

RISE OF USE EFFECTIVENESS OF SOLAR ENERGY IN SOLAR SYSTEMS

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This article covers the results of investigation of solar radiation incoming on the solar collectors. Dependence between the amount of discrete orientations of the solar collector and efficiency of work of its system has been established. The results of the experimental researches of one constant and four variable orientations of the collector on the Sun are given. The dependence between different orientations of the absorber and different constructional overall dimensions are determined. It is shown that we can receive more energy from triple orientation collectors than from traditionally flat.

Key words: solar collector, discrete orientation, solar energetic.

Подано результати досліджень надходження сонячного випромінювання на сонячні колектори. Отримано залежність між кількістю дискретних орієнтацій та ефективністю роботи даної системи. Подано результати експериментальних досліджень стаціонарних та дискретноорієнтованих сонячних колекторів відносно сонячного випромінювання. Встановлено залежності між різними орієнтаціями теплопоглинача і ефективністю роботи геліосистеми. Показано, що із дискретноорієнтованих сонячних колекторів можна отримати більше енергії, ніж із стаціонарних.

Ключові слова: сонячний колектор, дискретна орієнтація, сонячна енергетика.

Putting of the problem

System of supplying solar heat is one of the most perspective themes in solar energetic. Despite the great variety of solar systems, practically each of them has three main elements: energy receiving system (solar collectors), energy transferring set (heat carrying medium) and energy using system (system of supplying warm water, heating, etc). Accumulator of heat and extra source of energy can also be added. The efficiency of using solar energy coming from the sun depends on the right and coordinated function of these mentioned systems in complex and each systems alone.

Maximum receiving of energy by surface of a solar collector which corresponds to the highest efficiency and the most effective use of solar energy is reached by the way of putting the surface into the position, perpendicular to the falling sunrays.

The discrete reorientation of the collector gives rather a big gain of received energy comparing with energy that could come from the constant collector.

However it is unknown how many times per day collectors must be moved in order that the expenses for reorientation could be minimum and received amount of energy could be maximum.

So, the task is to find a simple and economical method of orientation of solar collectors, due to which one could get maximum possible amount of solar energy.

Survey of the latest researches and publications

A lot of works [1; 2; 3] are devoted to finding the best angles of slope of the collector to the horizon and azimuth of turning at which the greatest amount of solar energy will come. Everyone states that about 40% more energy comes from the collectors that change their angles of position than from the constant collectors [2].

Addressing these issues should be associated with problems such as optimization of deployment auxiliary structures in implementation of building thermal insulation [9] and air quality and effect of ventilation in buildings [10].

Daily change of the position of the angles of the collector cannot be necessarily constant but periodical too. So, a solar device is put in the best, for a given period of work, position and the collector of solar energy allows changing orientation by hand several times per day [5;6].

The idea of a “half follow” collector was suggested in the work [7]. The collector axle was bent to the horizon under the angle which is the best for any month. For twenty-four hours collector is moved around its axle every 30 minutes. As a result the collector received amount of energy which equals to amount of energy which would come on a constant regular moving collector and much more bigger amount of energy than on a constant.

All investigations show that daily reorientation of the collector gives rather a big gain of a received energy comparing to the energy that would come from a constant collector.

The aim and tasks of researches

Finding the best amount of turning of the solar collector at its discreet orientation for different regions of placing solar device from the point of its economical and energetic efficiency.

Description of experimental device

Device consists of two standard solar collectors, a tank for heat carrying, pipelines and hoses, control accessories (fig. 1)

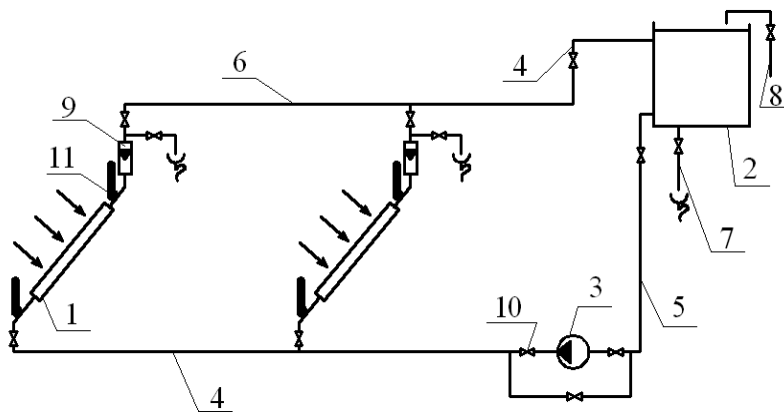


Fig. 1. Principle chart research plant:

- 1 – solar collector; 2 – tank for heat – carrying agent; 3 – circulating pump;
- 4 – distributive tubing; 5– supply tubing; 6 – reverse tubing; 7 – Interflow tubing;
- 8 – tubing of cold water; 9 – measurer of liquid; 10 – control accessories; 11 – mercurial thermometer

The general radiation on the horizontal surface was measured by a thermoelectric albidometer and the direct radiation on the perpendicular to the rays surface-by thermoelectric acidometer. All solar collectors are put in the best given surfaces on special stands with turning mechanisms which can ensure the orientation of each collector in the right direction and with a given of slope to the horizon.

Laboratory thermometers were used for determining the temperature of a heat carrier and the air.

Main part

Experimental research was carried out at such conditions and simplifications:

- incoming of solar radiation on the collectors was received in parts concerning the maximum possible;
- all solar collectors are put in the best given surfaces;
- liner size of pipelines was not changed;
- one constant orientation of the collector and 4 changeable its orientations were taken;
- measurements were done 6 times per year (fig. 2) with further average quantity of efficiency K_{ef} ;
- obvious results of the experiment and approximation $\alpha = 0,95$ are accepted;
- during mathematical evaluation of the results for discrete orientations continuous functional dependences were set.

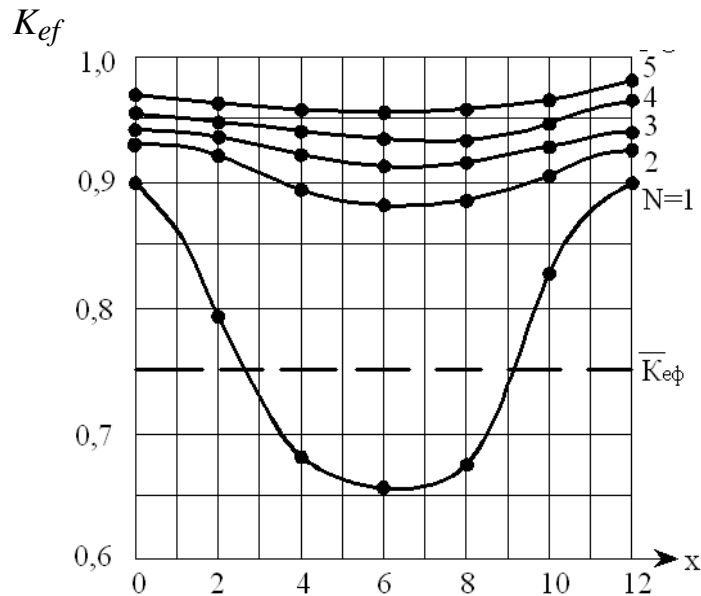


Fig. 2. Yearly changing of coefficient effectiveness K_{ef} of discrete methods of orientations N

Daily incomings to solar radiation on collector surface will be maximum when not only every direction during discrete orientation will be the best, but the time of reorientation will also be optimum for two next positions. Such condition is possible at receiving equality of the amount of solar radiation, which comes for a unit of time on the surface of receiving during the former and the next orientations [8].

On the basic of the data of the diagram (fig. 2) one can state that constant orientation ($N = 1$) of solar collectors on the south is the most effective, besides the smallest K_{ef} ($K_{ef} = 0,65 \dots 0,67$) comes on summer months, when incoming of solar radiation is the highest.

On fig. 2 we can see the curves of incoming solar radiation for all month of the year at different variants of orientations in regard to the maximum possible incoming of radiation on the collectors of follow orientation are shown.

This reference is the coefficient of efficiency \bar{E} of discrete method of orientation.

Diagrams (fig. 2) are approximated by the following way:

1. For constant orientation of a solar collector:

$$N=1: K_{ef} = 0,66 + (x - 6)^2 * 0,010.$$

2. For changable orientation of a solar collector:

$$- N=2: K_{ef} = 0,88 + (x - 6)^2 * 0,002;$$

$$- N=3: K_{ef} = 0,93 + (x - 6)^2 * 0,001;$$

$$- N=4: K_{ef} = 0,95 + (x - 6)^2 * 0,001;$$

$$- N=5: K_{ef} = 0,96 + (x - 6)^2 * 0,001,$$

where x – is the number of a month.

Then average figure of efficiency coefficient K_{ef} , was determined due to efficiency \bar{K}_{ef} was determined with the help of integration, during the year was determined its average year figure \bar{K}_{ef} , according to different number of discrete orientations of the collector N .

The average figure \bar{K}_{ef} was determined by means of approximation of diagrams (fig. 2) and further integration in limits from 0 to 12 by months. So, ensuring equality of surfaces of a curvilinear trapezium

($S_1 = \int_0^{12} f_i(x)dx$) and corresponding rectangles ($S_2 = \bar{K}_{ef} * 12$) the average figures were the following:

$$\bar{K}_{ef} = \frac{1}{12} \int_0^{12} f(x)dx. \quad (1)$$

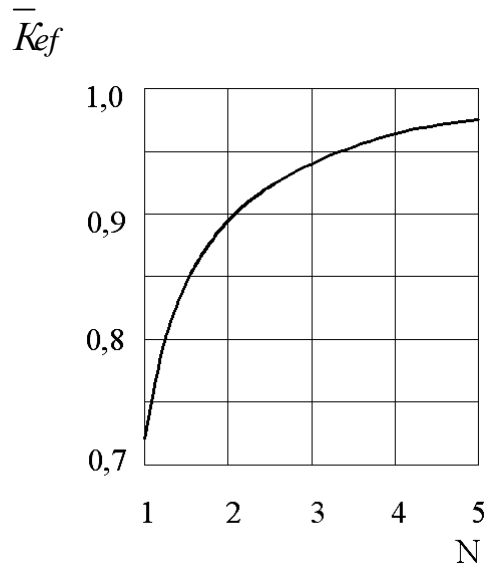


Fig. 3. Dependence of effectiveness coefficient \bar{K}_{ef} of quantity discrete orientations N

On the graph (fig. 3) one can see average figures of the effectiveness coefficient as for the constant position of a solar collector ($N = 1$), as well as for its changeable ($N = 2 \dots 5$) discrete orientation taking into account the yearly change of efficiency coefficient (fig. 2).

Average figure \bar{K}_{ef} (for example for $N = 1$) was received in such way:

$$\bar{K}_{ef} = \frac{1}{12} \int_0^{12} (0,65 + (x-6)^2 * 0,01) dx = \frac{1}{12} \left(0,65x \Big|_0^{12} + 0,01 \frac{1}{3} (x-6)^2 \Big|_0^{12} \right) = \frac{1}{12} (7,92 + 0,72) = 0,72.$$

As the diagram, on which we can see the dependence of \bar{K}_{ef} against amount of discrete orientation N , shows that the curve asymptotically comes to the straight line $\bar{K}_{ef} = 1$, which belongs to the follow system of orientation.

Graph (fig. 3) is approximated by dependence:

$$1 - \bar{K}_{ef} = \frac{a}{N + a}, \quad (2)$$

where a is a constant coefficient.

While using mathematical methods of calculating results of the experiment, the constant a was defined: $a = 0,21$, and formula looks like this:

$$\bar{K}_{ef} = \frac{N}{N + 0,21}. \quad (3)$$

But at increasing the amount of discrete turnings, the cost of the device is increasing too, that's why it is necessary to give corresponding economic data (fig. 4).

On graph (fig. 4) is shown dependence of relative value \bar{E} (relation of amount of discrete orientations E_i to maximum value E_{max} at constant ($N = 1$) collector and 4 changable orientations ($N = 2 \dots 5$) $\bar{E} = E_i / E_{max}$) from the amount of discrete orientation of the solar collector N .

This graph is described by linear dependence:

$$\bar{E} = 0,69 + 0,06N. \quad (4)$$

Graph (fig. 3) which characterizes efficiency K_{ef} , does not have points of extremum and is increasing monotonously but the graphic (fig. 4) which characterizes the cost, has the same principle. On account of this it is not possible to get the desired result in the points of maximum or minimum, since they do not exist.

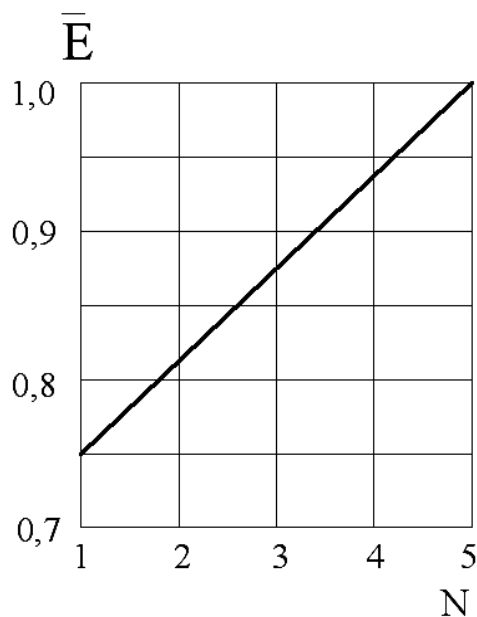


Fig. 4. Dependence relative cost \bar{E} from quantity discrete orientations N

So, it is necessary to establish the criteria of optimization – specific value E_o , as relation of the relative value \bar{E} to the average coefficient of efficiency of getting solar energy \bar{K}_{ef} :

$$E_o = \frac{\bar{E}}{\bar{K}_{ef}} \quad (5)$$

Taking into account dependences (3) and (4) we get:

$$E_o = 0,06N + 0,7 + \frac{0,145}{N} \quad (6)$$

Function $E_o = f(N)$ is not monotonous, it has point of minimum, so after differentiation it is not difficult to define $N = 1,55$.

At it was mentioned in conditions and simplifications one builds the graphic dependence, tabbing the formula (6). This graph (fig. 5) gives a real character of the function $E_o = f(N)$ and confirms the existence of the point of minimum (point A), for which indeed $N = 1,55$.

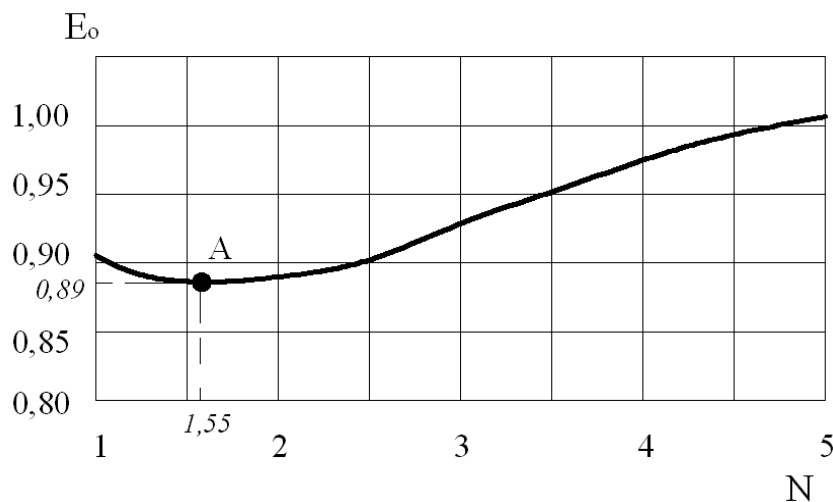


Fig. 5. Dependence of specific cost E_o against quantity of discrete orientations N

As a result it is necessary to round to the number $N = 2$.

Conclusions

Using of discrete orientation is the most effective in summer when it is possible to use the incoming of energy on the collector during the light 24 hours (in comparison at constant orientation the light period is only 70...80 %). So, due to discrete orientation it is possible to increase the process of taking energy from solar collectors to the figures which are slightly different from maximum possible.

Since with such increasing of the amount of discrete turnings, cost of the device is increasing too, the device with the smallest amount of turnings is better, that is $N = 2$. So, double orientation of a solar collector is enough for ensuring practically maximum incoming of solar energy on collector with such minimum expenses on orientation.

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