Atlantis Highlights in Material Sciences and Technology (AHMST), volume 1
International Symposium "Engineering and Earth Sciences: Applied and Fundamental Research" (ISEES 2019)

Heat Supply of Buildings and Structures with the Participation of Wind Power Plants

Bezhan A.V.
Northern Energetics Research Centre –
Branch of the Federal Research Centre
"Kola Science Centre of the Russian Academy of Sciences",
Apatity, Russia
abezh@rambler.ru

Furtaev A.I.
Northern Energetics Research Centre –
Branch of the Federal Research Centre
"Kola Science Centre of the Russian Academy of Sciences",
Apatity, Russia
ai.furtaev@rambler.ru

***Abstract* – One of the main ways to increase the efficiency of traditional heat supply systems is the transition to alternative energy-saving technologies for the production of heat energy based on the use of unconventional and renewable energy sources and in particular wind energy. In this case, wind energy may be involved in heat production technologies and then spent on the needs of heat supply. An assessment is made of the possible use of wind power plants in conjunction with the boiler house in ensuring the schedule of heating load of consumers located in an area with high wind potential, the average annual speed of which is about 7 m/s. The duration of the heating season in this area is 9-10 months per year. It is shown that the joint use of the boiler house and wind power plants for heat supply during the year can reduce the share of the boiler house in the heat supply of consumers by 50-70% or more.**

Keywords – renewable energy sources; heat supply; wind power plant; boiler house; energy saving; energy efficiency; fossil organic fuel.

I. Introduction

In the modern world, the existence of humanity and the successful development of most of its territories are directly related to the high level of energy consumption, which doubles every 12 years [1]. The production of a significant part of this consumed energy is usually based on the extraction and subsequent combustion of hydrocarbon fuels (coal, oil, natural gas), whose reserves are limited and have an uneven distribution throughout the Earth's territory. Figure 1 shows the structure of the global consumption of major energy sources [2]. The figure shows that the consumption of fossil fuels prevails over the use of other types of energy resources.

In turn, the consumption of a large number of such energy carriers adversely affects the ecological state of the entire natural environment. According to the data published by the organization "British Petroleum" [2], carbon dioxide emissions into the environment in 2018 were about 33 billion tons and based on the forecast corresponding to the main scenario (Evolving transition) of CO2 emissions in the future, by 2040 will increase by 10% ((fig. 2).

Currently, many scientists and researchers from around the world are engaged in finding ways and means that would contribute to the conservation and economical use of traditional energy resources, as well as the preservation of the ecological well-being of the environment. One solution to this problem may be the use of energy production technologies based on the use of unconventional and renewable energy sources (URES) and in particular wind energy. In this case, due to the use of wind power plants (WPP), the kinetic energy of the movement of air masses is converted into electrical energy generated by these wind turbines. In municipal heating systems, the energy received from wind turbines may be involved in heat production technologies and then spent on the needs of heat supply of cities and towns [3].

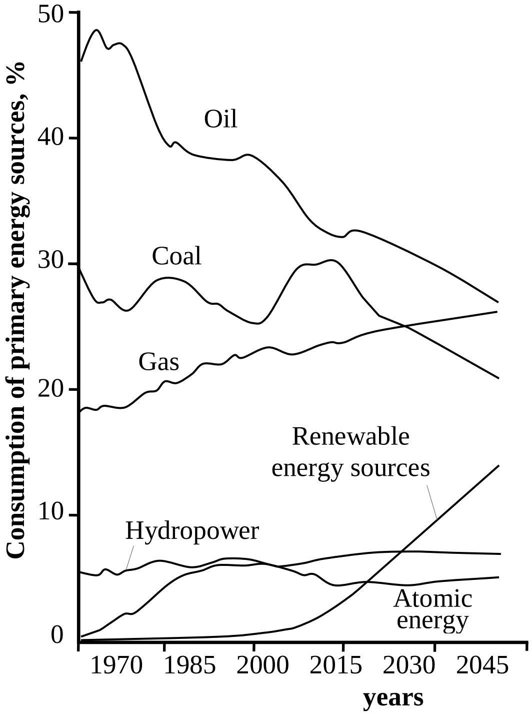

Fig. 1. The structure of consumption of major energy sources in the world.

Currently, many scientists and researchers from around the world are engaged in finding ways and means that would contribute to the conservation and economical use of traditional energy resources, as well as the preservation of the ecological well-being of the environment. One solution to this problem may be the use of energy production technologies based on the use of unconventional and renewable energy sources (URES) and in particular wind energy. In this case, due to the use of wind power plants (WPP), the kinetic energy of the movement of air masses is converted into electrical energy generated by these wind turbines. In municipal heating systems, the energy received from wind turbines may be involved in heat production technologies and then spent on the needs of heat supply of cities and towns [3].

Today, heat supply using renewable energy sources is based on the use of power plants, most often using the deep heat of the Earth, solar energy, biofuels and other sources. As such power plants used heat pumps, solar panels, bio-installations, etc. [4-6]. The use of wind energy for heating consumers has not yet found wide application and in most cases is of a research nature [7–9].

The use of wind energy for heating purposes is particularly advisable in areas that simultaneously have great wind potential and for a long time throughout the year have low outdoor temperatures, causing increased demands for thermal energy. These areas primarily include the northern part of Russia, Finland, Sweden, Norway, Alaska (USA) and part of Canada. In these places, the duration of the heating period is 8-9 months per year and more.

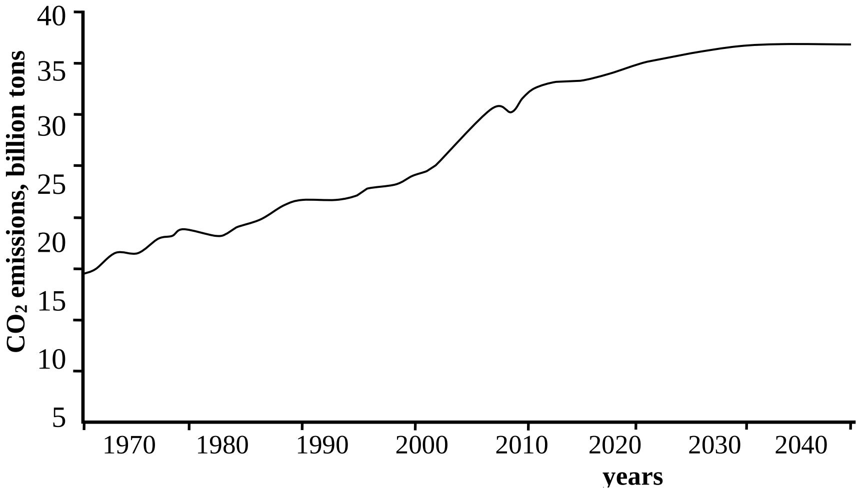

Fig. 2. Emissions of carbon dioxide and their forecast up to 2040

II. PROBLEM STATEMENT

The work of modern heat supply systems is directly related to the use of fuel and energy resources (FER), which causes certain energy, economic and environmental problems, which can only be solved with the use of energy-saving and energy-efficient technologies. In this situation, the use of wind energy in heat production technologies for heat supply purposes contributes to the energy efficiency of traditional heat and power facilities, and as a result, the economical use of fuel and energy resources, as well as reducing harmful emissions into the environment. Thus, it is very important to determine the possibility of including wind turbines in the heating systems of consumers and the effect that can be obtained from such measures.

III. DESCRIPTION OF RESEARCH TECHNIQUE

Traditionally, heat supply to consumers is realized from energy facilities (CHP, boiler houses, etc.) that run on organic fuel. If the only source of heat energy is the boiler house, then in general, the heat supply scheme may look like that shown in fig. 3. In this case, the heat coming from the boiler house for heat supply purposes is spent on replenishing the heat losses of heated buildings and structures. Mathematically, this can be written as follows:

$$Q_0 = Q_{\mathrm{Br}} \quad (1)$$

Equality 1 characterizes the process by which the heating load schedule is completely covered by the boiler room.

We introduce a parameter denoting the share of participation of the boiler house in the heat supply of consumers. In this case, it is equal to unity ($\gamma = 1$).

In heating systems, together with the boiler house, it is possible to use wind power plants as an additional source of thermal energy (Fig. 4). In this case, the heat required to maintain the required heat balance of heated buildings and structures is supplied simultaneously from wind turbines and the boiler house, which means that the need to use the boiler house for heating is reduced ($\gamma = 1$).

Let us consider in more detail the joint work of such sources of thermal energy. For this we turn to fig. 5, which shows the monthly graph of the heating load provided by the operation of the wind turbine (white area) and the boiler room (black area). The figure shows that there are three possible scenarios.

Option 1. At the times when wind turbines are able to fully provide consumers with thermal energy or even create an excess of it, boiler room participation in heat supply is not required ($\gamma = 0$).

Option 1. At the times when wind turbines are able to fully provide consumers with thermal energy or even create an excess of it, boiler room participation in heat supply is not required ($\gamma = 0$).

In this case, the condition:

$$Q_{\mathrm{WPP}} \geq Q_0\,,$$

Where Q_{WPP} – power output from wind turbines, kJ/s.

If the heat energy coming from the wind turbine is fully sufficient to compensate for the heat losses of heated buildings and structures, then equation 1 for the heating system shown in Fig. 4, can be rewritten as follows:

$$Q_0 = Q_{\mathrm{WPP}} \tag{2}$$

In Figure 5, this corresponds to the 11th, 30th and 31st days of the month in question.

During periods of time when there is a strong wind, there may be surpluses of energy $Q_{\mathrm{WPP}}^{\mathrm{Sur}}$ produced by wind turbines. In Figure 5, such periods correspond to time intervals from 7 to 10, from 12 to 13 and from 18 to 23 numbers. Formula 2 in this case can be represented as:

$$Q_0 = Q_{\mathrm{WPP}} - Q_{\mathrm{WPP}}^{\mathrm{Sur}} \tag{3}$$

Equations 2 and 3 describe the process by which the heating load graph is completely covered by wind turbines (Fig. 5, time intervals from 7 to 13, from 18 to 23, and from 30 to 31 numbers).

Option 2 characterizes the heating process when the wind turbine power is not enough to provide consumers with thermal energy, i.e. the condition is fulfilled:

$$0 < Q_{\mathrm{WPP}} < Q_0$$

In this case, the boiler house additionally enters into operation, and its share in the heat supply is in the range from 0 to 1 ($0 < \gamma < 1$) and can be mathematically determined from the expression:

$$\gamma = 1 - \frac{Q_{\mathrm{WPP}}}{Q_0}$$

Then in formula 1, you can add a term by getting an expression of the following form:

$$Q_0 = Q_{\mathrm{Br}} + Q_{\mathrm{WPP}} \tag{4}$$

Where $Q_{\mathrm{Br}} = \gamma \cdot Q_0$ – power output by the boiler house and characterizing its contribution to the heat supply of consumers, kJ/s.

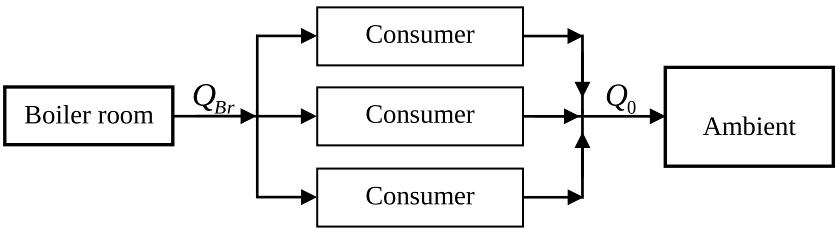

Fig. 3. Block diagram of the heat supply system sold from the boiler house.

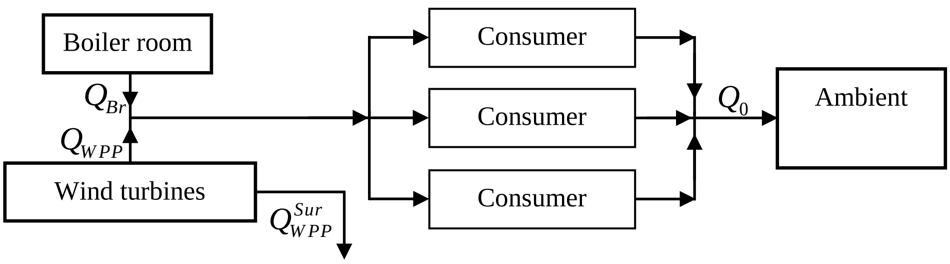

Fig. 4. The integrated heat-supply system based on boilers and wind-driven generators

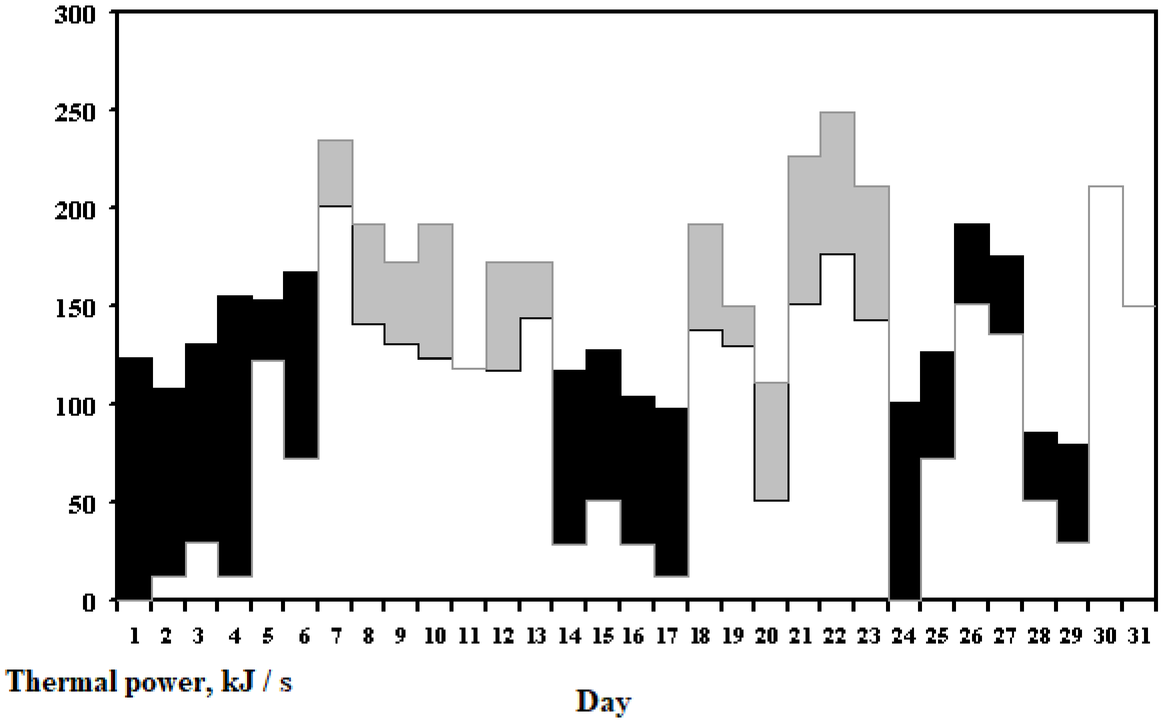

Fig. 5. Graph of the heating load by month. Areas of white and black colors - respectively, the participation of wind turbines and the boiler room in covering the heating load. The gray area is the excess power delivered by the wind turbine.

Such a variant of joint operation of a boiler house and a wind turbine for the needs of heat supply is presented in fig. 5, time intervals from 2 to 6, from 14 to 17 and from 25 to 29 numbers, where the areas of white and black colors correspond to the contribution of the wind turbine and the boiler room to the heating load schedule.

Option 3. This option corresponds to periods of no wind, when the wind turbine is at rest, ie:

$$Q_{\mathrm{WPP}} = 0$$

In this case, the heat supply is completely provided by one boiler room ($\gamma = 1$) according to equality 1 (Fig. 5, 1 and 24 of the month in question).

IV. Results

Using the example of the settlement (settlement) of Waida-Guba, we consider a practical variant of the possible operation of a wind turbine together with a boiler house for heating purposes. Settlement Waida-Guba is located in the north-western part of Russia on the coast of the Barents Sea in the wind zone, which is characterized by an average annual speed of 6.6 m/s.

The village is supplied with heat from the boiler house, the total connected load of which is 398 kJ / s, including 307 kJ/s for heating supply and 91 kJ/s for hot water supply. As an additional source of energy, working for the needs of heat supply, a wind power installation with a capacity of 250 kJ/s (80% of the connected heating load) was selected.

When making calculations, it was assumed that the loss of heat energy in the heat network and in the heating systems of buildings, as well as the loss of electrical energy during its transmission from the wind turbine will not be taken into account.

1. Heat supply without operation of wind turbines.

In this case, heat is supplied only from the boiler room in accordance with the heating load. It can be noted that the greatest need for thermal energy occurs in winter, when the outdoor temperature is minimal, and the wind intensity corresponds to the maximum values. In the spring and autumn months, the need for heating is reduced. In the summer, when there is no heating season, the boiler house is in an inoperative state.

2. Heat supply from the boiler house with the participation of wind turbines.

Consider Figure 6, which shows the possible inclusion of wind turbines in ensuring the heating load schedule. It shows that in periods of time with strong wind, the wind turbine is fully (sometimes partially) ready to provide consumers with heat (Fig. 6, white area). When the power output from the wind turbine is not enough, the boiler house enters the work and complements the wind turbine (black area). If the need for heat on the part of consumers will be less than the power received from the wind turbine, then in this case there may be excess energy (gray area).

The results of the calculations allowed to establish that the energy efficiency, which can be obtained during the year from the operation of wind turbines for heating purposes, resulted in a decrease in the share of the boiler house in heating consumers by about 60%, and, consequently, in reducing the consumption of organic fuel.

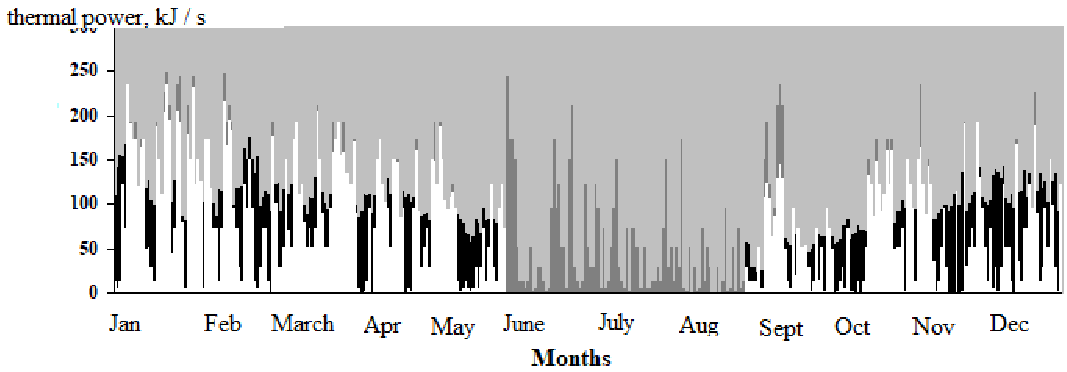

Fig. 6. Schedule heating load settlement Waida-Guba, provided by the boiler room (black area) and wind turbine (white area). Excess capacity of wind turbines - the area of gray

V. Conclusion

1. A method of heat supply of buildings through the use of boiler and wind power plants is proposed. In this case, the main effect of the use of wind turbines is reflected in the saving of fossil fuels, the use of which in some cases is associated with great difficulties, as well as with anthropogenic pollution of the natural environment.

2. Developed methodological foundations of the algorithm for the operation of wind farms in conjunction with the boiler for heat supply purposes. The basis of heat supply from such a combined system of energy sources is that the boiler house is put into operation, complementing wind turbines, only if there is a weak wind or lack thereof. In all other cases, the heat supply is provided by the operation of wind turbines, and the boiler house is in anticipation of the heating load.

3. It has been established that in areas with an average annual wind speed of about 7 m/s, the use of wind turbines for heating purposes in some months reduces the participation of the boiler in providing the heating load by 50-70% and, consequently, reduces the consumption of fossil fuels used in the boiler room.

References

[1] K. Amasyali, N.M. El-Gohary, “A review of data-driven building energy consumption prediction studies”, Renewable and sustainable energy reviews, vol. 81, pp. 1192–1205, 2018. doi: 10.1016/j.rser.2017.04.095

[2] British Petroleum. BP Energy Outlook 2018 edition (2018). Retrieved from: https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/energy-outlook/bp-energy-outlook-2018.pdf.

[3] A.V. Bezhan, V.A. Minin, “Mathematical Description of a Boiler House Operating Jointly with a Wind Power Plant and Heat Storage”, Thermal Engineering, vol. 58, no. 11, 2011, pp. 903–909, doi: 10.1134/S0040601511110024. (In Russian).

[4] J. Zheng, Zh. Zhou, J. Zhao, J. Wang, “Integrated heat and power dispatch truly utilizing thermal inertia of district heating network for wind power integration”, Applied Energy, vol. 211, pp. 865–874, 2018, doi: 10.1016/j.apenergy.2017.11.080.

[5] A.B. Alkhasov, Geothermal power engineering. Problems, resources, technologies. Moscow, 2008, 375 p.

[6] K. Abdelkrim, T. Khaled, B. Hocine, “Approach for the modelling of hybrid photovoltaic–thermal solar collector”, IET Renewable Power Generation, vol. 9, pp. 207–217, 2015. doi: 10.1049/iet-rpg.2014.0076.

[7] B.M. Shit, “Modeling of the heat pump station adjustable loop of an intermediate heat-transfer agent (part I)”, Problemele energeticii regionale, no. 2, pp. 1–13, 2009.

[8] O.S. Popel', S.E. Frid, D.V. Efimov, A.M. Anisimov, “Autonomous windpower systems with heat storage devices”, International Scientific Journal for Alternative Energy and Ecology, no. 11, pp. 78–84, 2008.

[9] O.V. Marchenko, S.V. Solomin, Economic efficiency of wind power plants in electrical and heat supply systems. Irkutsk, 1996, 28 p.