Wind power resources potential for energy supply of isolated regions of Kamchatska

Liudmila Nefedova*, *Sophia* Kiseleva, *Yulia* Rafikova. *Nina* Teterina

Lomonosov Moscow State University, Faculty of Geography, 119991 Leninskie gory 1, Moscow, Russia

Abstract. The paper presents the potential of the wind resources for energy supply in the Kamchatka Territory. This region is isolated from the United Energy System of Russia and has a large number of remote settlements. The possibility of using wind energy resources in the region to replace diesel power plants and to reduce CO2 emissions are assessed. Estimates of the average power output values of the wind turbine Enercon E-53 810 kW, on the basis of hourly data on wind resources over a 10-year period (2011-2020) and the share of consumer load coverage for 11 settlements in the region are calculated. Territorial distribution of the specific power generation potential for this wind turbine model is presented with the use of GIS technologies. Daily and seasonal variations in productivity and share of load coverage, as well as the territorial distribution of these characteristics of the energy supply potential by the use of wind resources, are determined.

1 Introduction

The main feature of the Kamchatka Territories energy sector is its isolation from the Unified Energy System of Russia, as well as its division into a large number of unconnected power systems. In 2021 in the region were operated several power plants:
- two large thermal power plants (PP) - TPP 1 and TPP 2, with a total capacity of 364 MW,
- three geothermal power plants (GeoPPs) - (Mutnovskaya GeoPP, Verkhne-Mutnovskaya GeoPP, Pauzhetskaya GeoPP) with a total capacity of 74 MW,
- four hydroelectric power plants (Tolmachevsky HPP Cascade and Bystrinskaya HPP) with a total capacity of 47.1 MW,
- three wind power plants (WPP) with a total capacity of 5.5 MW,
- a large number of small diesel power plants (DPP) with a total capacity of 160.8 MW, which generate about 6% of the power output of the region.

In 2020 30.8% of electricity in the region was generated at renewable energy facilities, including GeoPPs (25.1%), HPPs (4.4%) and WPP (1.3%). It is planned to install solar and wind power plants in the settlements of Klyuchi, Kozyrevsk, Ossora, Tilichiki and Manily combined with diesel power plants, to save fuel and reduce CO_2 emissions [1,2].

* Corresponding author: nefludmila@mail.ru

Studying the possibilities of energy supply in the Kamchatka Territory, many authors focus on the prospects of using various types of renewable energy sources (RES): small hydropower resources [3], wind energy resources and hydrogen technologies [4, 5]. An important role for the settlements of the Kamchatka Territory plays their remoteness from power grid and the reliability of power supply [6].

2 Object of study and methods

The objective of this study is to analyze the wind resources of Kamchatka Territory and the potential of wind energy to provide electricity to the settlements of the region, taking into account the consumer load in different seasons of the year.

Calculations of hourly values of electricity generation and capacity factor (CF) were carried out by using the author's program in the Visual Studio for the wind turbine Enercon E-53 810 kW (tower height H=50 m, wind turbine diameter D=52.9 m) based on hourly values wind speeds at a height of 50 m over a 10-year period (2011–2020), loaded from the NASA POWER open database [7]. To assess the distribution of this class wind turbines productivity for the territory of the Kamchatska, calculations of the potential for specific productivity per 1 kW of WWP power were made. Estimates and calculations were carried out on a regular spatial grid with a step of 1°x1°. To assess the potential of energy supply, load graphs of Kamchatka Territories settlements were used.

3 Results and discussion

The results of the calculations made it possible to prepare a map of the distribution of the specific generation potetial (SGP) for selected model of wind turbines for the territory of the Kamchatska. The values on this map vary from 0.5 to 4.4 thousand kWh/kW per year. At the same time, higher values are typical for the coastal and northern territories of the region, and low values are typical for the interior regions of the Kamchatka Peninsula (Figure 1).

To assess the effectiveness of the wind energy use, calculations were made for the capacity factor - average hourly, daily, seasonal and annual. The highest capacity factor wind turbines, according to calculations for a ten-year period, can be achieved at the village Nikolskoe on Bering Island (more than 53%), rather high efficiency in the coastal areas of the Kamchatka Peninsula (more than 30% on the east coast, about 18-20% on the west coast) and low efficiency at the inland regions of the peninsula (for vil. Dolinovka CF is less than 10%) (Table 1). The intra-annual changes of average monthly CF values show seasonal patterns: a decrease in the summer period of the year and an increase in the winter period. So, for the village Sobolevo CF varies during the year from 5% to 40%, and for the village Manily - from 10% to 75% (Figure 2).

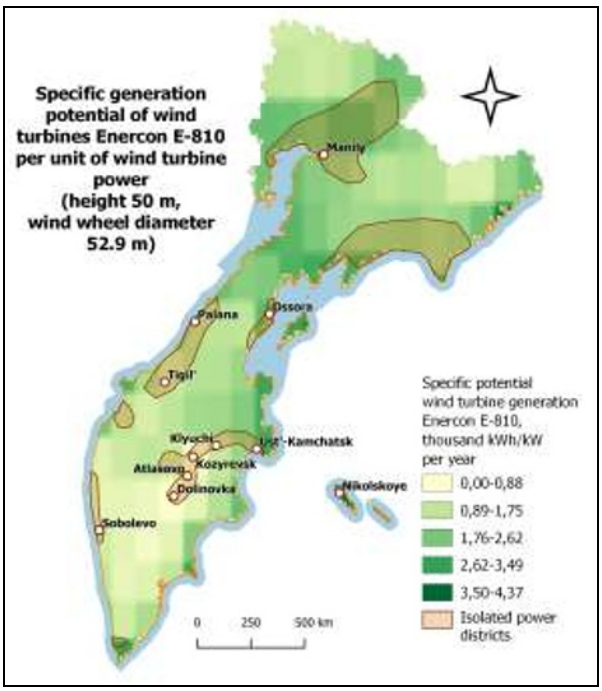


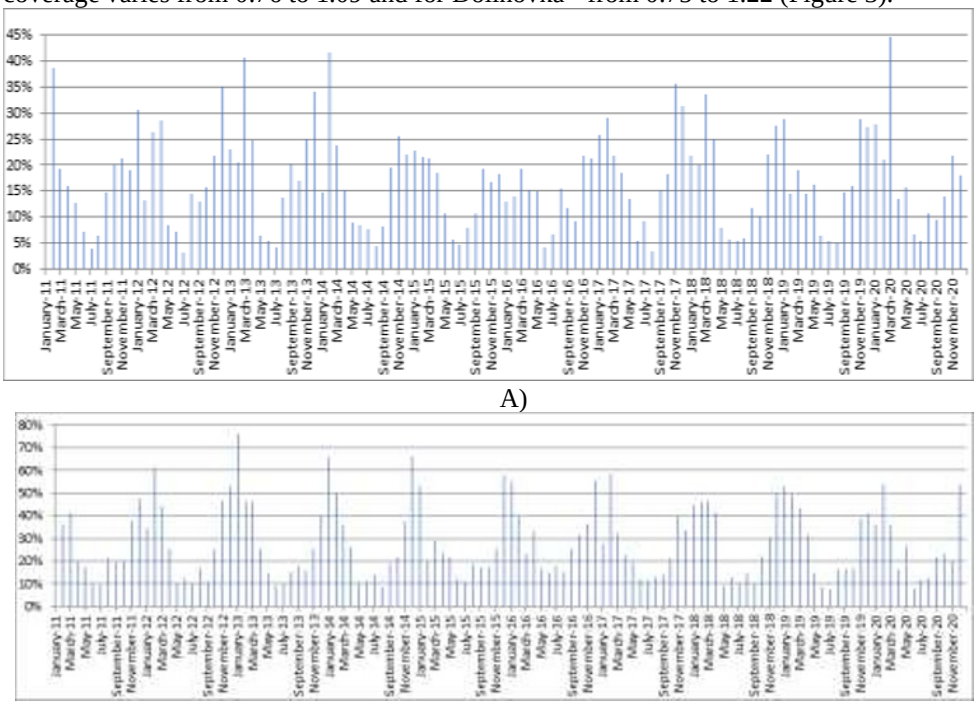
Fig. 1. The distribution of the specific generation potetial of wind turbines over the territory of the Kamchatka.

Table 1. The estimated required number of wind turbines and the annual average share of load coverage by means of wind generation for settlements of the Kamchatka Territory.

Settlements of the Kamchatsky krai	**Max load capacity kW**	**Min load capacity, kW**	**CF, %**	**SGP, thousand kWh/kW in year**	**The required number of wind turbines**	**The annual average share of load coverage by means of wind generation**
Sobolevo	1850	820	17.36	1.52	8	0.92
Dolinovka	120	30	9.59	0.84	1	0.97
Atlasovo	1660	113	10.87	0.95	9	0.93
Kozyrevsk	520	180	10.66	0.93	4	0.96
Ust-Kamchatsk	4900	200	33.54	2.94	10	0.97
Klyuchi	2850	1000	13.34	1.17	18	1.01
Tigil	1140	400	18.45	1.62	5	0.97
Palana	1960	760	20.13	1.76	8	1.04
Ossora	1300	650	33.43	2.93	4	1.06
Manily	930	320	26.66	2.34	3	1.03
Nikolskoe	560	245	53.71	4.70	1	1.03

Based on the data of energy consumption type in settlements, the values of the maximum and minimum power consumption and the values of CF of Enercon E-53 810 kW, for each of the 11 settlements under consideration, the required number of wind turbines was determined (Table 1). Further, hourly share of load coverage, the average values of this indicator for the day, month and 10-year for the period (2011 2020) were

calculated. With long-term average values of the share of load coverage close to 1.00, in some years the calculated average values differ significantly from the median value, depending on the variability of wind conditions. For example, for Sobolevo share of load coverage varies from 0.76 to 1.09 and for Dolinovka - from 0.75 to 1.22 (Figure 3).

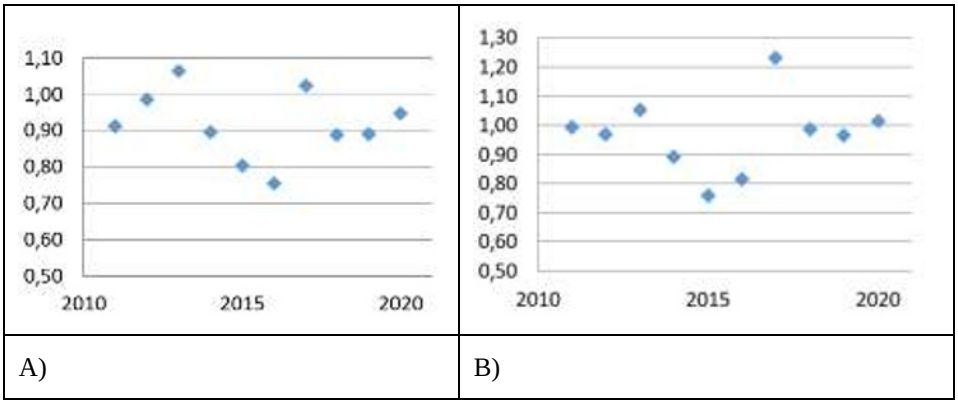


A)

B)

Fig.2. Average monthly values of CF for the period 2011-2020. Wind turbines in Sobolevo (A) and Manily (B).

The intra-annual course of change in the share of load coverage is characterized by even more significant changes (from more than 1.5 in the cold season (December-March) to 0.2-0.3 in the summer), which shows the need to maintain duplicate power capacities or to accumulate the electricity in the required volumes. Calculations of the daily energy balances ("production minus consumption") during the year make it possible to determine the periods of possible full energy supply to the consumer due to the operation of wind turbines and periods when additional energy supply is required due to standby power capacities (diesel generators). Autonomous operation of wind power complexes for energy supply in the Kamchatka Territory requires the accumulation of energy according to daily and seasonal schedules. For daily accumulation, energy storage electrochemical devices of various types can be used [8]. The problems of seasonal accumulation can be solved in the future with the involvement of the "green hydrogen" production, taking into account the presence of significant periods of excess electricity generation at wind farms in comparison with energy consumption schedules [9-12].



A) B)

Fig.3. The annual average share of load coverage values for a ten-year period (2011-2020) for the settlements of the Kamchatka Territory: Sobolevo (A) and Manily (B).

4 Conclusion

The energy system of the Kamchatka Territory is characterized by a noticeable increase in energy consumption, which is provided both by stations as part of local energy centers, and by autonomous diesel generators and wind turbines. A joint analysis of wind resources and load curves of isolated settlements makes it possible to determine the potential of wind turbines for power supply to autonomous consumers.

It is shown, that the performance and installed capacity utilization factor of model wind turbines varies significantly depending on their location, season and time of day for territories within the Kamchatka. Under the chosen scenario (the total capacity of wind turbines for each considered settlement is equal to the maximum load capacity for each village, taking into account the CF wind turbine), on average over 10 years a balance of consumption and production of energy from wind turbines is achieved. However. the intra-annual and intra-daily distribution of the load coverage share makes it possible to identify long periods of excess or lack of electricity generation from wind turbines. The required number of wind turbines in the power supply systems of settlements is determined by both the wind regime and the load schedule and requires a detailed feasibility study using the results were obtained in this study.

References

1. Scheme and program for the development of the Kamchatka Territory electric power industry for 2021–2025. Order of the Governor of the Kamchatka Territory No. 299-R (2021)
2. O.A.Belov, Bulletin of the South Ural State University. Series "Energy" **21**, 4 (2021)
3. D.S.Krotenko. V.A.Semchev. O.A.Belov. S.A.Zhukov, Bulletin of the Kamchatka State Technical University **51** (2020)
4. O.V.Marchenko. S.V.Solomin. Bulletin of the Irkutsk State Technical University, **22**, 3 (2018)
5. S.I.Nefedkin. A.O.Barsukov. M.I.Mozgova. M.S.Shichkov. M.A.Klimova, ISJAEE, **16-18** (2019)
6. B.A.Novakovsky. A.I.Prasolova. A.M.Karpachevsky. O.G.Filippova, Geodesy and Cartography, **78**, 5 (2017)

7. NASA POWER database https://power.larc.nasa.gov
8. S.V.Kiseleva. A.B.Tarasenko, ISJAEE, **19-21** (2018)
9. A.B.Tarasenko. S.V.Kiseleva. O.S.Popel, Int. Journal of Hydrogen Energy **47**, 23, 11991–11997 (2022)
10. I.A. Hassan, H.S. Ramadan, M.A. Saleh, D. Hissel. Renew. Sustain. Energy Rev. **149**, 111311 (2021)
11. A.M. Elberry, J. Thakur, J. Veysey J. Energy Storage **44**, 103474 (2021)
12. L. Nefedova. K. Degtyarev. S. Kiseleva. M. Berezkin, E3S Web of Conf. **265**. 04011 (2021)