The Influence of Snow Cover on the Power Generation from PV Panel in the Northern Part of the Russian Far East

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***Abstract*—The aim of this paper is to present a method to protect and reduce the impact of snow cover on the surface of PV panel in the northern part of Yakutia by showing graphs of the thickness of the snow cover on the panel surface and its influence on reducing the power generation of the panel before and after applying the proposed method. Experimental studies were carried out in the winter period of 2021 in the central part of Yakutia. In the course of the article, a method of protecting PV panels was used in the form of an additional coating based on polishing. In addition, a method was used to determine the statistical indicators of PV panel strength.**

***Keywords*—PV panel, solar, Yakutia, snow cover, monitoring**

I. Introduction

The rapid development of photovoltaic (PV) technology over the last decade has led to solar electricity generation on an unprecedented scale. It is now becoming feasible and economically viable to cover an increasingly larger energy demand with solar energy production almost all over the world, even in the boreal and polar regions.

While the solar radiation in these regions is of comparatively low intensity, and energy production will be greatly reduced during the winter, photovoltaic cells remain a viable source of energy for parts of the year.

The sustainable development of solar energy have a big role in the development of centralized and autonomous electric power systems in any countries. Yakutia is located on the II-V zones by the weight of the snow cover [1], and the average annual ambient temperature is -12 ^{0}C [2]. The energy system of Yakutia consists of 4 regions: Central, Southern, Western and Northern.

A significant part of the power districts of Yakutia has a centralized energy supply system, while the northern part has an autonomous system, consisting of groups of diesel generators, gas turbines, wind and PV plants.

The reason for introducing renewable energy facilities in the northern energy region is due to the need to increase reliability of energy supply in the context of a low level of development of transport infrastructure.

Due to the operation of renewable energy facilities in the Yakutia Territory, more than 350 tons of fuel were saved in 2020, which is equivalent to a reduction in carbon dioxide emissions of 1123 tons in the atmosphere. According to the plan and program for the development of the electric power industry in Yakutia from 2020 to 2024, it is planned to build 60 new wind and solar power plants [3].

However, in order to ensure the sustainable operation of the planned facilities when combined with renewable energy, it is necessary to take measures to improve the electric power efficiency, including for solar power plants.

External factors that significantly reduce the efficiency of operation of solar energy facilities are [4]:

1. Dust contamination of the PV-panels surface.

2. Snow cover on the PV-panels surface.

3. Seasonal increase in the number of cloudy days.

4. Seasonal air pollution caused by forest fires.

Fig.1 and Fig. 2 show the consequences of the factors influence 1 and 2, respectively, on the functioning of solar panels.

Fig. 1. External views of solar panels with a clean and dusty surface

Reducing the influence of factors 3 and 4 is impossible due to the significant dependence on the general climatic features of the environment, but reducing the influence of factors 1 and 2 is quite possible when certain methods and methods are applied. In this regard, the development of a method for reducing the impact of snow cover on the solar panels surface at low temperatures is relevant and in demand.

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Fig. 2. Exterior views of solar panels with a snowy surface

II. Review

The reference [5] describes field tests of a solar power plant in Antarctica. The operation of this facility is possible with constant cleaning of the solar panels surface from snow cover, which significantly reduces the generating power. Due to changes in external climatic parameters of the environment, snow cover is intensively formed on the surface of the panels, so it is relevant to search for new ways to protect the solar panels surface from the formation of snow cover and ice.

There is an example in [6], where it is proposed to introduce an Extreme Rainfall Detection System (ERDS) to ensure uninterrupted operation of solar panels. It is noted that this plant does not work correctly under the influence of factors that limit the constant activity of solar energy (cloudiness, fog, smoke in the air, etc.). The main function of the proposed system is the early detection of the above external factors using optimal parameters for routing to the light source. However, these technologies have a high cost for the purchase of components.

There is a way to protect solar panels from dust pollution in the form of polishes, which reduce the risk of surface pollution. The main advantage of this method is the standard application of polishing to the solar panels surface, which provides protection against dust formation for 30 days at low material costs [7].

The references [8-10] present the results of solar panels affected by dust pollution and suggest technical solutions in the form of different panels cleaning systems that reduce the risk of surface pollution. The analysis showed that the existing studies are aimed to study the impact of dust and snow pollution on the operation of solar plants and finding technical ways to reduce their impact. Hence the importance of using polishing materials, as field studies will be conducted to prove the possibility of using polishing materials to reduce the risk of snow cover forming on the surface of solar panels.

PV technology faces certain challenges in cold climates. Snow and ice may form and accumulate on the panels, obstructing light from reaching the cells, thus hampering electricity production. Full or partial obstruction will significantly reduce the electricity generation of the panels, at a rate disproportional to the area being shaded [11]. Snow and ice may linger for extended periods of time after their formation, until it melts away or is otherwise removed. Forceful or careless removal of the snow may also damage the panels.

The reference [12] discusses other challenges of snow removal from photovoltaic solar cell roofs, summarizing roof-related issues that have to be dealt with to efficiently operate a photovoltaic system on a roof in snowy areas.

Fig.3 shows the statistics of snow cover thickness for recent years in Yakutsk.

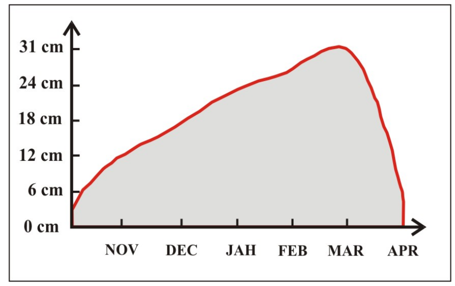

Fig. 3. Statistics of snow cover thickness

Fig.4 shows Statistics of snow cover density for recent years in Yakutsk.

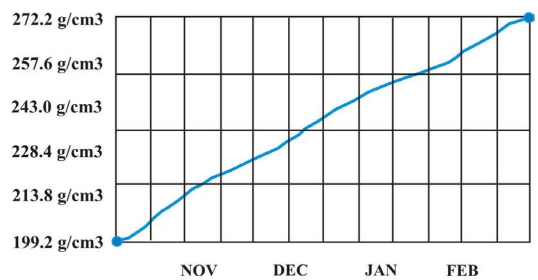

Fig. 4. Statistics of snow cover density

Fig.5 shows Statistics of air temperature for recent years in Yakutsk.

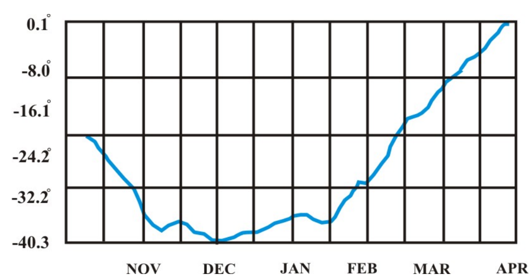

Fig. 5. Statistics of air temperature

III. Materials and Methods

Field studies were carried out in the winter period (October-November) 2021 in the northern part of Yakutia and an experimental setup [13-15] was used , consisting of: solar panels, charge controllers, batteries, auxiliary loads, recorders and software for processing data [16, 17]. The components of the experimental plant are shown in Fig.6.

Fig. 6. The components of the experimental plant

The location of the experimental work has the following indicators [18, 19]:

1. The duration of sunshine - more than 1700 hours per year.

2. The temperature minimum is -68 ^{0}C.

3. The temperature maximum is +40 ^{0}C.

4. The average annual precipitation less than 200 mm per year.

5. Soil type -stony and clay.

6. The presence of permafrost.

The procedure for carrying out experimental work has the following order:

1. Polishing is applied to the first solar panel, but is not applied to the second panel.

2. Placement of the first and second panels in the open air.

3. Registration of the electrical parameters of the installations and the thickness of the snow cover of the panels on a weekly basis during the day.

4. Taking into account the level of charge of the battery (the charge level is at least 30% in order to ensure the operability of the equipment and not more than 55% in order to prevent the battery from quickly charging).

5. Data processing of field studies.

6. Registration of the results of natural research [20-22].

IV. Results

In the course of studying the parameters of the operation of the experimental setup for the period of observation, measurements were made of the thickness of the snow covers formation on the polished and unpolished solar panels surface. Fig.7 shows a graph of the average snow cover thickness on the panels. From Fig.7, the analysis showed that:

1. On the 14-15th day of monitoring for the polished PV-panel, no snow cover was observed, but on the unpolished PV-panel, the thickness of the snow cover was 9-15 mm.

2. On the 16-31st day of monitoring for the polished PV-panel, the formation of a snow cover with a linear dependence is recorded at a thickness of 1-25 mm, but on the unpolished PV-panel, the thickness was up to 30 mm. Thus, the effectiveness of reducing the formation of snow cover when using polishes is substantiated.

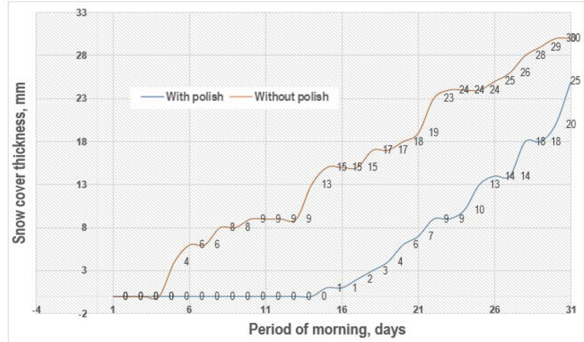

Fig. 7. The average snow cover thickness on solar panels

Table I shows the thickness of the snow cover on the surface of the polished and unpolished solar panel.

TABLE I. THE THICKNESS OF THE SNOW COVER ON THE SURFACE OF THE POLISHED AND UNPOLISHED SOLAR PANEL

№ week	Snow cover thickness, mm	
	Polished panel (%)	Unpolished panel (%)
0	0.00	0.00
1	0.00	8.00
2	1.00	15.00
3	9.00	23.00
4	18.00	29.00
5	25.00	30.00

Fig.8 shows the changes in power generation of the experimental polished plant with different monitoring times.

From Fig.8, the analysis showed that due to the formation of snow on the surface of the polished solar panel, the power generation of the experimental plant gradually decreased. A significant decrease in generating power is observed for the period from the 1st to the 2nd week of monitoring.

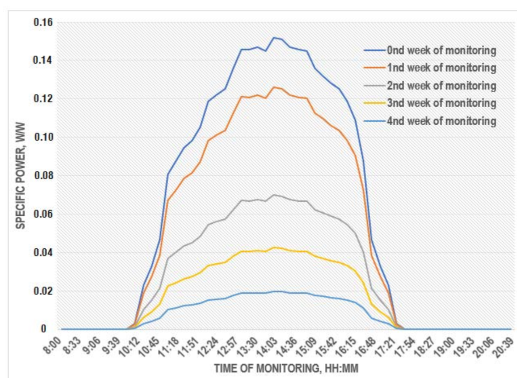

Fig. 8. The power generation of the experimental polished plant

Fig.9 shows a graph of the reduction in the generating power of experimental plant on polished and unpolished panels. The parameters are determined when calculating with indicators obtained during parallel monitoring with a similar model of a solar panel, but with a clean surface.

From Fig.9, the analysis showed that due to the influence of an increase in the thickness of the snow cover on the solar panels surface, the reduction in generating power increases, which has a polynomial and logarithmic dependence. It has been determined that when a snow cover forms on the solar panels surface with a thickness of 4 mm or more, the generating power of the plant is reduced by 40% or more.

Thus, small thickness of the snow cover can prevent direct sunlight from reaching the solar panels surface.

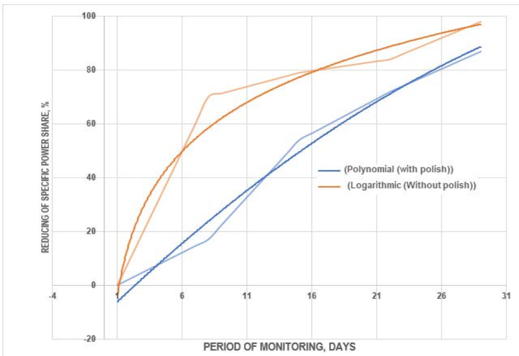

Fig. 9. The reduction in the generating power on polished and unpolished panels.

Fig.10 shows external views of solar panels for the monitoring period. From Fig.10 found that the period of effectiveness of the applied protection method based on polishes is 14-15 days. In later monitoring periods, snow cover is formed in almost the same way on polished and unpolished panels.

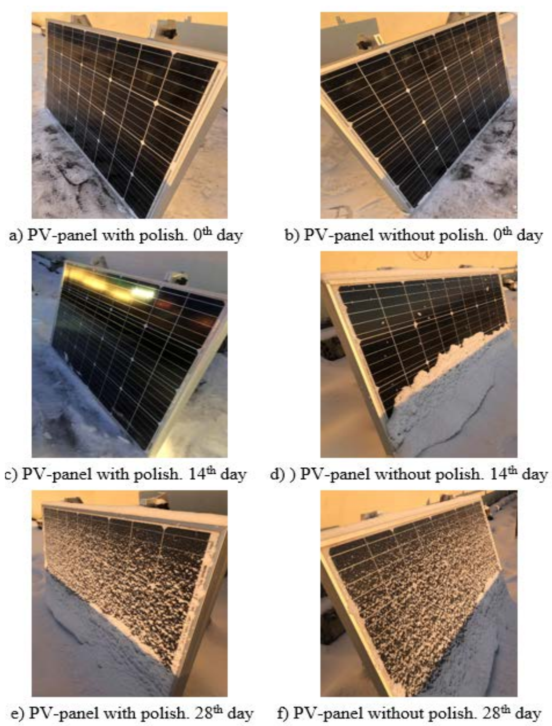

Fig. 10. External views of solar panels for the monitoring period.

TABLE II. THE REDUCTION IN THE GENERATING POWER OF THE EXPERIMENTAL PLANT DEPENDING ON THE MONITORING PERIOD.

№ week	Reducing the generating power of polished panel (%)	Reduction in the generating power of unpolished panel (%)
0	0.00	0.00
1	17.00	70.00
2	54.00	79.00
3	72.00	84.00
4	87.00	98.00

From Table II, the analysis showed that due to the effect of the polish on the surface of the solar panel, the formation of snow cover is significantly reduced. However, starting from the 2nd week of monitoring, there is a significant decrease in power generation due to the acceleration of snow cover formation.

Discussion

The authors of the article analyze the hypothesis of the possibility of using a method for protecting the surface of a solar panel from dust pollution in order to reduce the formation of snow cover on the surface of the panels.

As part of the justification of this hypothesis, the following provisions were obtained:

1. Field studies have been carried out to study the effect of snow cover on the functioning of the solar panel.

2. In the case of applying the proposed method, the risk of snow cover formation during 15-16 days at low temperatures is reduced.

3. During subsequent monitoring (3nd & 4nd weeks), the thickness of the snow covers on the surface of the polished solar panel increases linearly.

4. With the formation of snow cover on the surface of the solar panel, the generating power is reduced from 87 to 98%.

In this regard, through field studies, a hypothesis was proved about the possibility of using a method for protecting the surface of a solar panel in order to reduce the risk of snow cover formation in winter conditions.

The obtained results of the research can be applied in the development of practical recommendations for increasing the electric power efficiency of solar power plants for the winter period of operation.

Conclusions

1. Little knowledge of the effect of snow cover on the operation of solar power facilities in the conditions of the North leads to a difference between the actual and calculated (forecast) data for the generation of a solar power plant, which creates certain difficulties in assessing the potential of this type of plant.

2. As a result of field studies, indicators of the positive effect of introducing a method for protecting the solar panel surface from dust pollution were determined in order to reduce the formation of snow cover on the panels surface.

3. Due to the implementation of the above method, the thickness of the snow cover on the polished surface of the solar panel is up to 1 mm on the 16th day of monitoring, this is ensuring effective protection of the surface of the panel. However, with further monitoring, the cover thickness increases linearly.

4. It has been established that when a snow cover forms on the panel surface with a thickness of 4 mm or more, the power generation of the solar panel decreases by 40% or more. Thus, a significant effect of the thickness of the snow cover on the transmission power of the sun's rays is recorded.

5. The reduction in the generating power of the solar polished and unpolished panel after a month of monitoring was 87% and 98%, the thickness of the snow cover was up to 25 mm and 30 mm, respectively. This circumstance leads to the need for further research and development of a methodology for assessing the effect of snow cover on the zoning map according sunlight falling the solar panels surface to accurately determine the potential of solar generation.

6. The obtained indicators of the change in the generating power of the PV-panel before and after the application of an additional coating based on polishes can be used in the development of programs to improve the electric power efficiency of solar power facilities located in the territory of III-VIII snow regions in Yakutia, where the annual ambient temperature is in the negative rang.

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