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Development of Method of Protection of Solar Panels Against Dust Pollution in the Northern Part of the Russian Far East

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***Abstract*—The paper is devoted to research about the method of protection against dust pollution of the surface of a polycrystalline solar panel of small power in the northern part of the Russian far east (the territory of the North), where the article presents graphical interpretations of power generation depending on dust content parameters and calculation of changes in electric power generation parameters. The purpose of this paper is to find an effective method for protecting the surface of a polycrystalline solar panel of small power from dust pollution. The result of this article is the calculation and derivation of solar panel generation indicators with the presentation of graphical interpretations of power dependence on monitoring time. In addition, based on the calculated comparison of solar panel generation using various chemical liquid coatings, the article presents a specific type of chemical material that protects the surface of the solar panel from dust pollution and reduces the effect of adhesion properties on the period up to 15 days. Thus, the above-mentioned method of protecting the surface of the solar panel from dust pollution can be applied in research institutes and generating enterprises in order to increase energy efficiency and generate electricity in solar power plants in the northern part of the Russian Far East.**

Keywords—Polycrystalline solar panel, dust, pollution, performance monitoring, EPEVER

I. Introduction

The electricity supply to the territory of the North is usually provided by traditional energy sources like diesel generators, gas turbine plants, and others. For example, in the Republic of Sakha (Yakutia) territory, 143 diesel power plants, and 23 solar[1],[2],[3] power plants (another 5 are planned to be commissioned until 2024), and 2 wind power plants. The introduction of renewable energy sources in the electric power system of Yakutia is justified by the need to achieve a diesel fuel economy in conditions of high prices and long transportation times. However, it should be noted that the main areas of renewable energy, subject to operation in the northern part of the Russian Far East, are wind energy, small hydro energy, and solar energy [4],[5],[6].

Fig.1 also shows a map of the average annual wind speeds in Russia, where it is clear that the construction of wind farms in the northern part of the Far East is possible in the northern part of Yakutia and Chukotka. Thus, the introduction of wind power for power supply to remote consumers of the North is impractical[7],[8].

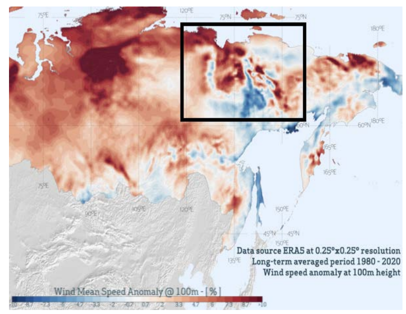

Fig. 1. Map of the average annual wind speed of Russia.

Small hydropower has its drawbacks, such as high cost of equipment and construction procedures and a small period of positive environmental temperatures (no more than 4 months per year), where Fig.2 shows the monthly average temperature in the village of Belaya Gora, which is located in the northern part of Yakutia at the following geographical coordinates 68° 32' 16.3" north latitude and 146° 11' 05.2" east longitude [9],[10].

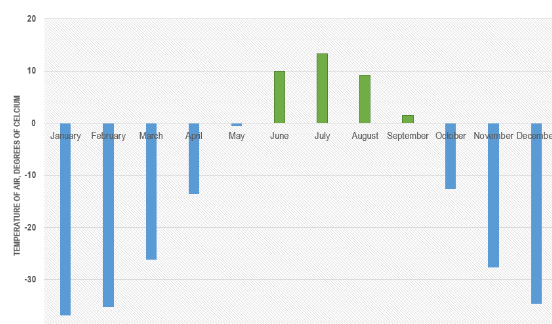

Fig. 2. Graph of annual month temperature in Belaya Gora.

Thus, the introduction of small hydropower facilities in the North and the Arctic is technically and economically impractical.

Fig.3, Fig.4 show maps of the duration of sunshine and solar insolation in Russia [11],[12],[13]:

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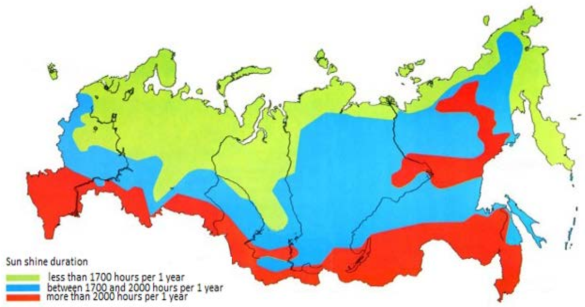

Fig. 3. Map of solar duration in Russia.

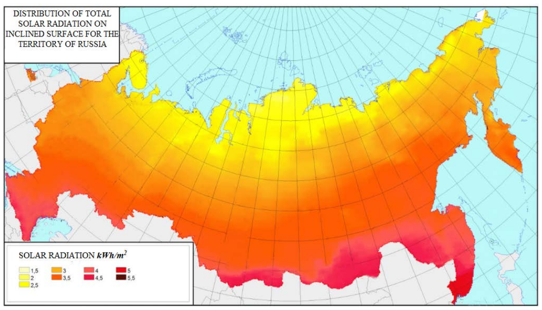

Fig. 4. Fig.4.Map of solar insolation in Russia.

During the analysis of the above graphical interpretations of solar[14],[15],[16] radiation in the northern part of the Far East, it is necessary to note the following points: Annual solar duration approximately 2000 h/year, annual solar insolation from 3.0 to 3.5 kw.h/m^2 in day, sunshine and solar insolation duration indicators in the northern regions of the far east (Yakutia, Chukotka and Magadan) are satisfactory for the design and construction of solar power facilities.

Thus, the introduction of solar power facilities in the north and the arctic is technically feasible [17],[18].

In 2020, P.I. Melnikov Institute of Permafrost Research of the SB RAS conducted a study to determine the main reasons for the high degree of a dusting of the environment in Yakutsk which are [19],[20]:

1. Type of soil inside and around Yakutsk. This reason is due to the prevalence of sandy-clay soils, which are converted to dust.

2. Anthropogenic factors. This reason is due to the formation of significant volumes of suspended particles that are contained in exhaust gases, and the import of sand and soils into the city from outside for the construction and filling of roads.

II. An Overview of Soil Quality in the Territory of Yakutia

The profile of pale-metamorphic soils, of relatively low power, is characterized by a combination of medium pale-metamorphic and accumulative-carbonate horizons.

Also, soils are slightly differentiated by color, structure, granulometric and gross chemical composition.

Fig.5 shows a photograph of soil in Yakutsk which consists of four layers (AJ-BPL-BCA -Cca) [21],[22].

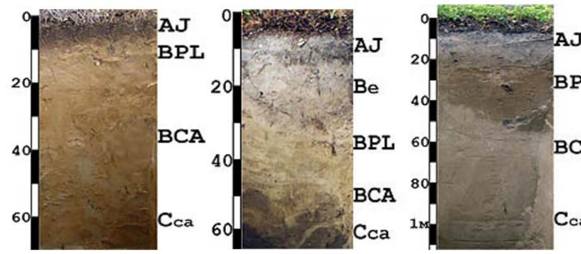

Fig. 5. External types of soil in the territory of Yakutsk.

Soils are diagnosed by light-humus, pale-metamorphic and accumulative-carbonate horizon. They are characterized by a slightly differentiated profile with a monotonous pale color, in which light-humus and whitish-light-brown accumulative-carbonate horizons are most noticeably distinguished. The light-humus horizon of fawn soils with a capacity of 15-20 cm has a grayish-light-brown color and a small powder-shaped structure. Due to the weak degree of humification of plant residues in its upper part, the horizon has some similarity to the gray-humus horizon, however, due to the saturation of the absorbing complex and the reaction of the medium close to neutral, it is defined as light-humus. The middle part of the profile is represented by a pale-metamorphic horizon, compacted. Pale soils occupy a strictly defined ecological niche. They form in the Taiga and Tundra zones of Central Yakutia and adjacent territories with an extracontinental seven-humid-semiarid climate, in the area of continuous permafrost, the upper boundary of which does not drop below 1–2 m during the period of maximum thawing [23],[24].

The Yakutsk Department of the Hydrometeorological Service submits a report about air quality in the territory of Yakutsk that the level of atmospheric air pollution in April is increasing. The increased degree is determined by concentrations of suspended substances (dust) and phenol. The highest dust repeatability was **6.6%,** the daily maximum permissible concentration reached 1.3 **MPC$_d$**, the average monthly - **1.6 MPC$_m$.** The recurrence of excesses of MPC (maximum permissible concentration) in phenol was 1.9%, the standard index was 1.2.

Fig.6 shows a graph of the composition of air pollution in Yakutsk, colored red.

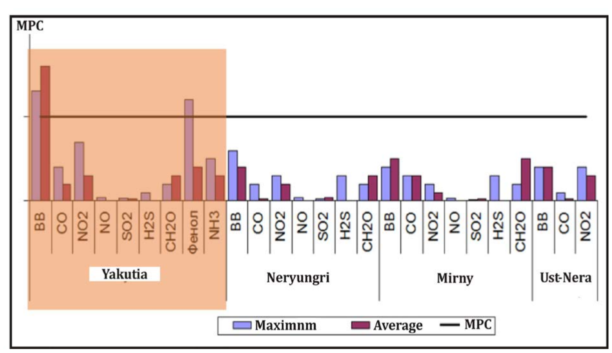

Fig. 6. Graph of the composition of air pollution in Yakutia

Thus, in Yakutsk there is significant air pollution by suspended substances (dust, soot, smoke, etc.), which is also one of the main catalysts for increasing the degree of dust content in Yakutsk. In this regard, the construction of solar power plants at a close distance from settlements and roads is not recommended [25],[26].

III. Materials of Experiment:

Let us turn to the development of an experimental low-capacity solar power plant (150 W) which consists of the following components:

1. Polycrystalline solar panel with output 150W. Type: polycrystalline. Mark: Delta-150-12p.The choice of this panel model is justified by the possibility of the unit operating at temperatures from -40C to + 80C, which fully corresponds to the climatic conditions of the cold climate of the north.

2. charge controller (Tracer2210 AN).

3. 75 Ah Delta battery.

4. Load (lamp 7.5 W).

5. MPPT solar charge controller (EPEVER).

6. Personal computer.

7. EPEVER software.

The solar power plant 150 W which we use has certain advantages: the dimensions (1*1*2)m^3,weight 30 kg, possibility of monitoring power plant operation by electric power parameters (current, voltage and power) [27],[28].

Fig. 7. The Components of solar power plant 150 W.

TABLE I. List of Liquid Coatings to Be Used to the Surface of the Solar Panel[29],[30]

№	Name of polish	Type of polish	Country	Structure
	Sample №1 «Sonax Profi Line»	Silicon	Germany	Emulsion consisting of wax, silicone, solvents and water, abrasive
1.	Sample №2 «AUTO GLASS CLEANER»	Alcohol	UK	Water, isopropyl alcohol, butter alcohol, perfume, dye, nonionic surfactant, etc.
2.	Sample №3 «Lavr Fast Wax»	Wax	Russia	Synthetic wax, aliphatic alcohol, organic acid, distilled water

After assembly of the unit (solar power plant 150 W) the method of search of the best liquid is developed for painting on the surface of the solar panel for ensuring protection against dust pollution, that due to the effect of dust pollution where the generation of electricity from solar panels is reduced to 40%.

The experiments were carried out in March on the basis of the training ground of the V.P. Larionov SB RAS in Yakutsk at the following geographical coordinates: 61° 59' 45.7 "N, 129° 41' 10.7" E.

The choice of the angle of inclination of the solar panel is justified by calculations using the licensed program Drofa, where Fig.8 shows a cut of the results of these calculations, with the help of which the optimal angle of inclination of the solar panel is calculated depending on the latitude and observation period with instructions for use in 5 steps.

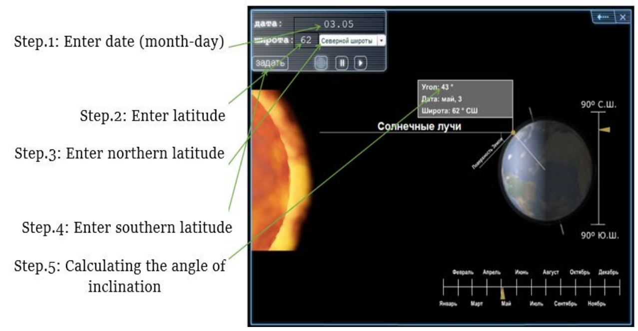

Fig. 8. Clipping from the licensed Drofa program

IV. Method of Experiment:

- Preparation and installation of the plant.
- Preparation of EPEVER.
- Test of the unit (solar power plant 150 W) serviceability.
- Turning the load (lamp 7.5 W), which is supplied from the battery through the unit charge controller.
- Painting the liquid to the clean surface of the solar panel.
- Placing the polished solar panel in the open air at the angle of tilt of the panel 47° relative to the surface of the earth.
- Starting record indicators (voltage, current and power) in sunny weather from 13:30 to 14:00 hours after midnight.
- Turn off the plant and processing the results of the experiment.
- Repeat the previous steps, but using a dusty panel.
- After that, clean the solar panel and use the next liquid and repeat the previous steps.

V. Results

Fig.9, Fig.10, Fig.11 show the external views of the polycrystalline solar panel, taking into account the use a liquid of (Sample №.1. №.2. №.3).

Where:

a) surface during polishing;

b) polished surface;

c) dusted surface (after 15 days of open air).

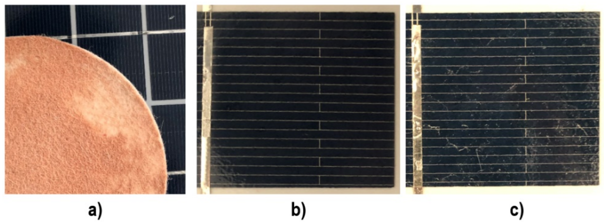

Fig. 9. Comparison of polycrystalline solar panel surfaces (Sample №.1)

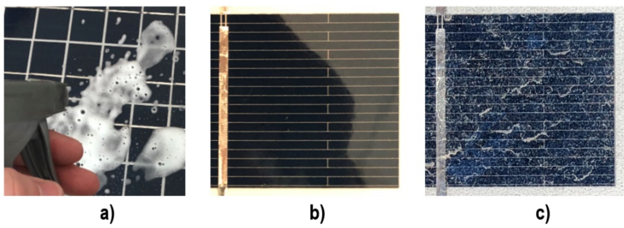

Fig. 10. Comparison of polycrystalline solar panel surfaces (Sample №.2)

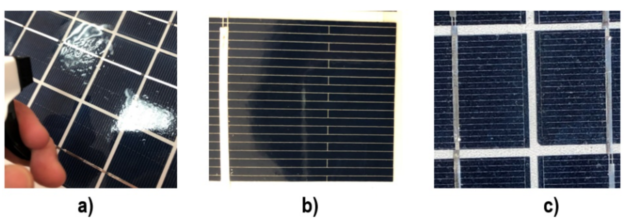

Fig. 11. Comparison of polycrystalline solar panel surfaces (Sample №.3)

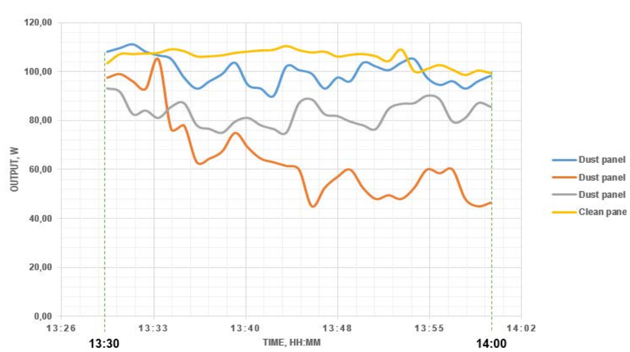

Fig. 12. Graph comparison of generation of polycrystalline solar panel with Samples №.1, 2,3. shows:

- A graph comparing the generation of the polycrystalline panel, which shows the panel power in blue using Sample №.1 (silicone), orange using Sample №.2(alcohol) and gray using Sample №.3 (wax).
- Sample №.1 (silicone) has higher power generation rates than Samples №.2 and №.3. It should be noted that all experimental procedures were conducted under the same conditions for each sample.

The reduction in power generation during dusting of solar panels is calculated by equation:

$$\Delta_n = \left(1 - \frac{\sum_{i=1}^{30} P_{idust}}{\sum_{i=1}^{30} P_{iclean}}\right).100\% \qquad (1)$$

where: Δ_n – indicator of power generation efficiency decrease;

n – sample number of liquid (№.1, 2,3);

P_{idust} – power index of the dusted solar panel in a certain measurement step;

i – measurement step number from 1 to 30;

P_{iclean} – power index of the pure solar panel in a certain measurement step.

Table.II presents the results of the calculations according to equation 1, which shows the reduction in power generation during dusting of solar panels using samples (№.1, 2,3).

TABLE II. INDICATORS OF REDUCTION OF SOLAR PANEL POWER GENERATION AFTER DUSTING.

Sample №	Type of polish	Δ_n %
1	Silicon	- 8.21
2	Alcohol	- 44.15
3	Wax	- 9.90

VI. THE DISCUSSION OF THE RESULTS

From the experiments:

- When using liquid based on silicone (Sample №.1), it was determined that after 15 days, the power reduction was 8.21% and Fig.9c visually shows slight spraying of the panel surface. Sample №.1 had the best performance.
- When using liquid based on alcohol (Sample №.2), it was determined that after 15 days, the power reduction was 44.15% and Fig.10c visually shows significant spraying of the panel surface. Sample №.2 had the worst performance.
- When using liquid based on wax (Sample №.3), it was determined that after 15 days, the power reduction was 9.90% and Fig.9c visually shows slight spraying of the panel surface.
- Fig.12 shows that the generation power of the solar panel when using Samples No. 1 and 2 have the best performance when compared to the average generation of a clean solar panel.
- When using liquid based on silicone, the user needs a polishing machine that requires a long time to apply a liquid layer and has a high cost (from 4,500 Russian rubles).

VII. CONCLUSIONS:

From experimental studies in the North, the hypothesis of the possibility of reducing dust pollution of the surface of the solar panel by selecting the most suitable type of liquid has been proved, followed by applying and calculating a reduction in generation power.

There is a future plan to update the mathematical program for calculating the operating parameters of a solar power plant using the results of the study, where the program received a certificate of registration of the program dated /23.12.2020/ №.2020667411.

As a result of experimental studies, a type of liquid was obtained (Sample No. 1 - Silicon) which had the best performance, where dust pollution of the surface of the solar panel is significantly reduced (Fig.9c), and the reduction in generation power 8.21% in Yakutsk.

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