Assessment of the Performance of the Solar Power Plant with a Capacity 150W

Nikolay Mestnikov
Institute of Physical and Technical Problems of North SB RAS,
NorthEastern Federal University
Yakutsk, Russia
Sakhacase@bk.ru

Ahmad Alzakkar
Kazan State Power Engineering University
Kazan, Russia
Ahmadalzakkar86@gmail.com

Ilgiz Valeev
Kazan State Power Engineering University
Kazan, Russia
Ilgizvaleev@mail.yandex.ru

Victor V. Maksimov
Kazan State Power Engineering University
Kazan, Russia
Viktor.maksimov.1968@mail.ru

***Abstract*—The article presents the results of experimental studies on electrical energy operations of solar power with a capacity 150 W, with which experimental studies were carried out in the form of a change in the angle of inclination of the solar panel relative to the surface of the earth, during sunny weather in summer. In the course of these experimental studies, we used:(computing and measuring equipment, polycrystalline solar panel 150 W, charge controller, inverter and energy storage system in the form of a battery with a capacity of 75 Ah). The results of these studies were addressed by analyzing the resulting curves and the impact of the resulting values on the external parameters in the form of regression equation depending on the programs (Microsoft Office Excel - Mathcad Professional).**

Keywords—regression equation, solar power plant, inclination angle, luminous flux, inverter.

I. INTRODUCTION

Unconventional energy sources in Russia can be effectively used to supply energy to consumers, especially in areas that are not covered by the centralized energy supply [1]. These zones include vast territories of Russia, in which about 20 million people live, as well as remote areas of the Far North, Siberia, and the Far East and rural areas, including the central part of the country (Arkhangelsk, Vologda, Kirov, Yaroslavl, and some other regions) [2].

A review of unconventional energy sources shows that there are currently a variety of types and methods of generating electricity. However, the experience and practice of operating facilities of non-traditional energy sources show that the most efficient, and in-demand are wind and solar power, specifically the parallel electricity generation with the subsequent creation of combined power plants for small consumers of reliability of electricity supply the Far Eastern regions of the Russian Federation, where decentralized power supply systems are active [3–6]. At the same time, when analyzing solar radiation indicators in Russia, it was established that the average annual solar insolation will be 3.5 kWh/m^2 in the middle band of Russia and [4.0-4.5] kWh/m^2 in the southern strip of Russia.

Also, when analyzing solar radiation duration indicators in Russia, it was established that the highest duration parameter is more than 2000 h/year in the southern strip of Russia and in the center of the northern part of the Far East of Russia, where the northernmost entity of the Russian Federation is located (the Republic of Yakutia).

However, in the main part of Russia, there are from [1700 - 2000] h/year of sunshine duration, which is the main parameter for the average efficiency of generating electricity from solar panels [7],[8].

In fig.1 and in fig.2 show a map of the duration of sunshine in the territory of the Russian Federation and a map of solar insolation in the territory of the Russian Federation are presented.

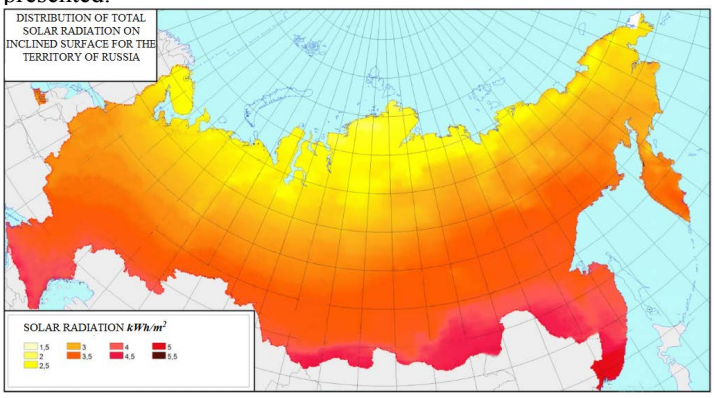

Fig. 1. Map of solar insolation in the Russian Federation.

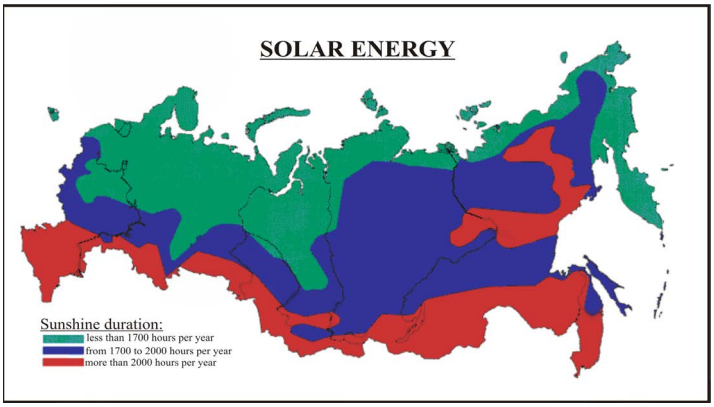

Fig. 2. Map of sunshine duration in the Russian Federation.

Thus, the operation of solar power facilities in Russia has several advantages for the possibility of increasing the share of

978-0-7381-3156-6/21/$31.00 ©2021 IEEE

generation with high sunshine duration in the southern and far eastern parts of the Russian Federation [9–13].

In this regard, a simple model solar power plant in the form solar panel with a capacity 150 W was developed and assembled, shown in fig.3 [14].

Fig. 3. The solar power plant 150 W.

During assembly of the solar power plant, the generation indicators (V, I, P) were calculated depending on the angle of inclination of the solar panel relative to the earth's surface [15].

II. List of Used Equipment Used in the Experiment:

- **Polycrystalline solar panel type (Delta- 150 W):**

The purpose of this equipment is to generate electricity from solar energy. Fig.4 shows Delta 150W solar panel [16],[17],[18].

Fig. 4. Delta 150 W solar panel-one unit.

- **Battery type (Delta - GEL75Ah):**

The purpose of this equipment is to store electrical energy from the solar panel. Fig.5 shows Delta battery type GEL 75Ah.

Fig. 5. Delta battery type GEL 75Ah-one unit.

- **Inverter type (IS3-12-600M3):**

The purpose of this equipment is to convert direct current (DC-12V) to alternating current (AC-220 V).

Fig. 6. Inverter type (IS3-12-600M3)- one unit.

- **iSTA Breeze (12V-650W) hybrid charge controller:**

The purpose of this equipment is to collect electrical energy from solar panel and wind generator and transfer it to the storage system (batteries).

Fig. 7. Ista Breeze 650W Hybrid Controller.

- **Digital multimeter type (Mastech -MY62 13-2019):**

The purpose of this equipment is to measure the voltage and current parameters at the terminals of the wind generator and the solar panel.

Fig. 8. astech digital multimeter MY62 13-2019.

- **Other equipment.**

A laptop to process the obtained experimental data and a smartphone with an angular meter function (app).

III. TECHNIQUE OF RESEARCH

TABLE I. NECESSARY PARAMETERS OF THE EXPERIMENT USING THE SOLAR PANEL.

№	Required Settings and Actions
1	Conducting an experiment in sunny weather from 12:00 to 13:00
2	Safe import of the solar power plant 150 W
3	Safe removal of the solar power plant 150 W
4	Check for technical serviceability of solar power plant 150 W
5	Sampling of experimental data every 5 minutes
6	A sampling of experimental data - voltage, current and power using a multimeter and the angle of inclination of the solar panel relative to the surface of the earth using a smartphone (angular meter application)
7	Type of experiments: standard without external changes
8	Number of steps: 14
9	Number of experiments: 1
10	Processing Results by Calculating the Regression Equation

This technique determines the control points of the experiment to investigate the dependence of the electrical parameters (current, voltage, and power) [19] and the angle of inclination of the solar panel relative to the surface of the earth (α.) according to the following procedures:

1-Safe installation at the beginning of the experiment and dismantling at the end of the experiment of the solar power plant 150 W according to terms of electrical safety standards and requirements.

2-Placing a solar panel 150 W perpendicular to the light source (sun) along the front projection plane.

3-Connecting the terminal of the multimeter to the terminals of the charge controller from the side of the terminals to the solar panel.

4-Activation of the angular meter function on the smartphone and placing it on the frame of the solar panel in the red circle area, shown in Fig.3.

5-Changing the angle of inclination of the solar panel in one degree increments and measuring voltage and current from the side of the solar panel terminals, shown in fig.9.

6-Step-by-step change of solar panel inclination angle (in degrees) at the range from 31° to 45°.

The experiments were carried out on August 4, 2020 in the village of Borogontsy, Republic of Yakutia (Sakha), located at the following geographical coordinates.

- Latitude: 62°40′14 ″ N.
- Longitude: 131°09′48 ″ E.
- Altitude: 124 m.

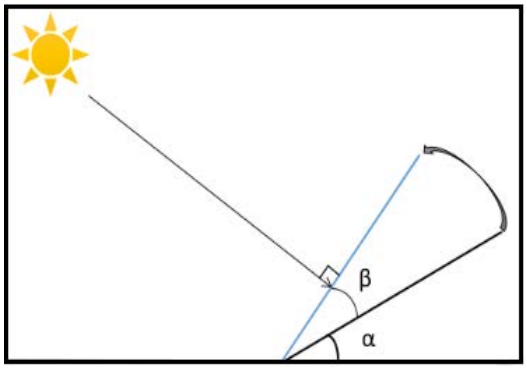

Fig. 9. Change of solar panel inclination angle relative to the ground surface.

Where (α=30°) and (β=45°) of the angle of inclination of the solar panel relative to the surface of the earth.

IV. RESULTS

Experiments with a solar panel having an area of 0.9916 m^2 were carried out on a sunny day in dust weather from 12:00 to 14:00. The results are shown in Table II.

TABLE II. RESULTS OF EXPERIMENTS TO DETERMINE THE SOLAR PANEL GENERATION VOLUME DEPENDING ON THE INCLINATION ANGLE.

α(deg)	I(A)	U(V)	P(W)
30	3.31	13.68	45.28
31	3.32	13.75	45.65
32	3.34	13.90	46.43
33	3.36	13.90	46.70
34	3.43	13.93	47.78
35	3.44	13.95	47.99
36	3.45	13.92	48.02
37	3.47	13.98	48.51
38	3.47	13.95	48.41
39	3.52	14.06	49.49
40	3.52	14.06	49.49
41	3.52	14.07	49.53
42	3.52	14.06	49,49
43	3.48	14.07	48.96
44	3.49	14.06	49.07
45	3.49	14.06	49.0

V. THE DISCUSSION OF THE RESULTS

By performing mathematical processing of the obtained data, the graphical interpretations and regression equations presented in Table II. are obtained using the computer program Microsoft Office Excel and Mathcad Professional.

At the same time, the curves and regression equations of the dependence of the current of the Solar Power Plant 150W on the inclination angle of the solar panel relative to the earth surface are presented (fig.10 - equation.1).

The dependence of voltage on the angle inclination of the panel relative to the ground surface (Fig.11 - equation.2) and the output on the angle of inclination of the panel relative to the ground surface (Fig12 - equation.3).

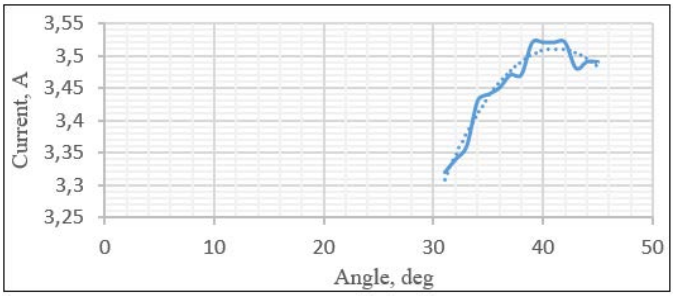

Fig. 10. Dependence of current on the angle of solar panel inclination relative to the ground surface.

A regression equation:

$$I_0 = -0.0019\alpha^2 + 0.1603\alpha + 0.2091 \quad (1)$$

α : angle of solar panel inclination relative to the ground surface (deg).

Fig.10 shows that with an increase in the angle of inclination of the solar panel relative to the surface of the earth, the current increases, while this pattern is a polynomial dependency. With an increase in the inclination angle of 30%, the current increases by 6.02% within **(3.32 A; 3.52 A).**

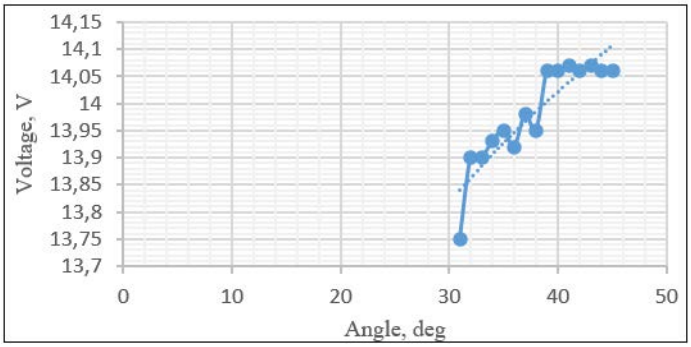

Fig. 11. Dependence of stress on the angle of solar panel inclination relative to the ground surface.

A regression equation:

$$U_0 = 0.7124 \times \ln(\alpha) + 11.395 \quad (2)$$

Fig.11 shows that with an increase in the angle of inclination of the solar panel relative to the surface of the earth, the voltage increases, while this pattern is a logarithmic dependence.

When the inclination angle increases by 30%, the voltage [20],[21],[22] increases by 2.32% within **(13.75 V; 14.07 V).**

A regression equation:

$$. P_0 = -0.0322\alpha^2 + 2.6858\alpha - 6.63 \quad (3)$$

Fig.12 shows that with an increase in the angle of inclination of the solar panel [23],[24] relative to the surface of the earth, power increases, while this pattern is a polynomial dependence.

With an increase in the inclination angle by 30%, power increases by 8.41% within **(45.65 W; 49.49 W).**

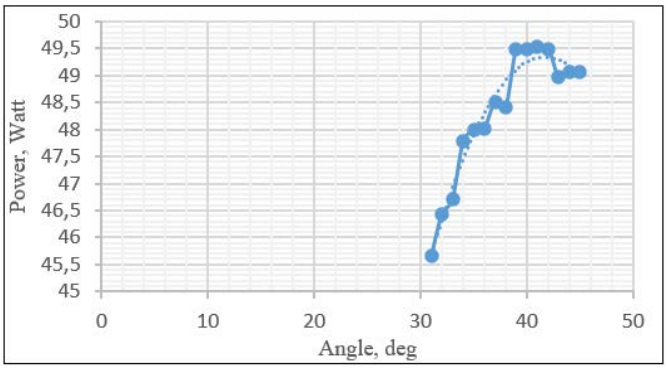

Fig. 12. The dependence of power on the angle of inclination of the solar panel relative to the ground surface.

However, it should be noted that due to the limited time of experiments (1 hour), therefore there is a probability of changing the obtained patterns with a longer time of experiments. Such experiments are made on one of the promising areas of future research in priority for whole light-days of observation.

VI. Conclusions

- As a result of experimental studies of a small-sized solar power plant, patterns the Solar Power Plant with a Capacity 150W established (equations 1,2,3).
- The analysis of the study of traditional and non-traditional energy sources showed that solar energy is the most energy-efficient in terms of autonomous electricity supply.
- It has been found that the highest efficiency of the solar panel is achieved at an angle of inclination from 40 to 45 degrees.
- It was found that the dependence of the generation of the solar panel on the angle of inclination of the panel relative to the surface of the earth is a polynomial dependence.

Acknowledgment

I would like to thank Professor Ilgiz Valeev for her expert advice and encouragement throughout this difficult project, as well as Dr. Maksimov Victor Vladimirovich for his brilliance in the lab.

References

[1] L. Alexandr and S. Inessa, “Main problems of termination of the mechanism of tariffs alignment for electric energy for industrial consumers of the Republic of Sakha (Yakutia),” Revista ESPACIOS, vol. 40, no. 43, 2019.

[2] Power Present Future, 2020. [Online]. Available: http://energetika.in.ua/ru/books/book-5/part-1/section-2/2-8

[3] M. Shaikh and S. Labade, “A Review Paper on Electricity Generation from Solar Energy,” Int. Journal for Research in Applied Science & Engineering Technology, vol. 5, pp. 1884–1889, 2017.

[4] L. V. Kalimullin and D. K. Levchenko, “Priority areas, key technologies and scenarios for the development of energy storage systems,” IGEU Bulletin, pp. 42–54, 2019.

[5] A. Madhugiri and S. Karale, “High solar energy concentration with a Fresnel lens: A Review,” Int. Journal of Modern Engineering Research, vol. 2, pp. 1381–1385, 2012.

[6] H. Kulkarni and N. Shinde, “Review of Different Reflectors materials used for Concentrated Solar Energy Collectors,” National conf. on emerging technology on renewable energy, pp. 33–37, 2012.

[7] P. Revankar and M. Gorawar, “Evaluation of Thermal Performance of Paraboloid Concentrator Solar Cooker,” Int. Journal of Innovative Research in Technology & Science, vol. 1, pp. 58–65, 2018.

[8] H. Abou-Ziyan, “Experimental investigation of tracking paraboloid and box solar cookers under Egyptian environment,” Applied Thermal Engineering, vol. 18, pp. 1375–1394, 1998.

[9] S. Pohekar, “Utility assessment of parabolic solar cooker as a domestic cooking device in India,” Renewable Energy, vol. 31, pp. 1827–1838, 2006.

[10] S. Koushik, “Energy and exergy efficiency compar-ison of community size and domestic size paraboloid solar cooker performance,” Energy for Sustainable Development, pp. 61–64, 2008.

[11] N. Gupta, G. F. Alapatt, R. Podila, avd R. Singh, “Prospects of Nanostructure-Based Solar Cells for Manufacturing Future Generations of Photovoltaic Modules,” Int. Journal of Photoenergy, vol. 3, pp. 94–113, 2009.

[12] H. Kai, S. Lin, and E. Voronkov, “The Contribution of China's Renewable Energy to the Formation of the Global Technological Cycle,” MPEI Bulletin, vol. 6, pp. 43–50, 2018.

[13] R. Vishal, Ajay G. Chandak, and R. Indu, “Procedure for thermal performance evaluation of steam generating pointfocus solar concentrators,” Solar Energy, pp. 1390–1398, 2011.

[14] S. Chinnmai, “An Economic Analysis of Solar Energy,” Journal of Clean Energy Technologies, vol. 1, 2013.

[15] S. Mohammed and A. Al-Soud, “A parabolic solar cooker with automatic two axes sun tracking system,” Applied Energy, 87, pp. 463–470, 2010.

[16] R. M. Muthusivagami, R. Velraj, and R. Sethumadhavan, “Solar cookers with and without thermal storage,” Renewable and Sustainable Energy Reviews, pp. 691–701, 2010.

[17] L. Wong, “Solar radiation model,” Applied Energy, 69, pp. 191–224, 2017.

[18] A. Lecuona and J. Nogueira, “Solar cooker of the port-able parabolic type incorporating heat storage based on PCM,” Applied Energy, 2013.

[19] A. Alzakkar, I. M. Valeev, and N. P. Mestnikov, “Harmonics and Their Impact in Determining the Method of Reactive Power Compensation in Electrical Grids,” Int. Conf. on Industrial Engineering, Applications and Manufacturing, 2020.

[20] A. Alzakkar, I. M. Valeev, and N. P. Mestnikov, “The Artificial Power System Networks Stability Control Using the Technology of Neural Network,” Int. Scientific and Technical Conf. Smart Energy Systems, 2019.

[21] F. Alhajj Hassan and A. Sidorov, “Study of power system stability: Matlab program processing data from Zahrani power plant (Beirut, Lebanon),” E3S Web of Conf., 124, 2019.

[22] A. Alzakkar, F. A. Hassan, and N. Mestnikov, “Support of Frequency Stability in Electrical Power System at Voltage 400 kV in Syria,” RusAutoCon, 2021.

[23] S. Zekai, “Solar energy in progress and future re-search trends,” Progress in energy and combustion science, vol. 30, pp. 367–416, 2004.

[24] N. Kumar, S. Agravat, T. Chavda, and H. Mistry, “Design and development of efficient multipurpose domestic solar cookers/dryers,” Renewable Energy, 33, pp. 2207–2211, 2008.