HYBRID C-PVT INSTALLATION

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ABSTRACT. Today the cost of commercially produced silicon photocells dropped below one dollar, and conversion efficiency of solar energy into electricity reached 19%, but at the cost of billions of dollars of costs. Each following percent of its increase is accompanied by a sharp complication of production technology and increase in the cost hundreds of times. For example, an increase of output of electric current is carried out through the absorption of light of different wavelengths by several multi-layers of photocell, which differ in composition of chemical elements. Therefore, new developments due to their high cost are not enough future-oriented for wide use. Here we have a task to improve the efficiency of using traditional cheap photocells. We offer a fundamentally new solution, which is based on a more complete use of thermal properties of photocells.

Keywords: concentrators, hybrid, thermophotovoltaics, energy perfomance.

The purpose of research is to obtain the maximum output of electricity and heat by photocells using concentrated solar radiation in a new design of hybrid solar installations. This work presents results of studies of one of them with single-coordinate monitoring of sun by the concentrator, comprising two photo modules with channels for heat carriers and one collector. The figure 1 shows the concentrators of solar radiation installation and monitoring equipment for its operating elements [1,2].

Figure 1. Concentrators with PV modules and the collector (top), measuring stand (bottom)

There are used photocells of different manufacturers, capable of operating at 10 times the concentration of the sun. For their cooling there is used a heat transfer fluid that intensively removes no less than 75% of heat generated by them and transports it to the consumer with minimal losses. As a result, the output of effective electricity and heat is summed up (18 67) %, which can be considered as efficiency upgrading of photocells.

With rising temperature of photocells, the output of electric current is decreased, so the temperature is controlled at the level of 50 ^{0}C by change in coolant rate by means of circulation pumps. Coolant temperature rises during the second stage of heating - in the collector channel. The latter, in this case is a consumer of heat energy of photocells simultaneously converter of solar energy into heat energy of the coolant. To improve the efficiency of the collector there is used 5-fold concentration of solar radiation on its walls with selective coating. Coolant with temperature above 60 ^{0}C at the output of the collector is sent to boiler, where through the walls of coil it resets the accumulated heat to industrial water.

Fundamentally new in the process of converting solar energy and design of installation is the use of large-area silicon photocells as heat generators for creating thermal protection along the walls of collector in order to reduce heat loss by convection. Such use of photocells also increases their effectiveness as except for electricity at the point of their location, heat energy generated by them is used. Experiments with thorough measurement of output characteristics showed that the introduction of thermal barrier on the way of convective heat losses transfers collector with a concentration of sun into the category of vacuum manifolds. Thus, the cost of collector is much lower than the vacuum collector's cost. Now there are no test methods for these collectors. In our research, we settle down a new approach to the determination of efficiency coefficient of collectors operating with concentration of solar radiation.

Presented the results of theoretical calculations and experiments on integral output parameters of hybrid solar installation with an aperture area of 11.7 m^2. Its peak electric power ≈ 1,6 kW and heat ≈ 7,1 kW. As the coolant there is used industrial water in summer and cooling fluid in winter.

In the developed hybrid installation explores the formation of a protective thermal layer on the walls of the collectors due to the generation of heat by photocell plates placed below [3]. Heat emission from photocell plates creates vertical natural convection, which flows to collector walls located above.

Theoretically describe the motion generated by flows in a continuous two-dimensional environment on the surface of the collector is difficult, so we used the technique of experimental study of heat transfer processes on the laboratory stand. As for collectors, solar rays fall through the glass and a layer of air on the selective film, where they are converted to heat which are transferred through the channel walls to the heat transfer fluid. It is important to respect the equality of emissivity selective film and heated by the current thin film of nichrome.

In this case, the coolant does not distinguish the heat source - the sun or electric current transfers heat to the wall.

Figure 2 (top) shows developed experimental stand - collector of stainless steel, and below it, nichrome plates and temperature sensors and a flow rate of the convection air, along the walls of the collector. Figure 2 (bottom) the use of a compact mobile stand for testing collectors and PV modules in winter conditions and a method for measuring the wall temperature by pyrometer.

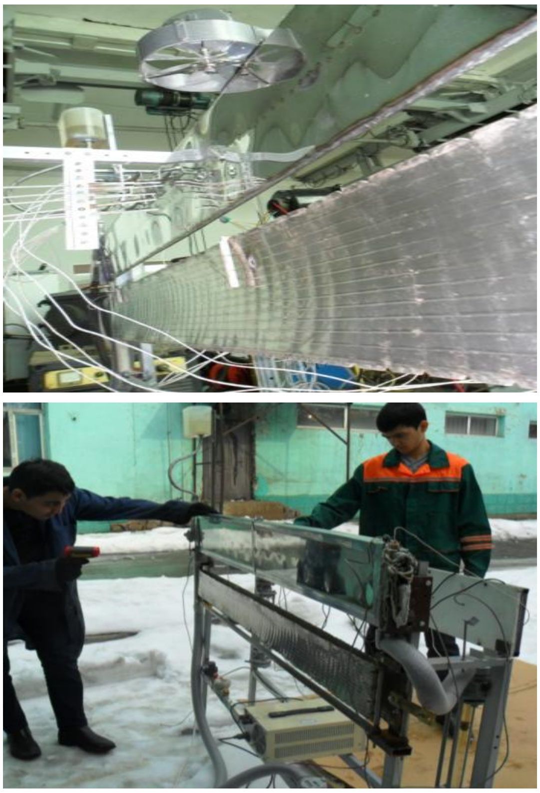


Figure 2 Figure the collector plates and nichrome, temperature sensors and flow rate in the laboratory (top) and outdoors in winter (bottom)

Figure 3 shows the averaged results of several experiments on the measurement the temperature at the inlet and outlet of the collector and flow at $G = 12{,}6 \cdot 10^{-3}$ kg /s and the power released on the walls the collector $P_K = 1780$ watts. At the bottom curve on the experimental points displayed interval accuracy of temperature measurement. As can be seen from the graphs, 10-15 minutes after engaging the power source and the circulation pump temperature difference between the inlet and outlet channel stabilized. On rates of temperature growth was estimated thermal inertia of the circulation circuit, which for reservoir parameters $L/b \geq 15$ (ratio of length to width) of less than twenty minutes.

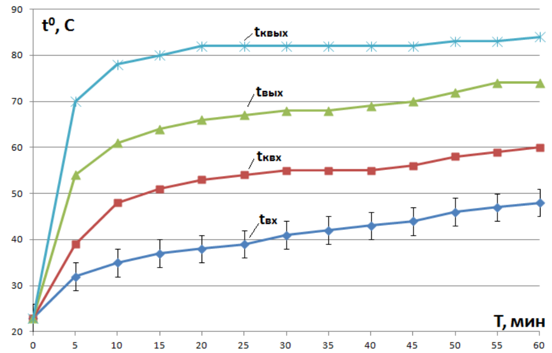


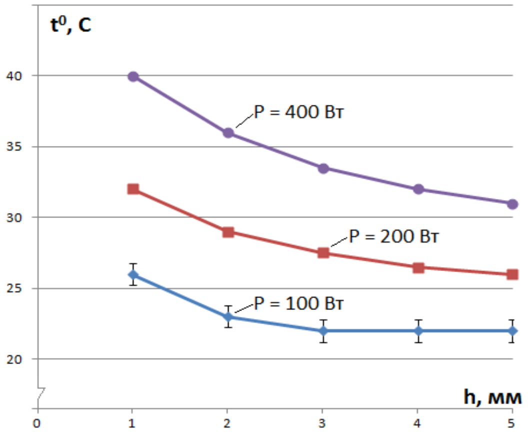
Figure 3 Change in the collector walls temperature $t_{Kвх}$ and $t_{Kвх}$ and heat transfer fluid (water) $t_{вх}$ and $t_{вых}$

Estimate the level of the heat power of solar cells for solar radiation with more than once density (1000 kW/m^2). We put under the collector two rows of solar cells with a total area ≈ 0,74 m^2 and focused on them reflected sunlight from the area of the mirrors, three times larger to compensate optical losses.

The result was approximately two-fold concentration of solar radiation for high-quality solar cells with an efficiency of ≈ 20% and the peak electrical power ≈ 320 W to charge the batteries. Most of the incoming solar energy ≈ 70% generated by the photocells into the heat and directed toward to the collector to form a protective thermal layer on its walls.

Figure 4 (top) shows the graphics of changes in air temperature near the walls of the collector at different power released by nichrome film. They indicate that by growth of the power released either the average temperature of the thermal protective layer on the walls of the reservoir is increasing. In the distance from the wall temperature varies only slightly and approaches the ambient temperature, which is clearly seen in the lower graph

Figure 4 (bottom) shows the dependence of air flow velocity along the collector walls from capacity allocated by plates. Within the measurement error dependence is close to linear. Lower speed curve obtained in the absence of heating the collector walls by electric current (let's call her initial) and reflects a purely convective flow from the heated surface of the nichrome plates.



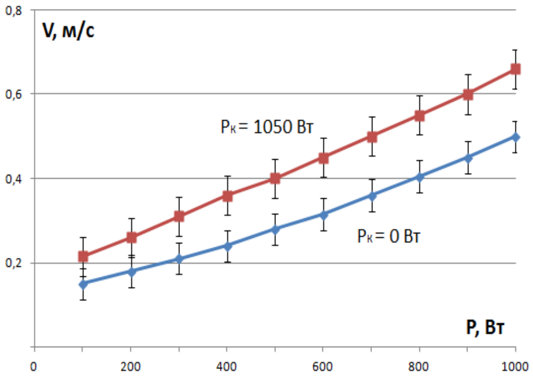


Figure 4 Effect of allocated power by photocells on the temperature and velocity of air flow along the collector walls

Simultaneously with heating collector walls, to the convection from hot plates added convection from the hot walls of the collector. Is difficult to separate them. The upper curve corresponds to the case when the walls of collector capacity of is allocated 1.05 kW, and the average temperature of the walls equal in length to about 62 ^{0}C. Obtained using two curves the difference between the flow velocities along the walls of collector indicates the presence of the effect of "thermal" pump of collector - photocells. If you transfer the results of these experiments on the photographic plates, at the level of actual heat power (≈ 400 W), we can expect an increase in air flow velocity by ≈ 22% of the initial. This increases the heat transfer rate and the amount of electricity generated.

Figure 5 show a graph of collector efficiency dependancy from the power released on the the heated nichrome film. It can be seen that the generated thermal energy below the collector walls increases its efficiency. Quantify the effect reaches up to 25%, in the case of generated heat output 400 watt, it just achieved the level of solar cells power output working with twice concentration of solar radiation.

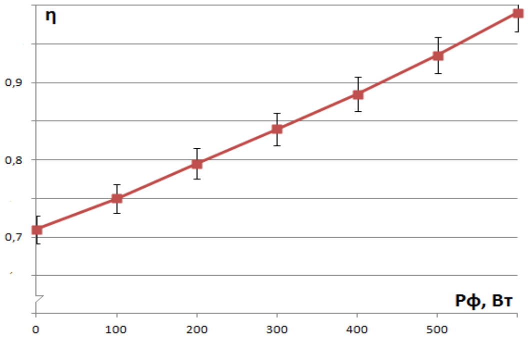


Figure 5 Growth of collector efficiency depending on thermal power generated by plates. $G = 10{,}2 \cdot 10^{-3}$ kg/s, $P_K = 510$ W

CONCLUSION

Develop design of solar installation expands the scope of a large area silicon solar cells application as a heat generators for generating thermal protective layer along the walls of collectors. Depending of real solar cells thermal energy efficiency of solar collectors at the expense of the protective thermal layer increases to 25%. Simultaneously with that, the intensity of solar cells cooling and the amount of photovoltaic electricity generated by them. Using tandem "collector - solar cells" creates the effect of "heat pump" enhancing air consumption along the photocells. Physical modeling of heat transfer processes of developed collectors with the environment on the technical stands allows to receive the main outputs characteristics and thereby improve their designs, change heat transfer, circulation schemes in a short time without the need in expensive field experiments.

REFERENCE

[1] Innovative patent of The Republic of Kazakhstan №25139 dated 30.12.2010 “Solar Power Installation”.

[2] Innovative patent of The Republic of Kazakhstan №25139 dated 30.12.2010 “Solar PVT power station”.

[3] Accepted for publication an Innovative patent of The Republic of Kazakhstan №18664 dated 16.07.2014 “Solar Installation with a concentration of solar radiation”.