The influence of some natural factors on efficiency of operation of photoelectric elements under conditions of North Kazakhstan

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Abstract. The article presents the results of studies of some natural factors on the productivity of solar cells. In the study of output characteristics, the dependence of the generation of electrical energy on the number of incident solar radiation on photoelectric converters was obtained. From these characteristics it can be precisely said that the dependence of the operating current and voltage on solar radiation and temperature is not completely proportional. The humidity exerts the most insignificant influence on the solar installation. Particular attention should be paid to the dependence of voltage changes on the magnitude of solar radiation. It has been revealed that in low power plants the influence of temperature will not play an extremely important role on the output parameters, but at higher powers the losses associated with the increase in temperature will be correspondingly large. The generation of electrical energy from solar photoelectric converters depends on many factors, not only on incoming radiation, but also on aspects such as: the location of the solar transducer to the sun, pollution of solar cells, icing and snow cover of solar cells. In this scientific work was made an analysis of the effect of snow precipitation on the productivity of solar cells in the characteristic climatic conditions of North Kazakhstan.

1. Introduction
The generation of electrical energy from solar photoelectric converters depends on many factors, not only on incoming radiation, but also on aspects such as: the location of the solar transducer to the sun, pollution of solar cells, icing and snow cover of solar cells. All these factors significantly affect the output parameters of solar cells [1, 2]. The use of systems for tracking the sun is not always justified from the point of economic indicators view, especially for low-power photovoltaic installations. Therefore, the installation, as a rule, should be installed under a certain average angle of inclination; this solution is cheap and simple. Installation of solar panels at an angle is not always effective. This efficiency depends on the location of the power plant. For Kostanay region such a decision is certainly justified in the summer, but during the period from November to April installing the solar panel at an angle may not be entirely expedient [3]. It often snows in Kostanay and a heavy snow storm takes place to be, and in the autumn and spring the frost falls on trees and buildings, which subsequently fall to the ground, all of which adversely affects the efficiency of using solar panels [4]. Therefore, studies
were conducted in winter with vertically arranged solar panels in comparison with solar panels at an angle.

2. Materials and methods
The objects of research were solar cells and batteries. The methodological basis of the research was formed by general scientific methods of cognition: scientific abstraction, analysis and synthesis, systemic and structural approaches. The research used methods of mathematical analysis, subject-logical and structural-functional analysis [1, 4, 5].

For the analysis was used an installation consisting of three elements of 250 W each, all elements connected in parallel.

The research was conducted as in below:
1. The solar battery was gradually cleaned of snow, while the open-circuit voltage and operating current were measured.
2. The solar battery was gradually filled with snow and also the output parameters were measured.

After that the dependencies were constructed, which revealed that: the greater the probability of snowfall precipitation during the winter period, the greater the efficiency of using solar panels located in an upright position.

The most effective angles of inclination of the solar panel for the vernal equinox and the inclination angle in the winter and summer periods under the calculated climatic conditions of the Kostanay region were preliminarily investigated.

Preliminary studies have shown that the most unfavorable months are December and January, where the declination of the Sun is from 18 to 24 °. The city of Kostanay is located at latitude of 53.1°, and for this latitude the effective angle of inclination equals to 74.4 ° has been calculated. The duration of illumination in June with the same decline will be 16.17 hours. Kostanay region is characterized by abundant snowfalls in winter, so the location of the solar battery at a small angle is critical, as it contributes to the settling of snow on the solar panels.

3. Results and discussion
The main criterion for the operation of a solar cell is the magnitude of solar radiation. The solar radiation that comes to the surface of the earth is divided into two types [6]: The aggregate of direct and scattered radiation is the total radiation, and is found by the expression (1):

$$H = H_N \cdot \sin X + H_d = H_d + H_D$$

where: $H_D$ - the direct radiation; $H_d$ - scattered radiation index.

To study the dependence of the generation of electrical energy on the illumination of the solar battery, high-tech equipment of the university was used. This equipment consists of converters and their components (Figure 1).

![Figure 1. Schematic diagram of the research installation.](image-url)
region. The solar cells themselves have a crystalline base and are fixed vertically and are directed to the south.

To study the indices of solar radiation and generation of electricity, part of the circuit shown in Figure 1 was used. Three photoelectric converters of 250 W were used, and the readings were taken directly at its common output. Measurements of solar radiation and output parameters were carried out at different times of the day.

To fully assess the effect of solar radiation and other external conditions on the performance of the solar cell the graphs were constructed (Figure 2).

![Figure 2. Graph of dependence of output parameters on external factors.](image)

If we analyze the graphs in Figure 2, then we can accurately say that the dependence of the operating current and voltage on solar radiation and temperature is not completely proportional. The most insignificant influence on the solar installation has the humidity. Particular attention should be paid to the dependence of voltage on solar radiation. Solar radiation began to be registered from 07:03 am to 10:07 pm. The peak of solar radiation fell at 14 hours 00 minutes and amounted to 767 W/m^2. The voltage at the output of the solar photovoltaic system appears even in low light, but the operating voltage is reached at 160 W/m^2, and is observed from 8:00 am to 10:00 pm. Also, an interesting fact is observed with the temperature dependence. For example, according to the graph, it is seen that in the vicinity of 11 am the voltage had its maximum of 34.9 V, and then the voltage began to slightly drop while solar radiation and temperature grew. Of course, in a photoelectric installation of a small power the effects of temperature will not play a very big role on the output parameters of the element, but when it comes to high power the losses associated with the increase in temperature will be correspondingly large. Especially the effect of temperature on the performance of the solar battery will be significant when it reaches a mark of 40 degrees Celsius. The electric current in this circuit is very small, since the battery was fully charged. The current in the graph represents a straight line; this indicates that the electrical load did not affect the parameters under study in any way.

To analyze the effect of snow precipitation on the output parameters of the photoenergetic converter the research method was used, which consists in alternating cleaning of the panel from snow by 10% [7].

During the experiments, the open-circuit voltages Uoc and operating current I were measured, then all this was compared with the maximum power of the unit. The instrument readings are given in Table 1.

This installation consists of a mechanism for adjusting the inclination of solar cells, a site for batteries, a frame, a fastener for solar cells and a hinge that allows rotation.
Table 1. Output parameters of panels depending on the snow layer.

| Snow cover | 10%  | 20%  | 30%  | 40%  | 50%  |
|------------|------|------|------|------|------|
| U<sub>OC</sub>, B | 18.30 | 16.20 | 14.40 | 13.30 | 12.40 |
| I<sub>SC</sub>, A   | 0.61  | 0.31  | 0.28  | 0.21  | 0.12  |
| Snow cover | 60%  | 70%  | 80%  | 90%  | 100% |
| U<sub>OC</sub>, B | 11.80 | 11.10 | 10.10 | 8.80  | 2.50  |
| I<sub>SC</sub>, A   | 0.1   | 0.09  | 0.05  | 0.04  | 0.01  |

According to the measured data of the open-circuit voltages the dependence of its magnitude on the area of the snow layer is constructed (Figure 3).

![Figure 3](image1.png)

**Figure 3.** Dependence of the open-circuit voltage on the degree of snow covers of solar panels.

![Figure 4](image2.png)

**Figure 4.** Dependence of the short-circuit current on the degree of snow cover of solar panels.

Based on the measured short-circuit current data, the dependence of its magnitude on the area of the snow cover is constructed (Figure 4).

To illustrate the analysis of the dependence of the generation of electrical energy from solar photoconverters, one more graph is constructed - the dependence of the generated power on the coating of the photoconverter with snow (Figure 5).

For a more accurate analysis of the generation of electric energy of the photoenergy installation, depending on the coverage of the photocells by snow sediments, more measurements were made [8]. The essence of such measurements is in a smooth coating of photocells with snow thickness from 0 to 6 mm, while reading the output parameters. The dependence of the open-circuit voltage on the
Figure 5. Dependence of power on the degree of snow cover of solar panels.

Figure 6. Dependence of the open-circuit voltage on the thickness of the snow cover.

Figure 7. Dependence of the short-circuit current on the thickness of the snow cover.

Figure 8. Graph of the dependence of the generated power of the photoenergy installation on the thickness of the snow cover.
thickness of the snow cover is shown in Figure 6.

Similarly, according to the above operation, the dependence of the short-circuit current on the magnitude of the snow cover was measured (Figure 7).

The resulting dependency graph of the generated power of the photovoltaic installation on the thickness of the snow cover is constructed (Figure 8).

Analyzing all the measurements and dependences according to the two methods, it can be said with certainty that for the Kostanay region to install solar panels in the winter period is more effective in the vertical way. The efficiency curves of the proposed method of panels are shown in Figure 9.

**Figure 9.** Efficiency of a photovoltaic installation depending on the amount of covering snow.

In this graph, below the numeral 1, the loss point for the vertical orientation of the solar cells is shown. Under Figure 2, the minimum level of efficiency is shown. Under Figure 3, the power advantage indicator for the vertical position is shown.

### 4. Conclusions

The conducted studies of the energy parameters of solar cells have shown that to date the efficiency of solar cells does not exceed 25.7%. Despite this, it was possible to develop solutions that will allow more efficient use of solar cells. In the study of output characteristics, the dependence of the generation of electrical energy on the illumination of the solar battery was obtained. The orientation of the solar cells relative to the position of the Sun has been studied. Optimum angles of inclination of the solar battery for the Kostanay region were calculated. For the summer period, the effective tilt angle is - 31.9 °, for the winter period - 74.4 °. Despite these design angles, it is also necessary to take into account the natural conditions of the installation site of the solar station. Also, when choosing the power of a solar battery, it is necessary to take into account the operating conditions of photovoltaic cells: in order not to turn out that in winter the electricity production would be normal, and in summer with excess. To prevent this phenomenon, it would be economically correct to take the average angle between the summer and winter periods, in our case it was 53.2 °.
An analysis of the effect of snow fall on the productivity of solar cells was made. By virtue of these studies, it was revealed that the greater the probability of snowfall precipitation during the winter period, the greater the efficiency of using solar panels located in an upright position.

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