The use of wind potential in the local energy of Yakutia

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Abstract. The article is devoted to the possibility of using renewable energy sources for electricity supply to consumers in remote regions of Russia, isolated from power systems. The use of wind energy resources for power supply will reduce the consumption of diesel fuel and, thus, improve the reliability and efficiency of electricity supply to consumers. At the same time, wind power stations are considered as a complementary energy source when working together with diesel power plants, which are the main ones for power supply to decentralized consumers. The construction of wind farms in addition to existing diesel power plants in modern price conditions is cost-effective in the Arctic regions of Yakutia. The extent of the use of renewable energy sources is currently very small. Justification of the use of wind energy for each locality requires a separate specific study to assess the financial and economic efficiency with a preliminary determination of the optimal capacity of wind farms.

1. Introduction

Recently, the use of renewable energy sources (RES) for providing a more reliable power supply to remote consumers' areas of Russia isolated from the energy system is becoming increasingly relevant. The longest zone of decentralized power supply is located at the territory of the Sakha Republic (Yakutia). This is due to a number of reasons, one of which is the weak transport development of the Northern and Arctic regions of the republic where the scheme of fuel delivery is complex and multi-link (railway, waterway along rivers and through the Northern sea route, road transport) with the length over 5 thousand km. That is why the limited time of seasonal importation, dependence on fuel supplies and as a consequence its rise in price, irregular power supply to consumers which is provided with electricity from autonomous energy sources, mainly diesel generators, take place. In modern conditions the price of diesel fuel in the Northern regions is 50–60 thousand rubles/t, and the transport component in the cost of fuel exceeds 60 %. Because of the multi-link schemes of fuel delivery its loss is great – about 20 % [1]. In this regard, the cost of electricity production reaches 30–40 rubles/kWh.

The Arctic regions are the most attractive in the republic in terms of the use of wind potential for energy supply: here the average annual wind speeds at the height of the weather vane of hydro meteorological stations are 5–7 m/s [2]. In the rest of the Republic this figure does not exceed 3 m/s. The use of wind energy resources for power supply will reduce the consumption of diesel fuel and, thereby, increase the reliability and efficiency of electricity supply to consumers.
At the same time, the scalability of renewable energy sources on the republic territory is currently very small and represented only by solar power plants in the amount of 13 units with a total installed capacity of 1335 kW. The only wind power plant (wind turbine) in Tiksi (250 kW) failed in 2015 as a result of strong winds.

The paper makes an analysis of preconditions for harnessing wind energy in the Republic of Sakha (Yakutia), which include the problems of energy supply to the northern settlements and available considerable wind potential. The factors that affect the efficiency of the wind potential implementation are presented. Firstly, wind speed and wind annual distribution vary depending on site location: sea coast, bay, mainland. Secondly, in the last years there has been a tendency towards a decrease in the wind speed compared to the average long-term data available in reference sources. Thirdly, the efficiency indices are greatly affected by the choice of a standard size of wind turbines because of a difference between the wind energy parameters at the height of the tower and at the height of the weather station vane. The wind speed frequency in terms of intensity and electricity output of wind turbines of different types are analyzed and the analysis results are presented.

The relationships between the wind energy potential indices and annual distribution, and the efficiency for the off-grid consumers in the Republic of Sakha (Yakutia) are presented considering energy consumption curves. The results of investigating the technical capability and cost-effectiveness of using small-capacity wind turbines in the northern regions of the Republic of Sakha (Yakutia) are demonstrated. Technical requirements for the wind turbines to be used in the northern areas, which are related to the installation and operation problems under the conditions of remoteness and low temperatures, are described.

2. Methods and materials
Using the WindMC-Analyzer program, the calculation of wind speeds repeatability was carried out by gradations and estimated the possible power generation of wind turbines for each gradation of wind speeds. The method developed by the authors [8] is used to determine the optimal capacity of renewable energy sources for a decentralized consumer.

3. Results
Low use of renewable energy sources, including wind power plants, is due not only to their high capital intensity but to the uneven and unstable presenting features of renewable natural resources energy both in time and also depending on the territorial location of an object.

One of the important characteristics that determine the energy value of wind is its average annual speed. This indicator at the height of the weather vane in the Central part of the Republic of Sakha (Yakutia) does not exceed 2–3 m/s. This is practically the only zone in the Republic where it is possible to use wind potential for energy purposes. The highest wind speeds in the Republic are observed on the coast of the Northern seas – 4–6 m/s (Fig. 1).

Despite the fact that the Arctic regions have natural and economic prerequisites for the use of wind energy resources, there is a number of limitations, also due to natural and, to a greater extent technical factors rather than economic ones.

The development of wind power in areas with cold climates has a number of specific features. It is necessary to use wind power plants of Arctic design, without hydraulic braking system, without reducer, with adjustable angle of attack of the blades, the possibility of Autonomous operation, remote control and monitoring of work. It is necessary to take into account the problems of transportation of the wind power plant and its construction at the site in conditions of poorly developed transport infrastructure. Special cold-resistant steel grades must be used in the model. Low-temperature synthetic lubricant for key bearings and generator bearings, synthetic gear oils should be used everywhere in the Arctic and cold climate, even if it is not necessary under the conditions of winter minimum temperature. Heating of the controller, wind direction sensor and anemometer is required. Protection of the blades from icing can be carried out by applying anti-icing paint. Thus, when
choosing a model of a wind power plant, a detailed analysis of technical characteristics and assessment of working conditions is necessary.

Figure 1. Distribution of the average annual wind speed at the height of the weather vane on the territory of the Republic [2]

Due to the isolation of decentralized consumers from the power system, their annual electricity consumption schedules with small loadings and prevalence in them of a municipal and household component have a pronounced effect maximum in wintertime. This imposes certain limitations on efficiency of the use of wind energy potential which has a high seasonal irregularity.

In this regard, wind power plants are considered as a complementary energy source when working together with diesel power plants which are essential for the power supply of decentralized consumers. When analyzing the feasibility of wind energy resources using for energy purposes, it is important to take into account not only price indices, but also various natural factors that affect the efficiency of wind power plants.

The annual distribution of wind speeds is essential. There can be maxima in different periods of a year. According to the results of the monitoring of average wind speeds changes during a year on the territory of the republic three groups of settlements with different graphics of annual distributions of wind potential were identified.

For the sea coasts (villages Ust-Olenyek, Ust-Yansk, Tabor, Chokurdakh, Kolymskoye) it is more typical to have summer maximum and the greatest values of wind speeds. At the same time in bays (Tiksi, Ambarchik) the wind potential also has high values but its distribution is different – here it is observed winter maximum. For the mainland (Sanyjyakh, Eik, Okhotsky Perevoz, Olyekmisk) it is more typical to have the double autumn and spring maximum and a much lower rate of wind speeds. It should be noted that in these groups there can be locally different distribution depending on local characteristics, for example: depressions or elevations of relief, river beds, etc.
The effect of annual distribution of wind potential is that for the power supply at the same annual values, the best conditions for its use will be areas with winter maximum. This dependence is related with a great correspondence of schedules of WPP power generation and its consumption with a winter maximum of wind potential, slightly less-with spring-autumn one, and at the summer maximum, electricity generation and consumption schedules are in the opposite phase.

Another important factor for using the wind potential is the reliability of its indicators and the change in wind speeds depending on the period of measurement. The results of research conducted by A.V. Meshcherskaya, V.V. Eremin et al. on the change in wind speed in the North of Russia in the second half of the 20th century [3], which considered the testimony of 23 weather stations for 1936–2000, confirm the conclusion that in the vast majority of territories the wind speed decreased, especially in the intra-coastal areas significantly (in some regions more than 2 times).

As an example considered the comparative change of average monthly wind speeds during one year in the area of the weather station in Chokurdakh settlement (Allakhovsky ulus) located near the coast of the East Siberian Sea. According to the long-term observations for the period of 1936–1960 during one year the prevailing wind speed was 4–5 and 6–7 m/s [2]. The average annual wind speed at the height of the weather vane of 11 m hydro meteorological station was estimated at 4.7 m/s.

The results studies on the decline of average annual rate in recent years compared to the period 1936–1960, which is reflected in the reference literature [2], fully consistent with the findings cited by A.V. Meshcherskaya, V.V. Eremin and others in [3].

With the program WindMC-Analyzer the data on average monthly wind speeds were obtained in the area of Chokurdakh weather station for the period 2001–2012. The average annual speed for this period is 3.78 m/s. The biggest difference of indicating is observed from March to October and is 1–1.6 m/s.

At the same time, according to the results of the statistic estimators of wind speed the average coefficient of variation for the period of 2001–2012 was 0.59, RMSD of wind speed is 2.22 which indicates quite favorable conditions for the use of wind energy in the area.

In work [3, 4] it is noted that the possible causes of such reductions can be: the change in the height of a wind measuring device, the equipment of a network of stations with wind vane with a heavy board, the replacement of a weather vane with a wind indicator, the transfer of meteorological sites. In addition to methodological reasons the widespread decrease in wind speed can be determined by climate change, in particular, by the change in a general circulation of the atmosphere [3].

To assess the impact of the repeatability of different wind speeds during a year and the height of a wind power plant tower to generate electricity in Chokurdakh settlement the units of German companies have been considered: Turbowinds T-400-34, NW 44-850 VN, NW 66-1600 NY-P. The height of Turbowinds T-400-34 wind turbine tower is 34 m, for the rest is 68 m [5–7]. Starting speed is 3–4 m/s, speed of output at rated power is 13–14 m/s.

Using the WindMC-Analyzer program, the calculation of wind speeds repeatability was carried out by gradations for the period of 2001–2012 and estimated the possible power generation of wind turbines for each gradation of wind speeds. The results of studies have shown that with the same repeatability of wind speeds with the increase of a wind tower height the greatest output of energy is shifted towards lower speeds which in general increases total electricity production for a year.

All above mentioned factors induce in estimating of use efficiency for power supply of a settlement isolated from a power system the necessity to determine the amount of electricity generation by wind farm. Thus there is a task to correlate the schedule of annual power generation at a different set of wind turbines with a schedule of consumptions.
Taking into account the high capital intensity of renewable energy sources including wind farms for the effective application of consumers isolated from power systems the definition of their optimal power has a significant importance.

The authors developed a method to determine the optimal capacity of RES for a decentralized consumer. It is described in detail in [8] and based on the ratio of the cost indicators of RES and the displaced organic fuel on the existing energy source which is more dependent on the characteristics of potential of renewable natural energy resources. The main criterion in the technique is the maximum effect with a minimum of capital expenditure, i.e. the ratio of the cost of renewable energy and the displaced diesel fuel due to its operations.

At the modern price indicators the value of optimal power to a large extent depends on the natural potential which determines the installed capacity utilization factor (ICUF) of a wind farm.

For wind conditions of the continental zone (Sanyjyakhtakh and Verkhoyansk settlements) where wind characteristics are low, and, consequently, the ICUF has a small value, the optimal capacity of a wind farm is several times higher than the maximum load of consumers. In the coastal zone (Tajmylyr, Ust-Olenek and Chokurdakh settlements) at the ICUF more than 20 % the wind farm is close to the maximum load.

The studies conducted to assess the effectiveness of using wind farms show that the Arctic territories have the best indicators of their application [9–14]. The payback period of projects for construction of wind farms in coastal areas of the republic is 7 to 9 years.

As an example discussed discussed the comparative efficiency of wind power plants use for natural and price conditions of Chokurdakh settlement and the traditional scheme. According to the results of research the optimal capacity of a wind power plant for this settlement is 1700 kW as a part of two wind turbines on 850 kW each. The value of the wind farm optimal power is comparable to the maximum load of a consumer.

To assess the financial and economic efficiencies of wind farm applications for electricity supplies in Chokurdakh settlement it was used the production and financial model describing the dynamics of cash flows at operation of the wind farm in addition to the existing diesel power plant. The budget efficiency of the project was estimated, i.e. the costs from budget for fuel delivery and maintenance of energy sources for the selected options of a wind farm capacity in comparison with the electricity supply only from the existing DES.

Despite the significant one-time investments, the return on projects of WPP construction under conditions of Chokurdakh settlement is provided by reduction of annual costs for energy supply compared to the operation of one DES due to the fuel displacement.

The combination of graphs of the cumulative discounted costs for power supply only from DES and when working together DES and WES showed that the project of construction of wind power plant in Chokurdakh settlement with 850 kW power units is financially attractive: discounted payback period of the project is about 9 years.

4. Conclusion
The results of studies of the nature of changes in wind energy potential show that when considering the possibility to use of and justify the application of wind power plants it is necessary to take into account its distribution during a year, and use data on the magnitude of the potential for the modern period of measurements. Because ignoring this factor it would lead to overestimate the utilization factor of the installed capacity of renewable energy source in assessing the financial and economic efficiency of projects, as a result, a negative attitude towards renewable energy projects is formed due to non-receipt of the expected effect in practice. The best for use in terms of resource provision is the intra-annual distribution of wind potential which has a winter maximum.

The construction of wind farms in addition to existing DES in the current price environment is cost-effective in the Arctic regions of the Sakha Republic (Yakutia). The rationale for the use of wind energy for each settlement requires a separate specific assessment study of financial and economic efficiency with preliminary determination of the optimal capacity of wind farms.
The value of the optimal power of wind farms is influenced by the following factors: distribution of wind potential during a year, performance characteristics of wind turbines, electricity consumption schedule, remoteness and availability of a territory and, accordingly, the cost of fuel and equipments delivery. The value of the optimal capacity of a wind farm for power supply of a consumer isolated from the power system in the Arctic zone is comparable to the maximum of its load.

For the use of unclaimed electricity from a wind farm during the day it is necessary to conduct additional studies to assess the effectiveness of its daily accumulation.

However, there are a number of technical limitations when using wind potential for energy supply under Arctic conditions. It is necessary to organize the production of Arctic wind turbines without hydraulic system braking, without a gear (direct drive), and with an adjustable angle of attack of blades, the possibility of autonomous operation, remote control and operation control [1]. In addition, it is necessary to take into account the problems of transportation of wind turbines and its installation on a construction under conditions of poorly developed transport infrastructure [15]. Models of wind turbines should provide for the possibility of installation without special means of rise. Special cold-resistant grades of steel and low temperature synthetic lubricants for key bearings and generator bearings, synthetic gear oils should be used.

It is necessary to provide heating of a wind turbine controller, the wind transducer and the anemometer. The protection of blades on a wind turbine from icing can be carried out by applying de-icing paint having a property of water repulsion. It is also possible to cover the surfaces of wind turbine modules by de-icing solution. Thus, when choosing a model of a wind turbine it is necessary to have the detailed analysis of technical characteristics and assessment of working conditions, similar presented in [15, 16]. When assessing the costs of construction and operation it is necessary to take into account all marked features and specifications.

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