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INFLUENCE OF THE COOLANT FLOW RATE ON THE TEMPERATURE CONDITIONS OF THE HYBRID PV MODULE OPERATION

Abstract: *Numerical researches of thermal regimes of a hybrid photovoltaic-thermal panels (PVT) for refrigerating conditions which are discriminated by way of a problem of the charge of heat-transfer agent are conducted. Two typical refrigerating duties PVT are observed, first of which is characterised not connected with sizes of an absorber the heat-transfer agent charge; second – a choice of the charge of heat-transfer agent depending on the absorber square. The work purpose – creation of a method of definition of temperature characteristics of thermal regimes for their rationalisation. Features of the observed regimes are shown. Proceeding from interconnection of temperatures of an absorber of a radiant energy and chilling heat-transfer agent, for generalisation of the solution of system of the equations the temperature factor is inducted. It defines a relationship of change of temperature of heat-transfer agent and average temperature of an absorber and is a parametre of efficiency of a heat transport from an absorber to chilling heat-transfer agent. As showed the analysis, the greatest agency on heat transport efficiencyratio under constant regime conditions is rendered by intensity of irrradiation, ambient temperature and absorber sizes. At the heat-transfer agent charge, connected with the absorber area, its magnitude does not influence heat transport efficiencyratio. Generalising dependences for calculation of temperature characteristics are offered.*

Keywords*: PVT, hybrid photovoltaic thermal panel, temperature regimes.*

Introduction

It is known that efficiency of electric energy production of the photomodule depends on its temperature. To decrease the heating of device apply natural and a forced cooling. In the last case the organised remove of warmth gives the chance to its use [1–3] that raises the general power efficiency of the device. In a hybrid solar collecting system (PVT) photocells are chilled by an active cooling system of by heat-transfer fluid through channels in a back part of the module.

Brief analysis of recent publications

Producers of photomodules restrict temperature level of maintenance of photomodules in limits 45°C, …, 50°C. However for PVT where the heat-transfer agent reheat temperature predetermines a direction of use of power resources, the thermal operating mode of the device should be proved. At sampling of temperature operating modes PVT, as a rule, use analytical models [3, 4]. Boundedness of the mathematical description on a way and detail of work of installations in interfaced and essentially variable conditions thus occurs. It complicates sampling of effective temperature operating modes PVT taking into account thermal and electric productivity at simultaneous satisfaction of the combined loading.

Goal

Working out of the integrated mathematical model for definition and rationalisation of temperature operating modes of a hybrid photovoltaic-thermal panels.

Method of investigation

For the analysis it is accepted the modelling structure of the device consisting of an absorber of solar energy which on the one hand is fenced from an outer space by a pellucid wall, with another is an element of the flat channel for chilling heat-transfer agent.

The heat transport in PVT is defined by external and internal conditions of a leakage of process. External conditions are intensity of irradiation PVT and heat exchange with environment. Internal conditions are formed at heat exchange between an absorber and heat-transfer agent, and also between heat-transfer agent and the back wall bounding on environment. These processes are presented by system of the equations of conservation of energy:

– in an absorber:

$$H(\tau\alpha)(1-\eta_{ep}) = U_{ab-a}(t_{ab}-t_a) + U_{ab-f}(t_{ab}-t_f) \tag{1}$$

– in heat-transfer agent:

$$cg\frac{dt_f}{dx} = U_{ab-f}(t_{ab}-t_f) - U_{f-w}(t_f-t_w) \tag{2}$$

– in a back wall of the channel:

$$U_{f-w}(t_f-t_w) = U_{w-a}(t_w-t_a) \tag{3}$$

where:

H – density of a quantity of radiant energy;
$(\tau\alpha)$ – reduced adsorption capacity of solar collector;
η_{ep} – efficiency ratio of transformation of solar energy in the electric;
t – temperature;
U – heat transfer coefficient;
g – heat-transfer agent mass flow rate;
a – ambient;
ab – absorber;
f – fluid;
w – back wall.

Value of efficiency ratio of transformation of solar energy η_{ep} depends on temperature [4]:

$$\eta_{ep} = \eta_{\max SC}\left[1+\alpha_P(t_{ab}-t_{SC})\right] \tag{4}$$

where:

$\eta_{\max SC}$ – efficiency ratio of transformation of solar energy photopanal in a point of the maximum power under standard conditions (SC);
t_{SC} – temperature panal at the SC;
α_P – temperature power factor cell, K^{-1} .

The system of the equations which includes on the equations in the algebraic and differential aspect, added with boundary conditions, characteristic for maintenance of solar devices, dared a numerical method. As change of temperatures in system occurs along a heat-transfer agent current, we make rationing of observed parametres concerning a channel width. Thus we gain that for the absorber area in characteristic functional parametre the length of the channel is.

Study results and their discussion

By consideration of the combined power device by analysis key parametres heat exchange processes the outlet temperature of heat-transfer agent and absorber temperature are. Observed parametres essentially change along an absorber surface as it is visible on figure 1, where it is shown a dynamics of characteristic temperatures PVT along the channel in conditions typical for such device. These are condition assumes working out simple in use of algorithm of definition of such temperatures. Recognising that presented on figure 1 dependence it is close to linear, in the capacity of settlement temperature of an absorber its arithmetic-mean magnitude can be accepted ($\overline{t}_{ab}$).

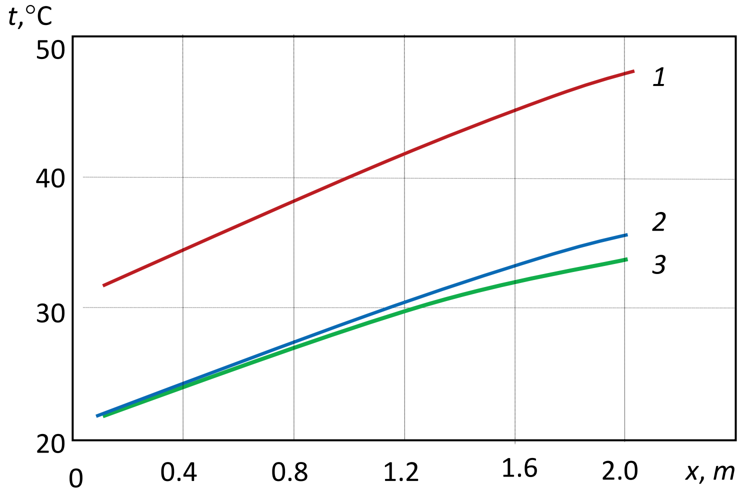

FIGURE 1. *Change of characteristic temperatures along the stream (coordinate x): 1 – heat-transfer agent; 2 – an absorber; 3 – an outdoor wall*

Let's observe two refrigerating duties PVT:

- first – not connected with sizes of an absorber the heat-transfer agent charge, $g \neq f\left(A_{ab}\right)$;
- second – at the heat-transfer agent charge, chosen depending on the area of an absorber $g = f\left(A_{ab}\right)$.

Regime $g \neq f\left(A_{ab}\right)$ means that the heat-transfer agent charge is set for one, base, area PVT and with area change its value remains to constants. In the given work in the capacity of the base the charge of a fluid typical for solar solar collector is accepted g = 0.015 l/s per 1 m^2 the absorber area. Thus, alternative sizes of the channel, proceeding from the accepted conditions on fixing of settlement width (1 m). Will be defined by length of the channel.

On average temperature of an absorber ($\overline{t}_{ab}$) the ambient air temperature influences (fig. 2) at increase t_a it grows. However rate of change ($\overline{t}_{ab}$) depends on length of the channel. With increase in length rate increases. From this it follows that at change of external conditions low temperatures of an absorber are characteristic for collecting panels of small sizes. The data is resulted for one value of intensity of solar intensivity – 800 W/m^2, but similar dependence occurs and at other values of irradiance.

As absorber and heat-transfer agent temperatures are interconnected, for generalisation of the solution of system of the equations we introduce a complex defining a relationship of change of temperature of heat-transfer agent and average temperature of an absorber. Such complex we name efficiency ratio of a heat transport from an absorber to chilling heat-transfer agent and we express in an aspect:

$$\eta_{he} = \frac{\delta t_f}{\bar{t}_{ab}} \quad (5)$$

where:

$\delta t_f = t''_f - t'_f$;

t'_f and t''_f – inlet and outlet temperatures of heat-transfer agent.

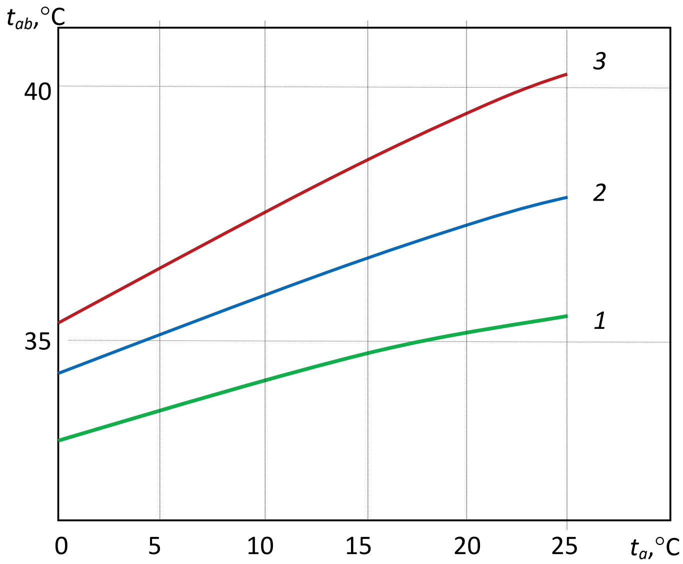

Figure 2. *Influence of amdient temperature and length of the channel on average temperature of an absorber at the constant charge of a fluid. Length of the channel: 1 – 1 m; 2 – 1.5 m; 3 – 2.0 m*

For PVT a concrete design the heat transport efficiency ratio depends on external conditions: ambient temperature and intensity of insolation (fig. 3). With increase in these parameters η_{he} increases. Besides, the additional factor of dependence is the length of the channel. The increase in length raises influence of these parametres on function. Thus, value η_{he} cannot be to the accepted constants and at regime calculations it is necessary to consider affecting of conditions of realisation of process.

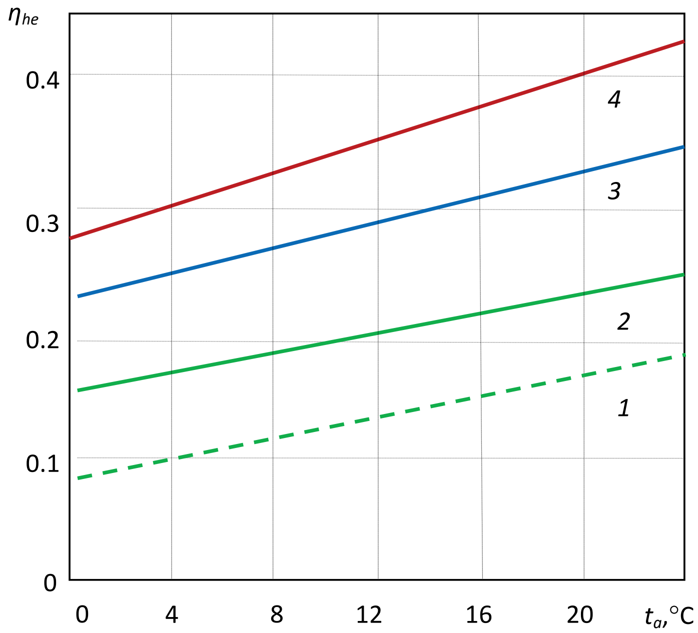

Figure 3. *Influence of external conditions on heat transport efficiency ratio at the constant charge of a flued. Length of the channel, intensity of radiation: 1 – 1 m, 500 W/m²; 2 – 1 m, 800 W/m²; 3 – 1.5 m, 800 W/m²; 4 – 2.0 m, 800 W/m²*

As showed the analysis, the greatest influence on heat transport efficiency ratio under constant hydraulic conditions is rendered by intensity of radiation, temperature of ambient air and absorber area. Taking into account it generalising dependence in an aspect is gained:

$$\eta_{he} = 0.1\left[t_a\left(\frac{A^*}{H}\right)^{0.48} - 1\right] + \left(0.424A^* - 0.0253\right)\exp\left(-\frac{233A^* + 141}{H}\right) \quad (6)$$

where:

H – intensity of radiation;

t_a – ambient temperature;

A^* – the area of an absorber led to its width.

Offered dependence can be used for definition of temperature of an absorber and outlet temperature of heat-transfer agent of the combined solar device in problems of regime optimisation. As characteristic temperatures – components of efficiency ratio of a heat transport are interconnected and defined by concrete conditions, for a finding of one of them from definition of a complex for η_{he} it is necessary to have a well-founded method of calculation another. Taking into account it, on the basis of resulted above model, dependence for average temperature of an absorber has been gained:

$$\overline{t}_{ab} = 1.306(14.6 - A^*) + 0.00464 \cdot H(3.22 + A^*) + 0.0667 \cdot t_a \quad (7)$$

This dependence at the found value of efficiency ratio can be used for temperature drop definition in chilling heat-transfer agent and a outlet reheat temperature t''_f at the accepted reference temperature. Here in the capacity of the initial accepts temperature 20°C.

In a regime $g = f\left(A_{ab}\right)$ the fluid consumption variable, proportionally depending on the absorber area. Under such circumstances the absorber temperature does not depend on its sizes. On figure 4 characteristic dependence between temperature of an absorber and external temperature is shown. Parametre here is magnitude of irradiance. Growth of external temperature, and also intensity of irradiance leads to increase in temperature of an absorber. This dependence for all sizes of the channel matches to conditions of base alternative with the area 1 m² (length, equal 1 m).

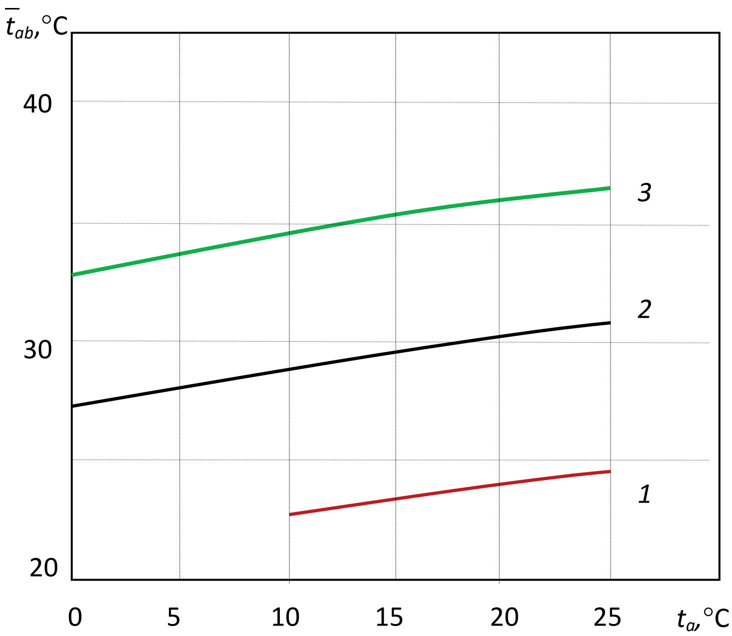

***FIGURE 4.** Dependence of temperature of an absorber on ambient temperature and irradiance at the variable consumption of a fluid, W/m²: 1 – 200; 2 – 500; 3 – 800*

The efficiency ratio submits to the dependences, gained for base alternative, and its magnitude does not depend on absorber sizes. Thus, at any sizes PVT of the deepest cooling it is possible to achieve in a regime $g = f\left(A_{ab}\right)$.

Proceeding from the gained data, the greatest influence on heat transport efficiency ratio under constant regime conditions is rendered by intensity of radiation and ambient temperature. Taking into account it for a refrigerating duty $g = f\left(A_{ab}\right)$ generalising dependence in an aspect is gained:

$$\eta_{he} = 0.143 \cdot \ln(H) - 0.797 + t_a (119 + 0.194H)^{-1} \tag{8}$$

Conclusions

Features of temperature refrigerating duties of hybrid solar collector are shown. For generalisation of the solution of system of the equations the temperature factor is introduced η_{he}. Which defines a relationship of change of temperature of heat-transfer agent and average temperature of an absorber and is a parametre of efficiency of a heat transport from an absorber to chilling heat-transfer agent. The greatest agency on heat transport efficiency ratio under constant hydraulic refrigerating conditions is rendered by intensity of radiation, ambient temperature of air and absorber area. At the heat-transfer agent charge, connected with the absorber area, its magnitude does not render agency on transfer efficiency ratio. Generalising dependences for calculation of temperature characteristics are offered. Offered dependences can be used for definition of temperature of an absorber and outlet temperature of heat-transfer agent of the hybrid solar device in problems of regime optimisation. Any of these parametres can be set any way.

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