Research of changes in the efficiency of renewable energy depending on external influences

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Abstract. The article presents the results of a study of renewable energy sources (RES) based on solar panels, the operation of which took place in the Irkutsk region. The results of changing the efficiency of the solar panels depending on the use of light energy concentrators and the temperature of the panel itself are presented. The authors set the task of increasing the efficiency of the solar panels through the use of technical and constructive solutions. The experiments were carried out in the laboratory of IRNITU "Modern Heating Equipment". For testing, we used a bench based on the TPM138 measuring regulator, an OVEN device of the IMS-F1.SHI brand with a set of thermocouples. The subject of the study was two solar panels, on one of which a Fresnel lens was installed. The article formulates the purpose and objectives of the study, conducted research on the parameters of solar panels depending on the influence of the light energy concentrator and temperature changes on the panel itself, depending on external influences. As a result of the work, it was found that the efficiency of solar panels in the Irkutsk region in the summer period of time decreases by an average of 14.5%. And in the winter time by 7.5%. It is shown that to increase the efficiency of solar panels it is necessary to apply technical and constructive solutions that will reduce the payback period of solar engineering systems by 10-18%.

1. Introduction
Unlike most developed countries, for our country the issue of developing and introducing new energy sources is far from relevant. In our country, extensive research is traditionally carried out in the use and production of oil, natural gas, coal, electricity. Despite the fact that oil and gas reserves are not unlimited, there is a potential reserve for our country, which allows us not to actively search for alternative energy sources. On the other hand, the real consumer is faced with a constant increase in the cost of traditional sources of heat and electricity and their unstable operation, which forces him to look for more promising and reliable options. An analysis of existing life support systems in the Irkutsk region showed that, in parallel with traditional energy sources, solar energy is preferred as a backup energy source. Basically, in these systems, solar hot water systems and solar power supply systems worked well. Despite our climatic conditions, a certain difficulty in operation, high cost and the likelihood that the profit from the introduction of such systems will not be able to cover costs, the devices are widely used [1-2].

Solar backup systems are very popular in our region, despite the fact that we have the cheapest electricity. Vast territories, climatic conditions, branched and outdated networks do not always guarantee a stable supply of energy to consumers. Therefore, studies in the field of the efficiency of
solar cells, depending on various factors, are relevant, and these works should be carried out in the aspect of practical application.

2. Literature review

For a number of reasons, including because of the huge reserves of energy raw materials, the issue of using renewable energy sources in the energy complex of Russia was practically not considered. In recent years, special attention has been paid to the use of renewable energy sources [3]. This is mainly justified by the need to fight for new opportunities to improve the quality of life of people living outside the city, the desire to improve the energy efficiency of the equipment used. Renewable energy sources are seen as a significant addition to traditional ones, with particular attention being paid to solar energy.

Solar energy has been used in engineering systems since the inception of mankind, when the concept of "engineering system" has not yet been invented. The International Energy Agency predicts that by 2050, solar energy will account for 27% of global energy consumption, and it will become the largest source of energy. In the coming years, the total capacity of photovoltaic stations in the world may double [4]. The leader in commissioning new solar power capacities is China. According to the closest forecast, by 2020 the total capacity of solar power plants will reach 110 GW. Analysts already predict a 10 percent decline in the cost of solar energy per year. Many world scientific schools are engaged in increasing the efficiency of solar installations. The main scientific direction is associated with improving the characteristics of semiconductor materials used in the manufacture of solar cells [5]. In addition, there are many works where the efficiency of solar cells is increased through the use of new design solutions and additional equipment [6].

One of the most promising areas of research in this area is the use of solar energy concentrators using Fresnel lenses. The Fresnel lens is one of the first devices whose operation is based on light diffraction. Despite a number of significant drawbacks that limit the range of application of these lenses in industry, they find their application in devices for the concentration of light energy.

Scientists from NASA conducted a series of experiments with these lenses to create miniature solar systems called SolarVolt [7].

A new installation using Fresnel lenses increased the luminous flux by twenty times. At the same time, final electricity production increased by 15 percent. In solar panels, such lenses were used with a thickness of only 0.2 millimeters.

When using lenses, the concentration of sunlight occurs on a smaller area, which allows to reduce the overall dimensions of installations without losing the amount of generated electricity. Due to new technologies, the size of solar panels is significantly reduced, and during the reconstruction of existing stations, their productivity will increase with the same occupied area [8].

Homemade solar panels using lenses were installed in California back in 1998 to provide electricity to a private home. Over the past 10 years, scientists from different countries have made great strides in the technology of manufacturing thin lenses for solar electric panels [9-12].

The most famous large company that tried to introduce lens solar cells was SolFocus (California, USA). In 2006, they were able to develop compact solar cell lenses. To create them, much less silicon was used than on conventional panels, since they used lenses and mirrors to concentrate sunlight.

In addition to the Americans, Russian and foreign scientists worked in the direction of creating solar concentrators for generating electric energy [13-14]. A large contribution in this direction was made by the Russian scientific school from Rostov-on-Don [15].

Using the technology of concentration of solar energy, Russian scientists managed to increase the efficiency of solar panels to 40%, and in field trials the efficiency of the installation reached 28.5%. In addition, the researchers noted that the use of solar energy concentrators is limited by the amount of solar energy entering the conditional area of the photodetector, with a significant concentration of energy, the panel overheats, and as a result, its efficiency decreases. Research in this area is carried out by many Russian scientific schools, mainly their research is geographically related to the location of the scientific organizations in which they work. But, based on the results of them research, it is necessary to carry out further work in the field of technical and structural solutions that will favorably affect the efficiency of solar energy systems [16-18].
3. Materials and methods
The experiments were conducted on the territory of the Irkutsk National Research Technical University in the laboratory "Modern Heating Equipment".

To measure the parameters of solar engineering systems, a bench was used based on the TPM138 counter-regulator, a universal eight-channel counter-regulator designed to build automatic control systems and regulation of production processes. Signals from thermocouples were recorded by this device using standard software supplied with the devices (OwenProcessManager).

The obtained graphs of changes in the parameters of solar engineering systems were imported into the MS Excel program. Monitoring of voltage, current, power was carried out by an OVEN company instrument of the IMS-F1.SH1 brand.

The OVEN device of the IMS-F1.SH1 brand is designed to measure electrophysical parameters such as voltage, current, frequency, apparent, active and reactive power and power factor.

For the experiments, a solar panel and a panel with Fresnel lenses from Delta were used.

4. The results of the study
The dependence of the efficiency of a solar panel on the temperature on its surface is a known fact. In the city of Irkutsk, the average temperature range extends from -20 to +30°C. The measured surface temperature of the solar panel showed that in winter on sunny days, the surface temperature reaches 40 °C, and in summer up to 70°C. In order to measure the real values of the dependence of the efficiency of the solar panel on temperature, with a stable light flux, we heated a pre-cooled panel from a temperature of -20 °C to a temperature of 110 °C. The change in voltage as a function of temperature is presented in Table 1 and in Fig. 1.

**Table 1.** dependence of the output voltage of the solar panel on temperature

| Temperature, °C | -15 | 0 | 15 | 30 | 45 | 60 | 75 | 90 | 105 |
|-----------------|-----|---|----|----|----|----|----|----|-----|
| Voltage, V      | 2   | 1,9 | 1,85 | 1,75 | 1,65 | 1,5 | 1,2 | 0,7 | 0,4 |

**Figure 1.** The graph of the dependence of the output voltage of the solar panel on temperature.

On a sunny summer day at 10 a.m. two solar panels were installed, one of which had a Fresnel lens. The temperature change on the panel depending on the operating time is shown in Fig. 2.

The graphs show that, being under constant solar radiation, the panel heats up the entire period of time, the heating process does not reach a stationary state. With a Fresnel lens, the heating process is faster, over the same period this panel heats up to 55 °C, and without a Fresnel lens to 42 °C.

When measuring temperature, was also measured the generated voltage on the solar panels at a current load of 1A. The experimental data are presented in graphical form in Fig. 3, table 2 presents
the numerical values of the generated voltage and changes in efficiency (K,%) depending on the time of day.

**Figure 2.** A graph of temperature versus operating time of the solar panel. Θ - with a Fresnel lens. Δ - without a Fresnel lens.

**Figure 3.** Graph of the dependence of the voltage change on the solar panels at a current load of 1A. □ - with a Fresnel lens. ◊ - without a Fresnel lens.

**Table 2.** Dependence of the voltage change on the solar panels at a current load

|       | U1,B | U2,B | K, % |
|-------|------|------|------|
| 0     | 1,6  | 1,9  | 20   |
| 1     | 1,7  | 1,8  | 10,5 |
| 2     | 1,65 | 1,85 | 8,3  |
| 3     | 1,65 | 1,8  | 11,1 |
| 4     | 1,55 | 1,85 | 13,2 |
| 5     | 1,55 | 1,6  | 13,9 |
| 6     | 1,5  | 1,3  | 13,5 |
| 7     | 1,6  | 0,9  | 18,8 |
| 8     | 1,3  | 0,6  | 25,0 |
| 9     | 0,9  | 0,45 | 14,3 |
| 10    | 0,6  | 0,4  | 11,1 |
5. Discussion and conclusions

Analyzing the results, we can conclude that additional measures to remove excess thermal energy from the solar panel will help increase efficiency by about 20%. Analysis of the voltage dependence graphs on solar panels with Fresnel lenses installed shows that at the initial moment the efficiency of a solar panel with a Fresnel lens is much higher than the efficiency of a panel without a Fresnel lens. The installation process was carried out at 10 o’clock, by 12 o’clock in the afternoon, despite the increase in the intensity of solar radiation, the efficiency of the panel with a Fresnel lens decreased, and the efficiency of the panel without a Fresnel lens increased. This effect is easily explained by the fact that with the installation of a Fresnel lens, the mass of the device increased, and, accordingly, its heat capacity increased. The heating process continued over time, in addition, as the solar radiation increased, the temperature of the solar cells increased, while the heat transfer region calculated for a certain amount of solar radiation remained. Table 2 and Figure 3 show that in the main period of time, when most of the electric energy is generated, the average value of the efficiency of the solar panel is 10.8%. But at the same time, it is clear that if additional cooling of the panel is provided, then its effectiveness will also increase. The results showed that seasonal changes in the weather in sunny weather affect the energy parameters of solar panels, and the temperature of the panels in the summertime heats up to a temperature of 70 ºC and higher.

The data obtained showed that the efficiency of the solar panel in the hot season decreases by an average of 14.5%. In winter, solar panels heat up to a temperature of 40ºC, and the efficiency of solar panels decreases by an average of 7.5%.

By organizing activities for the concentration of solar energy and providing stabilization systems for temperature parameters on solar panels, it is possible to increase the efficiency of these devices. In accordance with this, the payback period is reduced.

When using Fresnel lenses, efficiency increases by an average of 10% with minimal investment. It is also seen that, by changing the design of the solar panel, increasing only the heat transfer area on the back side, it is possible to increase the efficiency by at least 8% when implementing the measures described in this article, the payback cost of solar engineering systems can be reduced by 10-18%.

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