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Study of the Parameters of a Photo of a Thermal Battery with a cell Polycarbonate Collector

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ABSTRACT: The paper discusses the experimental results on the development of a photo thermal battery of a new design of increased efficiency with a new heat collector based on cellular polycarbonate, which leads to complete uniform thermal contact with the back surface of the photovoltaic battery (PhVB). It is shown that the use of materials with a high reflection coefficient of photovoltaic modules based on silicon phase transitions in the lateral reflection plane, increasing the accuracy of the operational guidance unit on the Sun, the ability to control the capacity of the thermal collector, ensures the reliability of the parameters, increases the power, and ensures the uniformity of the temperature of the back surface of the PhVB, which improves the efficiency of the photovoltaic installation.

KEYWORDS: Solar energy, photovoltaic, photo thermal, collector, polycarbonate, power, temperature, reflective, circuit current, crystal lattice.

I. INTRODUCTION

When using photovoltaic installations (PhVI) in countries with a hot climate (in particular in Uzbekistan), there are specific factors that differ from the conditions of use of other countries. Such factors are extreme temperature conditions, leading to a decrease in the conversion efficiency of photovoltaic stations (PhVS) and a relatively high dust content of atmospheric air. Both factors simultaneously act especially in the summer, from April to October. High dustiness of the air is practically valid all year round. Due to the fact that rural regions are the main consumer of electricity generated by PhVS in Uzbekistan, the influence of these factors on the performance of PhVS and energy use in rural areas is more pronounced. When using PhVS in rural areas, the presence of water (tap or artesian) should be taken into account. In the presence of water, it becomes possible to increase the efficiency of photovoltaic systems by creating combined photovoltaic batteries (PhVB) with heat collectors, and photos of thermal batteries (PhTB). In the case of isolated rural areas remote from centralized energy sources (from district centers), autonomous photovoltaic stations with a reliable power supply system should be created. PhVS needs to be equipped with PhTB batteries, which provides both electric energy and warm water to create comfort for various purposes.

II. RELATED WORKS

We have developed different options for thermal collectors of photo thermal batteries (PhTB) [1-6]. It has been established that the efficiency of the collector part of the PhTB is determined by the efficiency of heat transfer between the back surface of the PhVS and the material of the thermal collector in contact with it. The main reason for the low efficiency of the collector part is the small area of contact with the back surface of the PhVS. Along with this, the heavy weight, the cost of the material, the complex manufacturing technology of the collector part of the PhTB using metal structures makes it uncompetitive with the PhVB traditional design.

In this paper, we study the parameters of PhTB with a heat collector made of polymer cellular polycarbonate. Cellular polycarbonate has a unique set of properties; increased heat resistance, transparency, lightness, strength, flexibility, durability and is used as structural materials in various industries. The use of cellular polycarbonate as the

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main unit of the heat collector - heat sink (absorber), greatly simplifies the design and technology of its manufacture, in comparison with the use of polymer tubes [7-10]. The manufacturing technology of the thermal collector developed in this work provides the use of widely available tools and methods in the manufacture of the thermal collector.

To reduce heat loss around the perimeter, the collector is covered with a heat-insulating layer and reflective aluminum foil over the entire surface of the back side. A thick layer of heat-insulating coating on the back of the PhTB is fixed with a sheet of polymer material 2 mm thick. [11]. In such a system, heat transfer from the back surface of the PhVB to water increases significantly. Therefore, the recovery time of the open circuit voltage is reduced. Cold water is supplied to the collector part of the PhTB from the water supply using a rubber hose or, in its absence, from a thermally insulated pressure tank, which is located 1-1,5 m above the PhTB battery. The flow of water is regulated by metal taps.

III. METHODS

Another difference of this PhTB design is the presence of upgraded two lateral planes for the reflection of solar radiation along the length of the photoelectric part of the battery. The total area of the lateral reflection planes of solar radiation is equal to the area of the photovoltaic part of the battery. As reflecting solar radiation surfaces used are films glued to the surface of the lateral planes with an aluminum coating. In contrast to the previous versions, in the lateral planes the whole reflective films were used, covering the surface of each of the lateral planes in length and width. The reflection coefficient of the films is ~ 0,5. The angle of inclination to the solar radiation of the reflecting planes is changed and regulated. The optimal angle of inclination of the side reflective surfaces to the Sun is determined by the maximum value of the short circuit current of the photovoltaic battery. Reflective planes, not working hours, are used as a cover (protection) to prevent surface contamination of the photovoltaic battery. The design of the support device relative to the modernized installation with a heat collector based on polymer tubes in part of the operational guidance mechanism on the Sun was changed (Fig. 1). Significantly improved the accuracy of guidance using the mechanism with the possibility of continuous smooth change of the angle of guidance on the Sun. Figure 2 shows the PhTB with a lateral reflection plane in the process of measuring parameters and testing under the conditions of the Physics and Technology Institute of the SPA Physics-Sun in Tashkent.

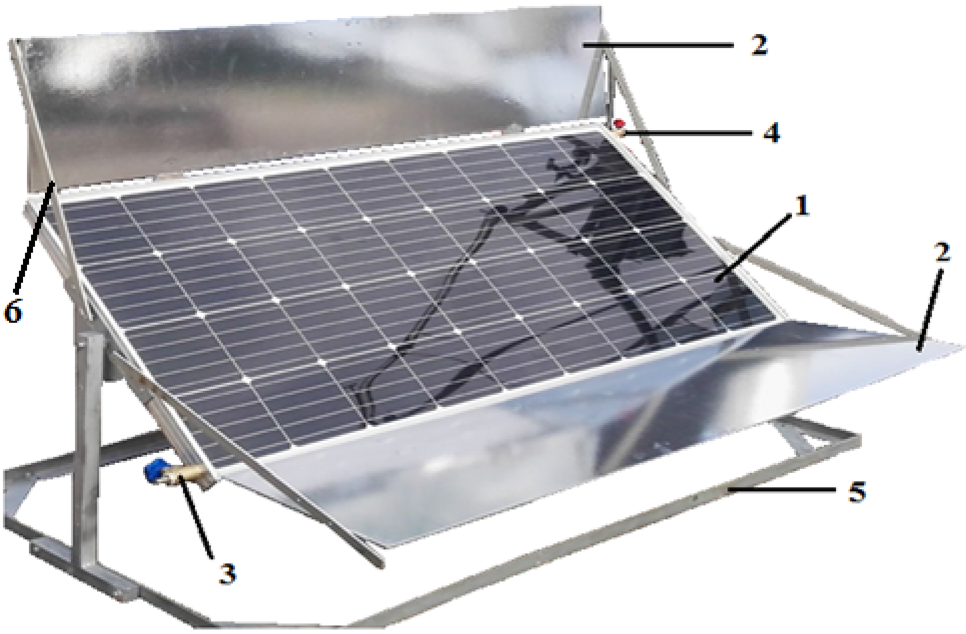

Fig. 1. Photo thermal battery preparation for measuring parameters in the field.
1- **photovoltaic battery of single-crystal solar cells with an efficiency of ~ 19,9%, power 175 W in conditions of AM 1,5. *2-* lateral reflective planes based on an aluminum film ("TIE BAO"), *3-* tap for cold water, 4-tap for warm water, 5-support structure, 6- precise orientation planes of the lateral reflective plane.**

The solar cell of «Oftob-Nur» company of Tashkent city with a single-crystal silicon SC with an efficiency of 19,9% and a total power of 175 W was used at the installation under development. The number of solar cells in the PhVB is 36 pcs. PhTB parameters were measured according to a previously developed technique [11]. In turn,

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measurements were made of the parameters of the PhVB with the heat collector turned off and without the use of a lateral reflecting plane (Fig. 1). Then, a heat collector with a cold water connection was used. At the end of the measurement, the lateral reflecting plane was pointed at the photovoltaic battery.

Fig. 2. Photo thermal installation after measuring the parameters in natural conditions.

IV. ALGORTHMS USED

The parameters of the installation were measured on July 24, 2019. Air temperature 37-38° C, humidity 26%, wind speed 3-5 m / s in clear weather, the measurement time is 11 hours 40 minutes to 13 hours 05 minutes. The density of solar radiation incident on the surface of the PhTB was measured by a reference silicon solar cell and was ~ 850-860 W / m^2 during the experiment. After measuring the parameters in full-scale conditions of solar radiation of the PhTB, the battery is covered with lateral planes ("cover") to prevent surface contamination (see Fig. 2).

Figure 3 shows the dependence of the open circuit voltage on time for the three modes in the case of using only the PhVB, using the PhTB and all three parts together with side reflective planes.

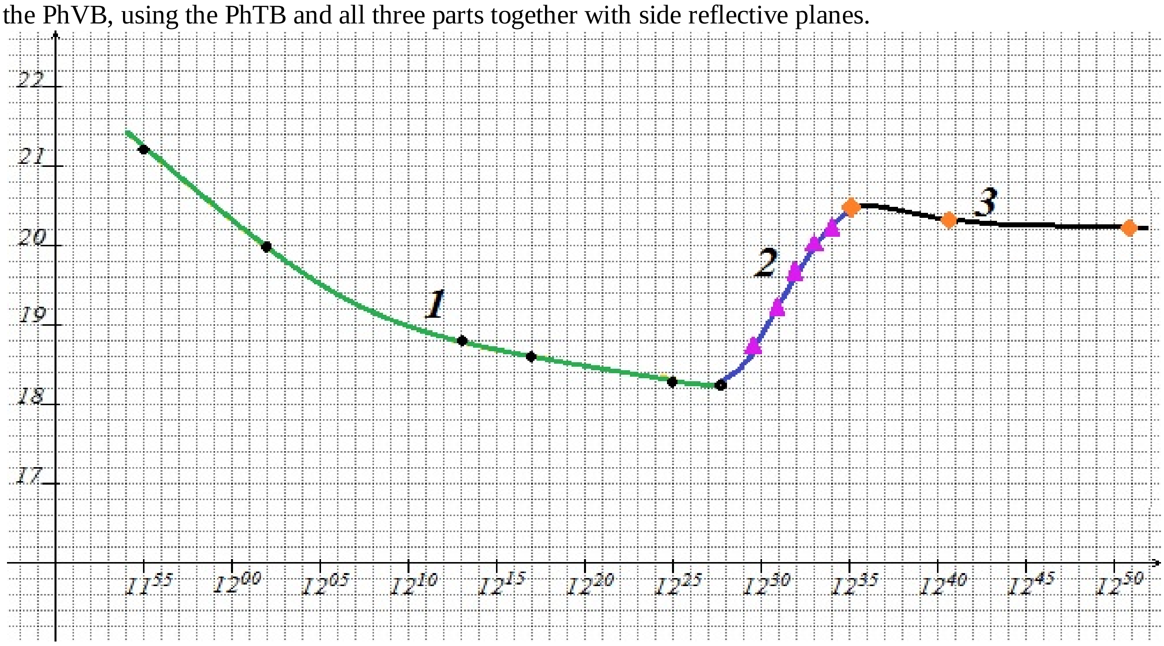

Fig. 3. The dependence of the open circuit voltage on time with three modes of use of the installation. *1* - use only a photovoltaic battery, *2* - use when photo thermal mode (PhVB + thermal collector), *3* - use all three blocks (PhVB + thermal collector + side reflective plane).

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The dependence of the open circuit voltage on the time of day for all three cases of parameter measurement repeats the dependence for the previous installation [11]. 1-section of the stroke of the dependence of the open-circuit voltage of the PhVB on time, a decrease in voltage by 3 V (from 21,1 to 18,1) due to heating in the absence of water cooling of the solar cells of the photovoltaic battery, which is ~ 14,3%. This decrease is ~ 1,4 times less than for previous designs of a heat collector with a soft design based on polymer tubes with "hydroprotection" [11-12] with an equal exposure time to solar radiation. With this rigid construction of a heat collector based on cellular polycarbonate, air remains in parallel channels (in acres) with dimensions of 8x10x1080 mm. Air heating occurs slowly, with the fall of solar radiation, on the multilayer structure of the photomultiplier, which is in contact with the thermal collector. This is due to the complex heat transfer process and the low value of thermal conductivity of the air. For example, when exposing the PhVB for about 60 minutes, the idle voltage drop is almost more than 3,6 V. *2*-section (Fig. 3) when water is passed through the heat collector, the idle voltage is quickly restored, with a recovery time of ~ two times less than when using a “soft” thermal collector. When testing separately a heat collector made of cellular polycarbonate, the process of lifting water through channels with parallel jets of equal cross section is visually observed. This leads to a stationary mode for water productivity. The *3*-section connection of the lateral reflective planes initially leads to a slight increase in the open circuit voltage due to an increase in the incident radiation density of ~ 1,3 times (850 W / m^2 to 1120 W / m^2). Then, due to the heating of the water, the work (curve 2) of the heat collector decreases to the mode value.

In general, the course of the open circuit voltage versus the time of day, in comparison with the heat collectors based on polymer tubes [11–12], for mode 1, the voltage decrease time increases. For mode 2 and 3, the idle voltage recovery time is reduced. The reliability of this design of the heat collector for hot climates and productivity in warm water is ~ 2 times more.

Fig. 4. The dependence of the short circuit current on the time of day is given. Three sections are distinguished, *1* — the dependence path for the PhVB, *2* — for the PhTB, and *3* — for the entire installation with the lateral reflection plane turned on.

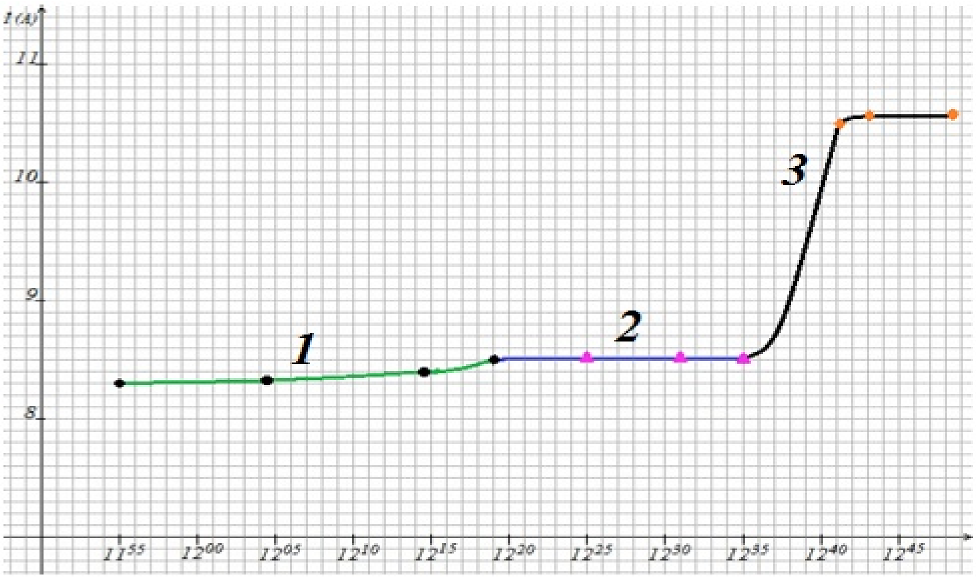

Fig. 4 The dependence of the short circuit current on the time of day. *1* - in the photoelectric battery mode, *2* - in the photo mode of the thermal battery, *3* - when turning on the side reflective planes.

The value of the short circuit current according to fig. 4 is: *1* - for the PhVB – 8,3 A, *2* - for the PhTB – 8,4 A (an increase in current by 0,1 A is associated with a change in the power of solar radiation from 850 W / m^2 to 860 W / m^2 during the measurement time), for a *3*-installation with a lateral reflecting plane, in this case it is 27.4% (increase in current from 8,3 A to 10,6 A) more than for the case of a photovoltaic battery (curve 3). This is explained by an increase in the density of the flux of solar radiation incident on the surface of the photovoltaic battery by ~ 26% when a side reflective plane is connected. Further, the value of the short circuit current depends on the density of the change in the density of the flux of solar radiation. Further research shows that the short-circuit current remains unchanged up to 15-16 hours.

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V. RESULTS

Figure 5 shows the dependence of electric power on the time of day for three modes of using a photo of a thermal battery. In the photoelectric battery mode (1-curve), the power of the PhVB decreases: almost complete absorption of solar radiation occurs, with the exception of the reflected part, by protective glass. The limited conversion efficiency of solar cells (at ~ 20%) leads to the fact that the remaining part of the absorbed energy in the volume of the crystal lattice increases the temperature of the crystal lattice and the low thermal conductivity of the rear part of the PVB structure and high air temperature (~ 37-380° C) do not allow scattering heat. The density of solar radiation incident on the surface was 850–860 W / m^2. The decrease in the electric power of the PhVB was 23 W (from 134 W to 117 W) or 12,7%. In the photo mode of the heat battery (2-curve), when cold water with a temperature of ~ 190 ° C is passed through the heat collector, electric power is restored to 130 W or an increase of 10,0%. The temperature of warm water at the outlet of the collector was 39° C. with the inclusion of a lateral reflective plane, the electric power increases to 158 W, with a simultaneous increase in the temperature of warm water at the outlet up to 44° C. In the future, the power of the PhTB installation up to 13 hours remains at the level of 158 W, which is associated with the large capacity of the thermal collector of 24 liters and a weak change in solar radiation. To reduce the temperature of the water from the installation to 39° C, it is necessary to increase the flow of water entering the heat collector, which will lead to an increase in electric power up to 163 W.

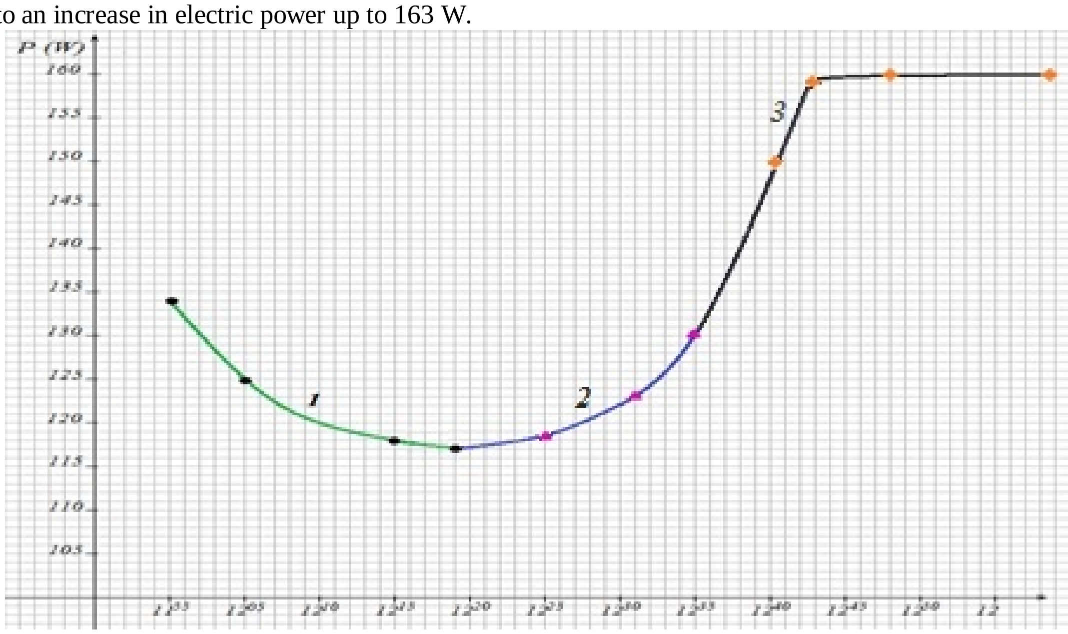

Fig. 5. Dependence of electric power on time for three modes of using a photo of a thermal installation. *1* - photoelectric battery mode, *2* - for a photo of the thermal regime, *3* - PhTB mode with side reflective planes.

VI. CONCLUSION

The mode of use of the PhTB installation with the lateral reflective plane turned on may be different. To quickly fill the shortage of electric energy, passing a large stream of cold water through the collector, you can get the necessary electric power, up to 1,5-1,6 times the energy of the photovoltaic part of the battery. If you need to reserve a large amount of hot water with a temperature of up to 50° C or more, you should reduce the flow of water passing through the heat collector.

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