;

$C = 520(1-0,000051\beta^2)$ при $0^\circ < \beta < 70^\circ$, at $0^\circ < \beta < 90^\circ$ used $0^\circ = 70^\circ$;

$e = 0,43(1-100/T_{pm})$;

β – collector tilt angle to the horizon (deg.);

ε_g – glass blackness (88);

ε_p – blackness of glass absorbing panel;

T_a – ambient temperature (K);

T_{pm} – average temperature of the absorbing panel (K);

h_w – heat transfer coefficient due to wind [W/(m^2·°C)];

The coefficient of heat loss through the rear surface of the FSC is approximately equal to:

$$U_b = \frac{1}{R_4} = \frac{k}{L}, \quad (2)$$

where,

k – coefficient of thermal conductivity;

L – insulation thickness;

R_4 – thermal insulation resistance;

The heat loss coefficient through the side surface of the FSC is approximately equal to:

$$U_e = \frac{(UA)_{edge}}{A_c}, \quad (3)$$

where,

$(UA)_{edge}$ – product of the lateral loss factor by its area;

A_c – unit of area FSC;

FSC total loss factor U_L equal to the sum of the loss coefficients through the front, back and side surfaces [14, 15, 16, 17]:

$U_L = U_t + U_b + U_t$, (4)

RELEVANCE:

Until now, the heat losses of the FSC at night in a dry and hot climate have not been experimentally investigated. Research and development of a design to reduce heat losses from the surface of the FSC absorber at night is relevant, since in this period of time, heat losses amount to 30% of the daily accumulated energy.

DEVELOPMENT:

A special automated design has been developed that does not require an external source of electrical energy, since it functions in an autonomous mode. The main purpose of the development is aimed at automatic closing of the FSC absorber at night and opening in the daytime to reduce the daily heat losses of the system (Fig. 2).

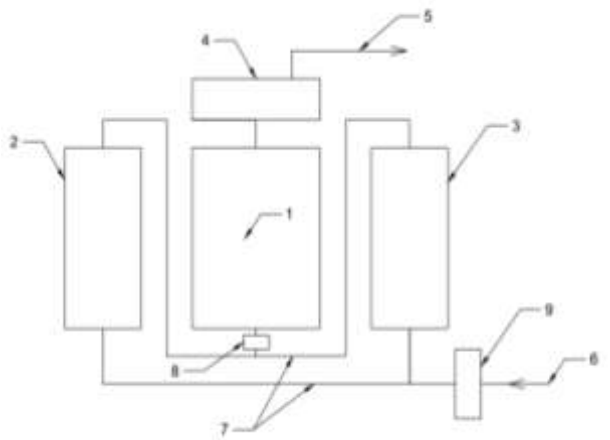

Fig. 2. Block diagram of the system: 1 – flat solar collector (FSC); 2, 3 – left and right photovoltaic modules with heat-removing absorbers; 4 – FSC accumulator tank; 5 – hot water outlet pipe; 6 – water supply to the system; 7 – flexible heat-insulating connecting hoses; 8 – 12 V solenoid valve; 9 – mechanical check valve.

The design consists of several blocks. The FSC unit has a standard design, which consists of a converter of the sun's radiant energy into thermal energy and a storage tank. Block of left and right photovoltaic modules with heat-removing absorbers that convert the sun's radiant energy into electrical and thermal energy, with calculated dimensions that cover the FSC absorber. Block providing a flow of a heat carrier liquid (water) with check and start valves.

The mechanical movements in the combined installation are based on special technologies on cables that provide closing and opening by scrolling forward and backward. Scrolling the cable forward and backward is carried out by a low-power single-phase electric motor with direct current due to the organization of the receiver (Fig. 3).

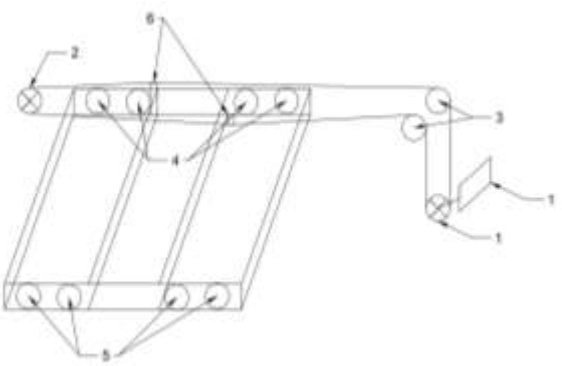

Fig. 3. Mechanical block diagram of the system: 1 – the driving roller of the receiver and the electric motor; 2 – driven pulley roller; 3 – support rollers of a brace; 4 – upper rollers of the structure; 5 – lower rollers of the structure; 6 – fastening elements of the structure.

The process in the system is carried out by a photosensor (PhS) with detection in the daytime and at night. A special control circuit automatically performs the opening and closing processes. The control system contains end motion sensors and an electric drive receiver circuit (Fig. 4).

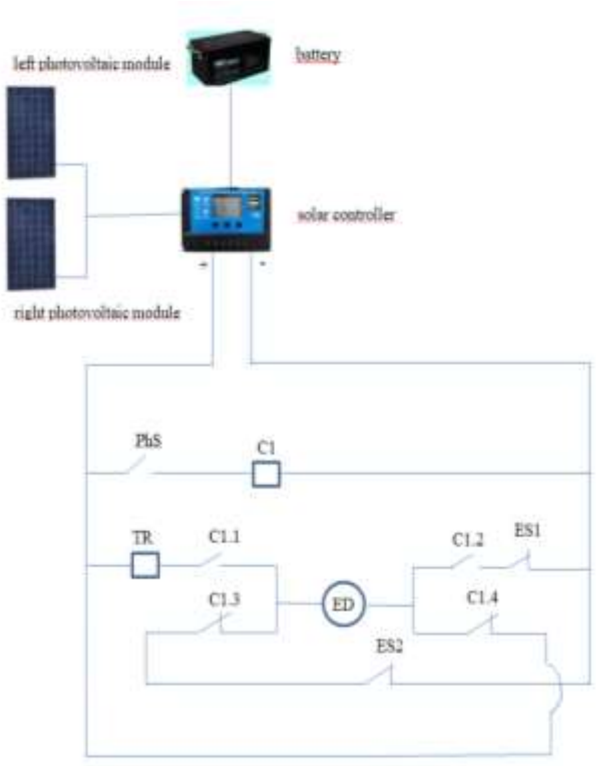

Fig. 4. Schematic diagram of the system control: C1 – multi-contact intermediate relay 12 V; PhS – photosensor with discrete output; TR – time relay; C1.1, C1.2 – normally open contacts C1; C1.3, C1.4 – normally closed contacts C1; ED – electric drive; ES1, ES2 – end sensors**.**

The diagram does not indicate the consumers of the generated electrical energy. In our case, a PV module with heat-dissipating absorbers, on average, produces an average of 100 W of electrical energy, the system consumption on average is only 30 W. Therefore, 70 % of the generated energy can be transferred to an external consumer. In the process of testing this design, the following experimental results were obtained (Tab.1.):

Table 1. Experimental test results

Number of the experiment	Experimental conditions	Time – 20^{00} t, in degrees		Time – 8^{00} t, in degrees	
		t in the FSC accumulator tank	t environment	t in the FSC accumulator tank	t environment
1	System not started	60	35	42	23
2	System not started	65	37	45	25
3	System started	57	30	48	22
4	System started	67	38	56	24
5	System started	58	28	49	20
6	System started	64	36	54	24

The mathematical processing of the results by graphical methods showed the following (Fig. 5):

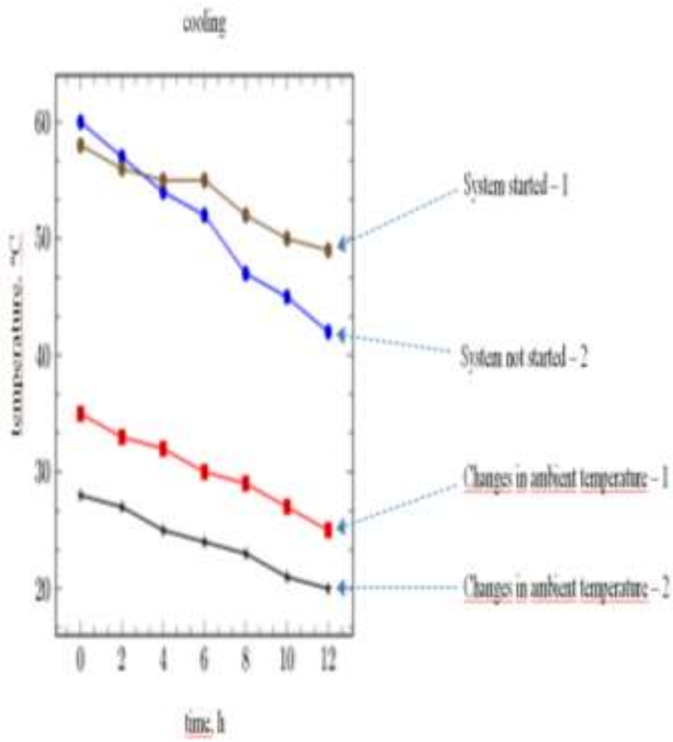

Fig. 5. Graphs based on the results of the measurements.

As the results of the experiment show, when the developed design was not started, heat losses averaged 30 %. In the running mode, heat losses are on average 15 %.

CONCLUSION:

The use of a new design of FSC absorber thermal insulation at night leads to a decrease in accumulated thermal energy losses by an average of 15 %, and increases the FSC efficiency up to 5 %, which is very important in relation to the issue of energy saving of low-potential heat and power systems.

REFRENCES:

1. Нигматов, У. Ж., & Наимов, Ш. Б. (2020). Анализ потенциала использования энергии солнечного излучения на территории республики таджикистан. In International scientific review of the technical sciences, mathematics and computer science (pp. 59-71).
2. Эргашев, С. Ф., Нигматов, У. Ж., Абдуганиев, Н. Н., & Юнусов, Б. С. А. (2018). Солнечные параболоцилиндрические электростанции-современное состояние работ и перспективы использования их в народном хозяйстве Узбекистана. Достижения науки и образования, (5 (27)).
3. Эргашев, С. Ф., & Нигматов, У. Ж. (2020). Солнечные параболоцилиндрические установки, конструктивные особенности и расчёт отдельных параметров. Universum: технические науки, (11-5 (80)).
4. Эргашев, С. Ф., Нигматов, У. Ж., & Пулатов, Э. У. У. (2018). Анализ перепадов температур, возникающих в тепловых трубах солнечных параболоцилиндрических установок. Проблемы науки, (5 (29)).
5. Эргашев, С. Ф., Нигматов, У. Ж., Орипов, А., & Ощепкова, Э. А. (2019). Энергоэффективный трекер без использования светозависимых датчиков (фоторезисторов, фотодиодов и тд). Известия Ошского технологического университета, (3), 234-236.
6. Нигматов, У. Ж. (2020). Анализ конструктивных элементов охлаждения гибридных солнечных коллекторов. Вестник науки и образования, (2-3 (80)).
7. Рахимов, Р. Х., Эргашев, С. Ф., Абдурахмонов, С. М., & Нигматов, У. Ж. (2017). Автоматизированная компьютерная система измерения производительности солнечных водонагревателей с порционной подготовкой горячей воды. Computational nanotechnology, (1).
8. Rakhimov, R. K., Irgashev, S. F., Abdurakhmanov, S. M., & Nigmatov, U. J. (2017). The automated computer system of

measurement of productivity of solar water heaters from portion preparation of hot water. Computational nanotechnology, (1), 23-26.
9. Р.Р. Авезов Альтернативная энергетика: достижения и перспективы. http://uza.uz/posts/131701
10. Solar photovoltaics (PV). (2021). Renewables 2021 global status report. P. 22.
11. Photovoltaics Report. (2021). Fraunhofer Institute for Solar Energy Systems, ISE with support of PSE Projects GmbH. P. 4.
12. Харченко, В. В., Никитин, Б. А., Тихонов, П. В., & Макаров, А. Э. (2013). Теплоснабжение с использованием фотоэлектрических модулей. Техника в сельском хозяйстве, (5), 11-12.
13. Рахимов, Р. Х., Эргашев, С. Ф., Абдурахмонов, С. М., & Нигматов, У. Ж. (2017). Автоматизированная компьютерная система измерения производительности солнечных водонагревателей с порционной подготовкой горячей воды. Computational nanotechnology, (1).
14. Pandya, R. (1995). Emerging mobile and personal communication systems. IEEE Communications Magazine, 33(6), 44-52.
15. Hottel, H. C., & Woertz, B. B. (2018). The performance of flat-plate solar heat collectors (pp. 324-355). Routledge.
16. Klein, S. A. (2018). Calculation of Flat-Plate Collector Loss Coefficients. In Renewable Energy (pp. 387-391). Routledge.
17. Tabor, H. (1958). Radiation, convection and conduction coefficients in solar collectors. Bull. Res. Counc. Isr., Sect. C;(Israel), 6.