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Heliosystem of Auxiliary Heat Supply for a Mining Enterprise

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Abstract. In the conditions of the global ecological crisis in the world and Ukraine, the issue of finding alternative energy sources becomes relevant. One of the most common types of renewable energy is solar energy. In Ukraine today, the most promising direction of using solar energy is its direct transformation into low-potential thermal energy. To get electric power, solar radiation is the mere alternative to electric power generated from mined fuel, and without the pollution of air and water, or adverse consequences manifested in global warming. The disadvantage of this type of installation is the limitation of the duration of light time, as well as the effect of cloudiness. During the day, the number of solar radiation changes, to stabilize it is necessary to accumulate and accumulate it for further use, the technical implementation of stable operation of solar installation due to the use of terrestrial radiation and the accumulator of a specific part of solar energy is proposed. The purpose of the work is experimental studies to ensure the stable operation of the solar collector under cloudy conditions. The paper is aimed at the stabilization of the operation of the solar installation and to obtain additional heat after the Sun's cloud cover. The use of a solar thermal collector is advisable in solar heating and hot water systems in conditions of alternating solar radiation. The results of physical modeling have proved the efficiency of the method of combining types of thermal radiation, due to the accumulation of energy it is possible to increase the quantitative index of solar energy in the conditions of cloudiness by 3 times.

Keywords: alternative energy, solar energy, solar collector, thermal energy, clouds, terrestrial radiation, ecology.

1 Introduction

The energy of solar radiation coming annually to the territory of Ukraine equals about $1.2 \text{ MW} \cdot \text{year}/\text{m}^2$ but it is just 1 % of the total energy belonging to the resources that are used in an economically expedient way. Studies state that the potential of solar generation in Ukraine could comprise about 4 GW. Considering the conditions of Ukrainian climate, the solar systems could work in an all-year manner. However, their effectiveness varying depending on the latitude of their location. The average annual potential of solar energy in Ukraine is high enough. Thus, allowing effective utilization of heat-and-power engineering equipment on the territory of the country.

One of the widespread versions of solar radiation transformation to heat energy is using solar collectors. The solar collector is the device that can transform solar energy into thermal one to be used in everyday human life for technological water heating or heating of premises. According to meteorological data, solar collectors work on the territory of Ukraine at least nine months a year. For

example, Donetsk Region has the potential of about $33 \cdot 10^9 \text{ MW} \cdot \text{hrs}/\text{year}$ of solar energy reception [1, 2].

During the day, the number of solar radiation changes, to stabilize it is necessary to accumulate and accumulate it for further use, the proposed technical implementation of stable operation of the solar installation due to the use of terrestrial radiation and the battery of some of the solar energy. An example of using solar energy for business purposes is an example of the mine “Halemba” (Poland), which installed solar panels serving as an auxiliary installation, instead of a backup heat source. Figure 1 presents a graph of the energy produced by solar installations at the “Halemba” mine during the 53 weeks of 2018 (Materials of the scientific conference “Górnictwo Zrównoważonego Rozwoju 2019” at the Silesian Technical University, Gliwice, Poland).

Solar energy is a renewable natural resource that does not require human involvement. It is the safest environmental source of energy. The benefits of solar power are much higher than the disadvantages. Among the main advantages are accessibility, environmental

friendliness, restoration, safety. The disadvantages include the limitation of the operation of the duration of light time, the reduction of efficiency in the cloud, significant prices for photovoltaics, and the occupation of large areas of land under power plants [2].

According to the presented graph (Fig. 1), the solar installation produces the most energy from the second part of spring, during the summer and the first month of autumn.

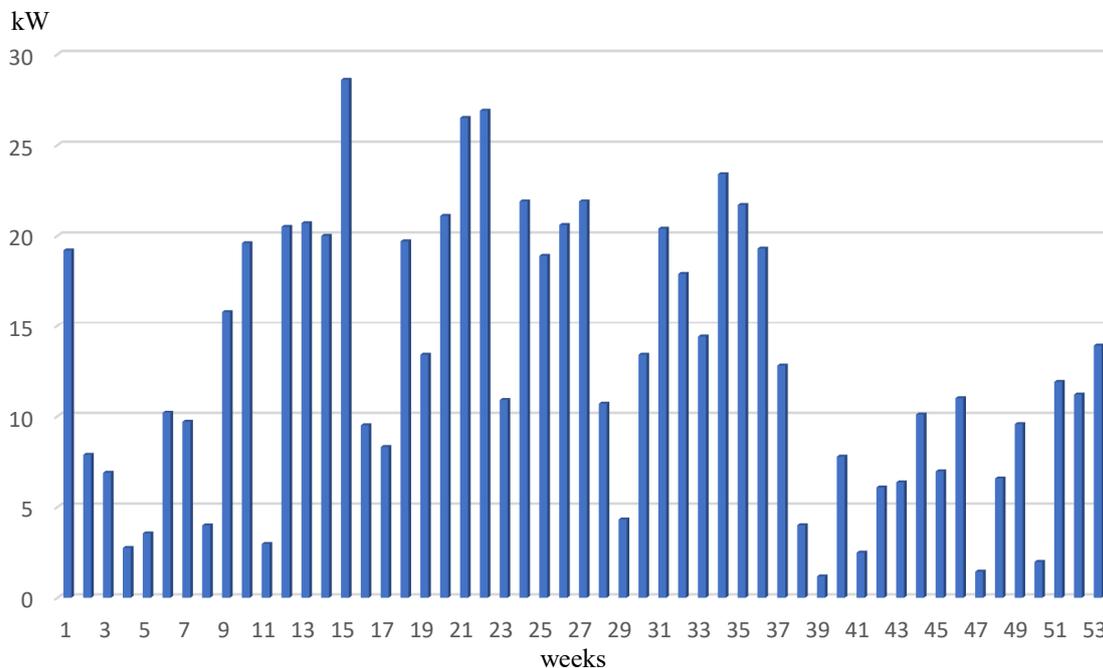


Figure 1 – Electricity produced by a solar installation at the mine “Halemba” of Ruda-Slaskie city (Poland) during 2018 [3]

The purpose of the work is experimental studies to ensure the stable operation of the solar collector in the cloud. The object of study is the processes of heat and mass transfer in the solar collector. The subject of the study is the conditions for increasing the efficiency of heat transfer under the influence of cloud cover. The research methods are physical modeling of heat and mass transfer in a solar collector.

To achieve the goal, the following problems should be solved:

- to identify the negative aspects of existing models of solar collectors;
- to solve the problem of ensuring the stability of the solar installation when changing the solar radiation;
- to justify ways to improve the performance of the solar installation.

The scientific novelty of the obtained results is in the following:

- for the first time the leveling of the negative influence of cloudiness on the work of a solar installation is proposed;
- it is experimentally justified to obtain additional energy from the solar collector by installing a battery.

The practical significance of the obtained results is to develop a way to solve the problem of the negative impact of cloud cover on the operation of the solar collector and increase the efficiency of the solar collector.

2 Literature Review

Currently, extensive work is underway to improve existing models of solar collectors and address this issue is extremely relevant to the universe. Most designs contain a frame housing an absorber with channels for circulation of the coolant, absorber of solar energy, transparent insulation located above the absorber, channels of input and output of working fluid and thermal insulation [3–7]. More productive is a solar collector containing a sealed housing, the upper part of which is made of a transparent material, and the inner surface facing the Sun has a dark coating that absorbs solar radiation, tubes with channels for the passage of coolant having an inlet and outlet on the surface of the solar collector [8]. Available solar driven water heating systems in the market, suitable to replace conventional electric water heater for multi-residential building.

Solar energy is an affordable and inexhaustible resource, currently free of charge, so it is advisable to use it for human needs to save on the use of abundant natural resources [9].

To get electric power, solar radiation is the mere alternative to electric power generated from mined fuel, and without the pollution of air and water, or adverse consequences manifested in global warming. One more advantage of such a technique is the absence of

dependence on stationary electric energy supply. The solar energy can heat water, cold and warm houses as well as provide continuous natural illumination [1].

Advantages of solar power plants are as follows:

1) solar energy is renewable and cannot be exhausted, at least within human understanding. We have a minimum reserve of five billion years to use Sun for electric power generation. It is more than enough since reserves of oil, gas, coal, and uranium can get exhausted in the nearest centuries;

2) ecological compatibility. Solar energy generation practically does not damage the environment [2];

3) great opportunities for implementation in various spheres of activity;

4) people's participation in the solar energy generation is reduced to a minimum;

5) access to solar energy is possible in any place of the world;

6) simple operation. Solar power plants, especially home ones, practically do not require any maintenance;

7) low noise;

8) the economy.

In Ukraine, "green prices" exist, i.e. overprices used by the state to buy electric power generated by an alternative

ecologically compatible method. According to Ukrainian law, the installation of electrical panels is encouraged by a special Green tariff [10].

The negative side of solar installations are as follows:

1) high equipment cost;

2) instability: the volume of power generated directly depends upon the intensity of solar radiation;

3) expensive systems for power accumulation;

4) broad areas required for solar energy installations: we can use the ground, walls of buildings or their roofs however the place is wanted ("On alternative energy sources", Verkhovna Rada of Ukraine, 2003, No. 24, Article 155; 2017, No. 27–28, Article 312; 2019, No. 23, Article 89); but the issue of ensuring the stability of work due to the influence of cloudiness is not solved.

The scope of solar installations is limited by the length of the solar season and the intensity of solar radiation, which depends on the season, so it is advisable to use such solar systems as ancillary. Considering the use of thermal energy by the example of a mining enterprise (Table 1), the main load from 8 hours to 17 hours during this period of energy consumption reaches a maximum mark, all branches of the enterprise work.

Table 1 – Chronogram of thermal energy consumption by a mining enterprise

Hours		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Work shift		IV				I							II						III				IV			
Consumers	Laundry								■	■	■	■	■	■	■	■	■									
	Workshop								■	■	■	■	■	■	■	■	■	■								
	Bath room					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					■	■
	Dining room					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					■	■
	Office complex	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Heater	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

The primary consumers of heat and hot water are laundry (washing and drying clothes), workshop (space heating), bathroom (bathing of workers, heating, and washing of premises), dining room (washing dishes, furniture and rooms), office (space heating), and heater (heating the trunks in the cold season).

Traditional means are used for the main heat supply around the clock, and during this period, it is advisable to use solar energy. At the same time, solar energy is necessary for the enterprise all year round. Therefore it is proposed to use a solar installation for this purpose.

The chronograph shows peak energy use periods at the plant to provide the plant with the necessary electricity. Usually, several boilers are installed to produce energy, and under favorable weather conditions, it is possible to replace the boiler with a solar installation, thereby reducing the environmental impact of emissions. Substances from the boiler and reduce the amount of fuel (coal, gas).

Because the use of electricity at the mine at night shifts is less than during the day, instead of a backup boiler, it is

advisable to install solar panels that will produce auxiliary energy for the dining, laundry and household needs, but the weather depends on the efficiency of these panels.

The main drawback of a conventional solar collector is the limited and unstable heat output, which is determined by the duration and intensity of the Sun's surface-containing irradiation, for example, due to cloudiness.

3 Research Methodology

Solar collectors are devices for the collection of energy radiated by the Sun in the visible and infrared spectrum. Solar collectors are designed for solar energy transformation to thermal one in water warming for domestic purposes and in the maintenance of heating facilities. Due to design improvement and the high absorption coefficient (95 %), solar collectors effectively work almost 9 months a year. The glass of solar collectors is impact-resistant and guarantees mechanical resistance to atmospheric precipitations (hail) or hard subjects' penetration.

Due to nonfreezing liquid (solution of glycol), utilization collectors can work at the low temperatures of about $-30\text{ }^{\circ}\text{C}$.

Today in Ukraine, the most prospective direction of solar energy utilization is its direct transformation to low-potential thermal energy. Systems of solar heat supply are the most reliable and durable ones provided their installation is correct and quality. Thus, the choice of construction materials for collectors' production is of great importance. The authors conducted laboratory tests to determine the characteristics of materials the inner surface for solar collectors' production. Black polyethylene $40\text{ }\mu\text{m}$ thick was represented in the tests together with 5 mm thick foiled polyethylene foam. Water warming using the black polyethylene was $0.4\text{ }^{\circ}\text{C}$ while for the foiled polyethylene foam, it was three times more efficient, i.e. $1.5\text{ }^{\circ}\text{C}$ [1].

Systems of solar heat supply are the most reliable and durable ones provided; they are characterized by proper calculation and high-quality installation [2].

The main disadvantage of standard solar collectors is the limited and unstable heat output determined by duration and intensity of radiation-related to surfaces holding sunrays, for instance, because of cloudiness.

As a principle of the proposed installation, the authors take the idea of replacement of the solar radiation reduced due to cloudiness by terrestrial radiation. The idea works in the following way [11]. A solar collector is installed on the bracket allowing its surface's semispherical turning. An accumulator of heating energy is erected close to the collector.

In the standard mode of work, the transparent surface of the collector gets solar rays. In the body of the collector, the dark surface absorbs the rays, and heat accumulation takes place to warm heat carriers in pipes and to transfer it to heat consumers.

The accumulator is also under the influence of sun rays, and the filling substance gets warmer than the surrounding environment. When the Sun is closed with clouds, and, consequently, the radiation intensity of the device's transparent surface becomes reduced, then the heat output of the solar collector gets lower too. In such a situation, using joints of the post and the bracket, the body of the collector is fixed above the accumulator to provide perimeters coincidence of the case and the accumulator. The accumulator's dimensions may considerably exceed the transparent walls of the collector, thus allowing the sizeable improvement of the thermal capacity of the accumulator.

The thermal energy gathered by the accumulator is directed towards the collector in the form of rays and convective streams. The inside reflective surface of the case prevents the loss of the radiation component of the energy, while heat-insulating material of the case prevents the loss of the convective component.

The availability of the case contributes to heat concentration towards the collector. The collector's heating from the accumulator continues until the substance of the accumulator becomes cooled to the level of the surrounding environment.

The design scheme of the solar installation and its operation principle are explained in Figures 1 and 2, respectively.

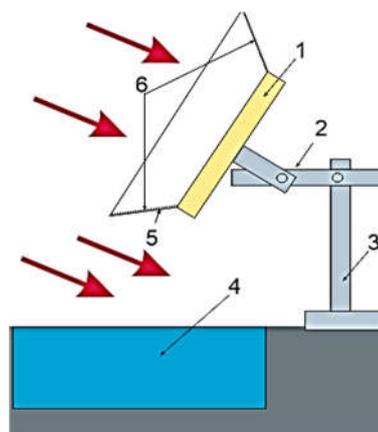


Figure 1 – The solar collector at regular sunlight [11]:
1 – body; 2 – bracket; 3 – post; 4 – accumulator of thermal energy; 5 – case; 6 – light-reflecting material layer

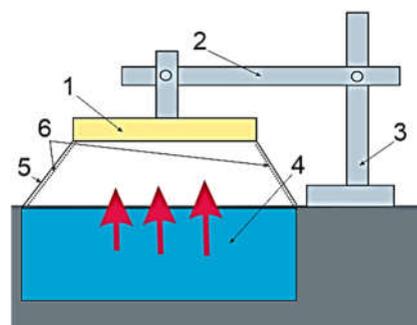


Figure 2 – The solar collector at cloudiness [11]:
1 – body; 2 – bracket; 3 – post; 4 – accumulator of thermal energy; 5 – case; 6 – light-reflecting material layer

The solar collector consists of the tight body 1, its upper part is manufactured of transparent material while the inside surface directed towards the Sun has the dark layer to absorb the solar radiation, and pipes with channels for bypassing of heat carrier with corresponding in- and outlet on the surface of the collector. The body 1 is fixed to the bracket 2, which, in its turn, is connected with the bearing post 3 using a joint. The accumulator of thermal energy 4 is placed close to the post 3. The case 5 made of heat-insulating material is situated around the tight body 1 of the solar collector, and the inside surface of the case is covered with the light-reflecting layer 6 while the outside perimeter of the case has the same dimensions with the accumulator's perimeter.

On sunny days the solar collector operates in the following way: body 1 is orientated towards the Sun with its transparent surface. Within the body of the collector 1 the dark surface absorbs rays followed by heat accumulation, the latter warming heat carrier in pipes to be transferred to heat consumers. The light-reflecting layer 6 of case 5 directs infrared rays falling on it. They are thus improving the collector's effectiveness. The accumulator

4 is also influenced by sun rays, and the substance filling it gets warmer than the surrounding environment.

When the Sun is shielded with clouds, the irradiation intensity of the transparent surface becomes reduced together with the heating output of the solar collector 1. The accumulator 4 is used for additional heat production as follows. By means of joints of post 3 and the bracket 2 the body of the collector is placed above the accumulator 4 to make the perimeter of the case and the accumulator coinciding. The thermal energy collected by the accumulator 4 is directed towards the collector 1 in the form of rays and convective streams. The inside reflective surface 6 of the case 5 prevents the loss of the radiation component of the energy while heat-insulating material of case 5 prevents the loss of the convective component. The availability of case 5 contributes to heat concentration towards the collector 1. In such a way the additional heat is received by the collector 1 after the Sun has been shielded with clouds. The collector's 1 heating from the accumulator 4 continues until the substance of the accumulator becomes cooled to the level of the surrounding environment [11].

4 Results and Discussion

The effectiveness check of the solar collector was done using laboratory equipment including the electro-heating source of thermal energy for the generation of infrared rays' stream, glass laboratory refrigerator one half of its outside wall opposite to the source of the infrared rays being covered with the light-reflecting film, and one side of the inside pipe of the refrigerator being connected to the water pipeline while water freely flows from the opposite side. The refrigerator imitated the solar collector. Distance L between the source of the thermal energy and the refrigerated was measured. Water temperature on the in- and outlet of the refrigerator was registered by electric meters. A container with water was placed below the refrigerator to be irradiated from the source of the thermal energy. That was the imitation of the thermal energy accumulator. The procedure was conducted as follows. Both electro-heating sources of thermal energy and water supply to the refrigerator was turned in, and the water temperature was detected at the inlet T_1 and outlet T_2 of the refrigerator. The process of heating continued until the stable level of T_2 temperature got established that was like natural sunshine. After that, feeding the thermal energy source was cut, and the duration t_b of water temperature decrease from T_2 to T_1 was measured imitating cloudiness. After that heating was cut in up to T_2 , then heating was cut off, the refrigerator and container with water were covered with the casing of light-reflecting film followed by time t_a detecting of water temperature decrease from T_2 to T_1 . Such operation was like the solar collector feed from the accumulator.

The generalized scheme of temperature change is represented in Figure 3 where b line characterizes the mode of water cooling in the collector without the accumulator while lining a – that using the accumulator.

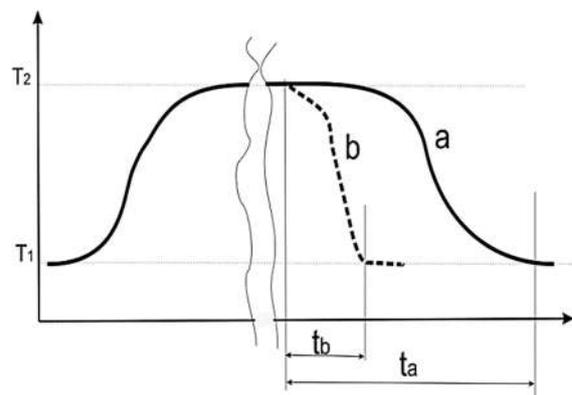


Figure 3 – The scheme of the heat carrier's temperature change at the outlet of the collector at cloudiness (a) and regular sunlight (b) [11]: T_1 and T_2 corresponds to the initial temperature and that at the outlet of the collector mockup, respectively; t_a and t_b are the corresponding time of water temperature decrease with and without the accumulator

Distance L between the source of the thermal energy and the refrigerator was altered all steps having been repeated. Corresponding findings are represented in Table 2

Table 2 – Modes of water cooling for different versions of the collector's operation [11]

L , cm	T_1 , °C	T_2 , °C	t_a , XB	t_b , XB	$t_b - t_a$, XB
20	25,0	29,5	10:00	35:00	25,00
25	25,0	28,1	6:02	28:00	21,58
30	25,0	27,5	4:35	11:00	6,25
35	25,0	26,1	3:10	7:00	3,50
40	25,0	25,4	1:20	2:00	0,40

In the decision to expand the work of solar installations and increase the level of additional heat after the cover of the Sun with clouds. They use a solar heat-collector wheel that reaches the solar hazard and solar water supply in the last solar radiation. The simulation results provided a strong hypothesis for the existence of additional solar collector energy to use the battery and redistribute its energy to the casing. The effectiveness of the proposed environment is confirmed.

The modeling results allowed the hypothesis substantiation on the possibility of new energy generation by the solar collector due to utilization of the accumulators, and redistribution of its power using the case. The effectiveness of the proposed device was confirmed.

The "Halemba" Mine (Poland) uses additional energy and uses them in solar panels. Considering that they make electricity at the mine in smaller shifts smaller, lower in the day. Own backup cats have installed solar panels, which have made the extra energy required for their operation, necessary and economical, but provided efficient working panels are used.

5 Conclusions

Application of the proposed design of the solar thermal collector the additional heat generation with the sunlight shielded with clouds as well as provision of stable operation of such solar installation. Therefore, the use of solar heat collectors is expedient in the systems of solar heating and hot water supply in the conditions of variable solar radiation.

The results of physical modeling established the effectiveness of the combination method of heat radiation and quantitative index, i.e. effectiveness got three times higher. Potential opportunities of alternative sources utilization are high enough and, what is exceedingly essential, safe for the environment. Thus, one can state that the substantial economy of mined fuel and energy resources is possible together with the improvement of ecologic characteristics of power supply.

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