ISSN 2518-170X (Online)
ISSN 2224-5278 (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ
Satbayev University

ХАБАРЛАРЫ

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ
НАУК РЕСПУБЛИКИ
КАЗАХСТАН
Satbayev University

N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF
KAZAKHSTAN
Satbayev University

SERIES

OF GEOLOGY AND TECHNICAL SCIENCES

5 (455)

SEPTEMBER – OCTOBER 2022

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

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«ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).

Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген **№ KZ39VPY00025420** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Тақырыптық бағыты: *геология, мұнай және газды өңдеудің химиялық технологиялары, мұнай химиясы, металдарды алу және олардың қосындыларының технологиясы.*

Мерзімділігі: жылына 6 рет.

Тиражы: 300 дана.

Редакцияның мекен-жайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19

http://www.geolog-technical.kz/index.php/en/

Типографияның мекен-жайы: «Аруна» ЖК, Алматы қ., Мұратбаев көш., 75.

«Известия НАН РК. Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ KZ39VPY00025420,** выданное 29.07.2020 г.

Тематическая направленность: *геология, химические технологии переработки нефти и газа, нефтехимия, технологии извлечения металлов и их соеденений.*

Периодичность: 6 раз в год.

Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19

http://www.geolog-technical.kz/index.php/en/

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).

The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. KZ39VPY00025420,** issued 29.07.2020.

Thematic scope: *geology, chemical technologies for oil and gas processing, petrochemistry, technologies for extracting metals and their connections.*

Periodicity: 6 times a year.

Circulation: 300 copies.

Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19

http://www.geolog-technical.kz/index.php/en/

Address of printing house: ST «Aruna», 75, Muratbayev str, Almaty.

NEWS *of the National Academy of Sciences of the Republic of Kazakhstan*
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
https://doi.org/10.32014/2518-170X.218

UDC 550.8.08

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METHODOLOGICAL BASIS FOR THE APPLICATION OF WIND GENERATORS IN GEOLOGY

Abstract. When carrying out geological exploration work, one of the primary tasks is energy supply. The energy supply system consists of many elements that ensure the production, transportation and conversion of energy. The specificity of geological exploration works is distinguished by its complexity associated with remoteness from the main energy systems, severe climatic conditions, and geolocation variability. In such conditions, the task of using alternative energy sources becomes relevant. One option is to use wind turbines. The development of wind turbines for geological exploration facilities is based on chaotic engineering solutions, which confirms the fact that there is no science-based methodology for the development of modern wind turbines.

The article reveals the methodological foundations for the application of wind turbines in geological research. The specifics of geological exploration work are such that even a slight interruption in the power supply leads to downtime of the main technological equipment. Based on this, when developing large mineral deposits, it is advisable to use combined energy supply systems, including both traditional sources of energy supply and alternative sources as backup power supply systems.

In the paper, based on the analysis of existing systems of alternative energy supply, a certain methodology has been developed that allows the most efficient and reasonable selection of one or another version of wind turbines.

Key words: wind turbines, energy supply, geological exploration, technological equipment, methodology, tower, rotary mechanism, power, wind speed.

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ГЕОЛОГИЯДА ЖЕЛ ГЕНЕРАТОРЛЫҚ ҚОНДЫРҒЫЛАРДЫ ҚОЛДАНУДЫҢ ӘДІСНАМАЛЫҚ НЕГІЗДЕРІ

Аннотация. Геологиялық-барлау жұмыстарын жүргізу кезінде бірінші кезектегі міндеттердің бірі энергиямен қамтамасыз ету. Энергиямен қамтамасыз ету жүйесі энергияны өндіруді, тасымалдауды және түрлендіруді қамтамасыз ететін бірқатар элементтерден тұрады. Геологиялық барлау жұмыстарының ерекшелігі оның күрделілігімен, негізгі энергетикалық жүйелерден алыстауымен, күрделі климаттық жағдайымен және геолокацияның тұрақсыздығымен ерекшеленеді. Мұндай жағдайларда баламалы энергия көздерін пайдалану міндеті өзекті болып отыр. Бір нұсқа – жел генераторларын пайдалану.

Жұмыста геологиялық зерттеулерде жел генераторлық қондырғыларды қолданудың әдіснамалық негіздері ашылады. Геологиялық-барлау жұмыстарының ерекшелігі электрмен жабдықтаудағы шамалы үзілістің өзі негізгі технологиялық жабдықтың тұрып қалуына әкеліп соқтырады. Осыны негізге ала отырып, пайдалы қазбалардың ірі кен орындарын игеру кезінде энергиямен қамтамасыз етудің дәстүрлі көздерін де, электрмен жабдықтаудың резервтік жүйелері ретінде баламалы көздерді де қамтитын энергиямен қамтамасыз етудің құрамдастырылған жүйесін пайдалану орынды.

Ғылыми мақалада баламалы энергиямен қамтамасыз етудің қолданыстағы жүйелерін талдау негізінде жел генераторларының бір немесе басқа нұсқасын тиімді және негізді таңдауға мүмкіндік беретін белгілі бір әдістеме жасалды.

Түйін сөздер: жел генераторлық қондырғылар, энергиямен қамтамасыз

ету, геологиялық-барлау жұмыстары, технологиялық жабдық, әдістеме, мұнара, бұрылыс механизмі, қуат, желдің жылдамдығы.

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МЕТОДОЛОГИЧЕСКИЕ ОСНОВЫ ПРИМЕНЕНИЯ ВЕТРОГЕНЕРАТОРНЫХ УСТАНОВОК В ГЕОЛОГИИ

Аннотация. При проведении геолого-разведочных работ одной из первоочередных задач является задача энергообеспечения. Система энергообеспечения состоит из ряда элементов обеспечивающих производство, транспортировку и преобразование энергии. Специфика геолого-разведочных работ отличается своей сложностью, связанной с удаленностью от основных энергетических систем, сложными климатическими условиями и непостоянством геолокации. В таких условиях актуальной становится задача использования альтернативных источников энергии. Одним из вариантов является использование ветрогенераторных установок. Разработка ветрогенераторных установок для объектов геолого-разведочных работ основана на хаотичных инженерных решениях, что подтверждает факт отсутствия научно-обоснованной методологии разработки современных ветрогенераторных установок.

В работе раскрываются методологические основы применения ветрогенераторных установок в геологических исследованиях. Специфика геолого-разведочных работ такова, что даже незначительный перерыв в электроснабжении приводит к простоям основного технологического оборудования. Исходя из этого, при разработке крупных месторождений полезных ископаемых целесообразно использовать комбинированные системы энергообеспечения, включающие как традиционные источники энергообеспечения, так и альтернативные источники в качестве резервных систем электроснабжения.

В научной статье на основе проделанного анализа существующих систем альтернативного энергообеспечения выработана определенная

методология, позволяющая наиболее эффективно и обоснованно подобрать тот или иной вариант ветрогенераторных установок.

Ключевые слова: ветрогенераторные установки, энергообеспечение, геолого-разведочные работы, технологическое оборудование, методология, башня, поворотный механизм, мощность, скорость ветра.

Introduction. More than 30 years have passed since the acquisition of independence by the Republic of Kazakhstan. During this period, the volume of exploration work carried out by domestic companies has decreased. There are quite a few reasons for this. One of the reasons is the remoteness of exploration objects from power supply systems.

In the conditions of high energy consumption in Kazakhstan and involvement in the global processes of dynamic development of renewable energy sources (RES), the field of wind energy is becoming extremely relevant. In this case, both several advantages, including the competitiveness of this type of energy production, and the great potential of Kazakhstan in its development in terms of the geographical position of the republic are important (http://www.magisterjournal.ru/number44_1.htm).

Following the National Program for the Development of Wind Energy in the Republic of Kazakhstan to 2024, goals were set for using the wind energy potential in Kazakhstan to generate electricity in the amount of 900 million kWh per year by 2015 and 5 billion kWh by 2024 in the light of the tasks set in the Concept of the transition of the Republic of Kazakhstan to sustainable development and the Strategy for industrial and innovative development of the Republic of Kazakhstan to preserve natural resources and the environment (National Program for the development of wind energy in the Republic of Kazakhstan until 2015 with a perspective until 2024).

It is also necessary to take into account the fact that certain economic conditions require more advanced ideas to improve the efficiency of exploration. The existing system of energy supply for geological exploration has low mobility and efficiency. Given the vast territory of the Republic of Kazakhstan, it is necessary to look for alternative sources of energy supply for geological exploration.

At present, there are several options for energy supply for geological exploration, differing in technical and economic indicators. The choice of one or another option depends on the mining and geological, climatic, and some other conditions (Has Affordable, Efficient Rooftop Wind Power Arrived? -http://www.popularmechanics.com/home/improvement/energy-efficient/4321836.).

Along with domestic companies, foreign companies also carry out exploration work in the territory of the Republic of Kazakhstan. Statistics show that these companies adhere to traditional approaches in matters of choosing an energy supply option and are not interested in conducting scientific research in terms of finding alternative energy sources. Especially with the transition to market relations. Also, environmental safety requirements are not always met.

Materials and methods. One of the alternative energy sources is wind turbines. The need to introduce wind turbines in the Republic of Kazakhstan is because enterprises that have been generating electricity since the USSR times are technically outdated, and the construction of new ones required large material costs. It was also affected by the fact that due to the lack of components, the construction of new energy supply enterprises turned out to be practically impossible. In this regard, the Action plan was developed for the development of alternative and renewable energy in Kazakhstan for 2013-2020 (Action plan for the development of alternative and renewable energy in Kazakhstan for 2013-2020; E.A. Efremenkov, et al., 2019).

In Europe wind turbines became widespread already at the end of the 20th century (Fig. 1). This was due to several factors, such as ensuring environmental safety, moving away from energy dependence on Russia, and reducing traditional energy sources.

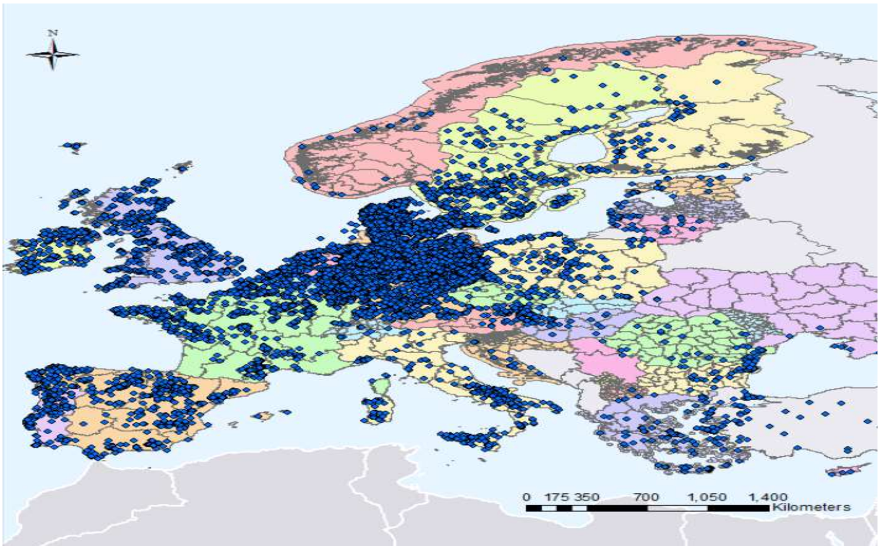

Figure 1 - Map of the location of wind turbines in Europe

Such a large number of wind turbines is explained by their purpose and technical parameters, as well as natural and climatic conditions. The experience of European countries shows that the most optimal condition is a wind speed of 15 m/s. Studies have shown that the power of wind turbines increases eight times when the wind speed changes from 5 m/s to 10 m/s. Also, important parameters are the installation height of wind turbines and the area of rotation of the generator blades (Tulegulov A.D., et al., 2022; Rooftop turbines/ -http://www.youtube.com/watch?v=WZ5kX5Yw4eY).

Figure 2 is a graph of wind energy generation in gigawatt-hours in the most advanced countries in 2018.

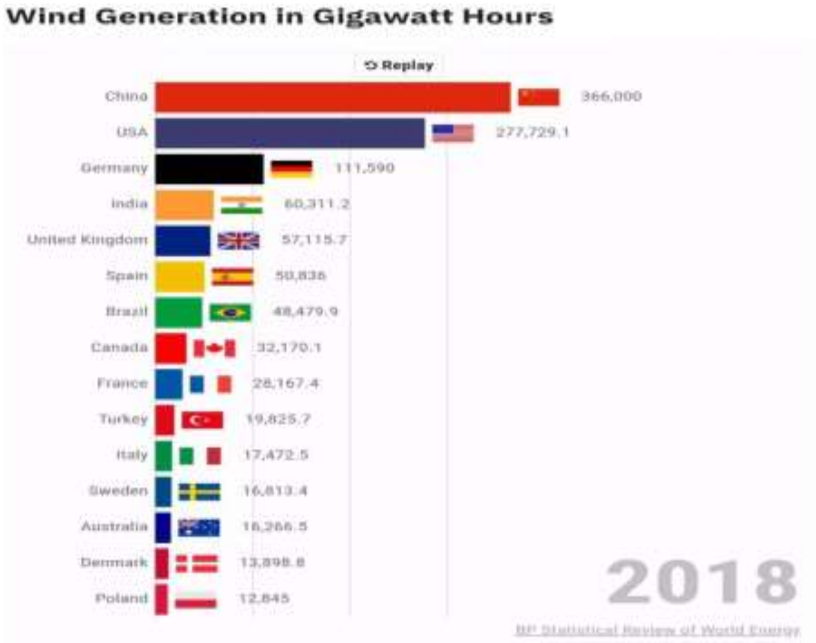

Figure 2 - Graph of wind energy generation in gigawatt-hours in the most advanced countries in 2018

As previously noted, certain conditions are necessary for the generation of electricity by wind turbines. Studies have shown that the most promising places for the production of electrical energy are coastal sea zones, where powerful air currents are formed throughout the year. The Republic of Kazakhstan also has access to the sea. However, given the fact that the Caspian Sea is an inland closed water body, the wind speed here is limited and reaches 7 m/s at best. This factor poses a serious challenge for local scientists in the search for new approaches to the design of wind turbines capable of generating energy under such conditions (V.S. Krivtsov, et al., 2003).

Figure 3 shows the wind atlas of the Republic of Kazakhstan.

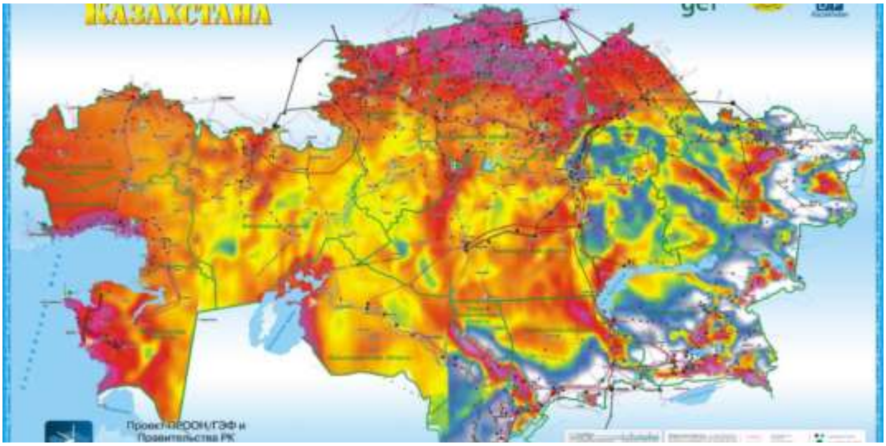

Figure 3 - Wind atlas of the Republic of Kazakhstan

The most suitable types for the conditions of Kazakhstan are wind turbines with a vertical axis of rotation. Table 1 shows the efficiency indicators of wind turbines by regions of Kazakhstan.

Table 1 - Efficiency indicators of wind turbines by regions of Kazakhstan

Region	Number of windy days per year	Efficiency in %
Astana	195	49
Pavlodar	198	50.8
Aktau	202	52
Atyrau	211	56
Petropavlovsk	224	60
Balkhash	230	63
Fort Shevchenko	241	69
Kulaly	243	70

From table 1, it is obvious that the most priority for the development of wind energy is the regions close to the Caspian Sea and Lake Balkhash, which is quite understandable.

Figure 4 shows the wind potential of the Republic of Kazakhstan.

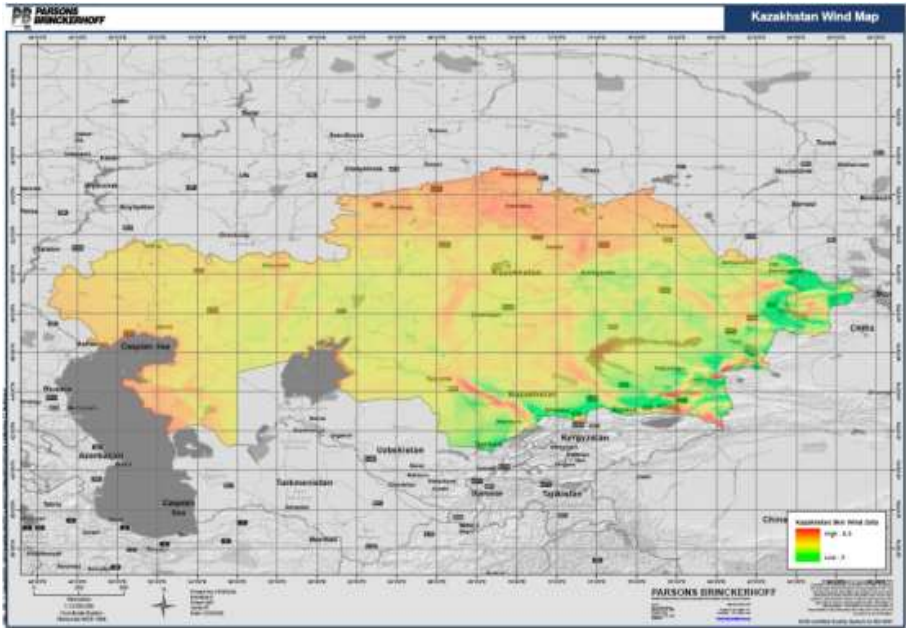

Figure 4 - Wind potential of the Republic of Kazakhstan

Scientific studies of recent years give positive forecasts in terms of the development of wind turbines in the Republic of Kazakhstan. It should be understood that initially Kazakhstan was positioned as a region with developed animal husbandry. Of course, the period of Russian colonial policy caused irreparable damage to the development of animal husbandry, but good results have been achieved in recent years. Therefore, the issue of energy supply for remote livestock farms and economies is especially relevant.

Analyzing the chronology of the development of wind turbines over 40 years, one can note low rates in terms of increasing efficiency. This is due to the instability of the speed of movement of air masses at altitudes of less than 200 meters. Scientific studies have resulted that at altitudes over 200 meters
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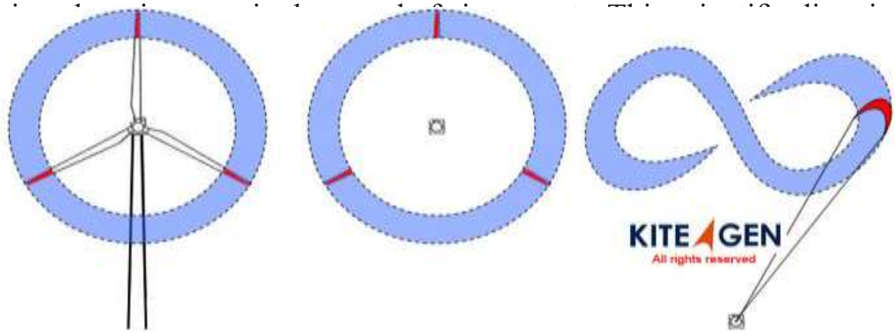

Figure 5 - Energy production using flying power plants

Based on the results, it is possible to predict an increase in the efficiency of wind turbines soon (Fig. 6).

Figure 6 - Forecast indicators of wind turbines

Increasing the height of onshore wind turbines to 130 meters and the rotor diameter to 174 meters will make it possible to obtain electricity of 5.5 MW by 2035. An increase in the height of wind turbines located on the sea shelves to 151 meters and a rotor diameter of up to 250 meters will make it possible to obtain electricity of the order of 17 MW by 2035 [M.E. Baymirov, 2007].

Despite the 40 years in the development of wind turbines, there were no particularly significant structural changes (Fig. 7). The basis of the design are the following elements:

- tower,
- swivel mechanism
- foundation,
- electric generator,
- propeller blades,
- power cabinet and control circuits.

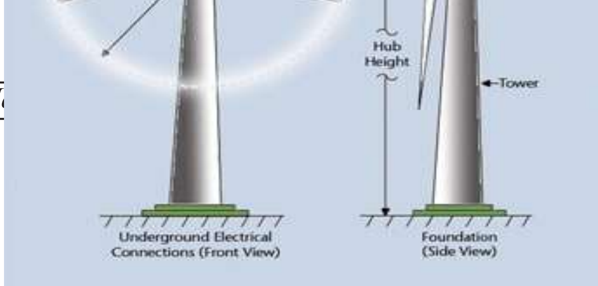

Figure 7 - The main elements of the wind generator

Calculations of wind turbine parameters.

There are several methods for calculating the parameters of wind turbines. To calculate the parameters of a wind generator and select a generator model, we define the criteria, according to which a specific wind generator model should be selected.

The first criterion is the average annual wind speed at the installation site.

The second criterion is the amount of generated electric power.

The third one is the value of the starting wind speed, which varies for different models in the range from 2 to 4 m/s.

The fourth is the nominal wind speed, which is usually 8 - 15 m/s.

The average annual wind speed is determined using the Beaufort scale and data obtained by observing the visible effect of the wind during the year (Fig. 8) at the site planned for the installation of a wind turbine (P.P. Bezrukikh, 2010).

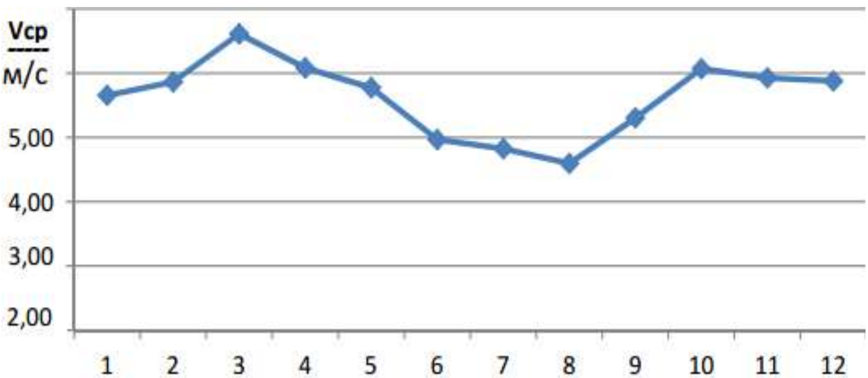

Figure 8 - Average wind speed by months

Let us now turn to methods for calculating systems with wind farms. First of all, we need to know the rated power of the object for which it is planned to install a wind generator. As a result of scientific research and practical experiments, a graph of the dependence of the power generated by a wind turbine on wind speed was obtained (Nikitenko G.V., 2008).

The power of the wind power plant is calculated by the formula:

$$N = p * S * \frac{\vartheta^3}{2}$$

where:
p is the density of air masses;
S is the total-blown area of the rotor blades;
V is the speed of the airflow;
N is the power of the airflow.

Since N is a parameter that drastically affects the power of the wind generator, then the real power of the installation will be close to the calculated value of N.

Calculation of rotors of wind turbines

When designing a wind turbine, two types of rotors are usually used:
- winged - rotation in the horizontal plane;
- Savonius rotor, Darrieus rotor - rotation in a vertical plane.

Rotor designs with rotation in any of the planes can be calculated using the formula:

$$Z = L * \frac{W}{60} / \vartheta$$

where:
Z is the degree of speed (low speed) of the rotor;
L is the size of the length of the circle described by the blades;
W is the speed (frequency) of rotation of the rotor;
V is the airflow rate.

Based on this formula, you can easily calculate the number of revolutions W - rotation speed

Also, one of the important indicators of a wind generator is a step.

This parameter can be determined using the formula:

$$H = 2\pi R * tg\alpha$$

where:
2π is a constant (6.28);
R is the radius described by the blade;
tg α is the section angle.

There are two types of wind turbines, differing in their technical parameters, one of the most important of which is power. The most distinguishing characteristic is the rotation geometry of the main rotor. On this basis, two possible options for wind turbines can be noted, namely, wind turbines of vertical and horizontal types. For vertical type wind turbines (Fig. 9), it is characteristic that the turbine is located vertically concerning the ground plane. For wind turbines of the horizontal (Fig. 10) type, it is characteristic that the turbine is located parallel to the earth's surface.

Figure 9 - Vertical type wind generator

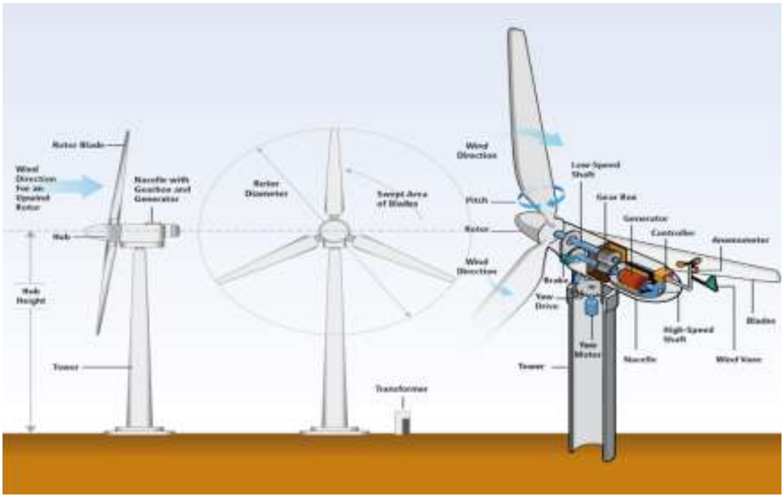

Figure 10 - Horizontal type wind generator

A feature of a vertical type wind generator is that it can operate at lower frequencies and is more practical to operate. Its design contains fewer mechanisms and components, which in turn increases the reliability of the vertical wind turbine. All this together allows you to get fairly high efficiency. In terms of environmental friendliness vertical type wind generator complies with European standards. Figure 11 shows wind generators of vertical type [Kargiev V.M., 2001].

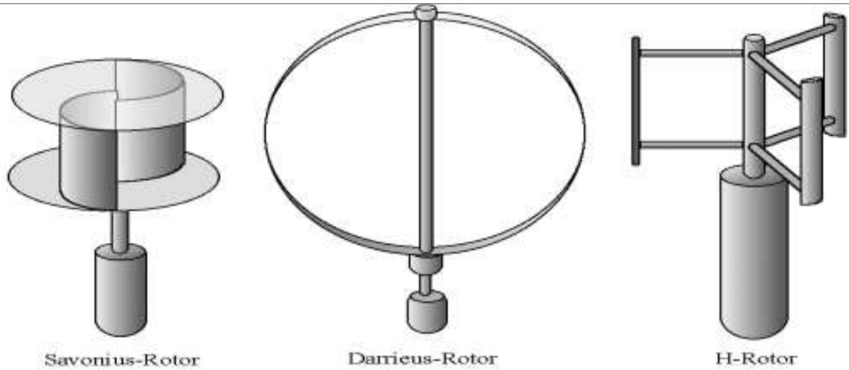

Figure 11 - Vertical type wind rotors

The basic principle of operation of a vertical type wind rotor is the principle of magnetic levitation. Under the influence of the wind flow, impulse and lift forces are formed simultaneously. Along with these forces, the actual braking force is formed as an element of braking. Impulse and lift forces act on the blades and set them in rotational motion. As a result, the rotor is activated, which initiates a magnetic field. In the future, this magnetic field is transformed into electrical energy (Zysin L.V., 2008].

Results. Thus, it is obvious that when choosing one or another version of a wind generator, it is necessary to take into account several factors that allow for achieving maximum efficiency in generating electricity. Our studies show that vertical-type wind rotors will be more practical for the territory of the Republic of Kazakhstan. At the same time, it is necessary to take into account the fact that even among vertical wind turbines, certain differences play a significant role in optimizing the operating modes of vertical wind generators. The most significant element according to our observations is wind traps. Depending on the goals set, it is necessary to make the right choice of wind catcher. Following the above calculations, the dependence of the generated energy on the wind power was simulated (Fig. 12)

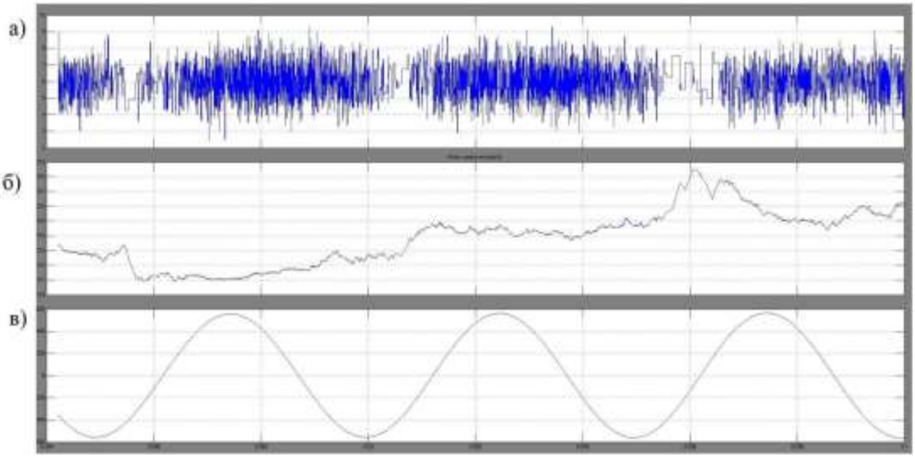

Figure 12 - The results of modeling the dependence of the power of the generated energy on the wind power: a) wind speed, b) rotation speed of the synchronous generator shaft, and c) generated voltage.

From the presented graphs, it is obvious that the rotation speed of the electric generator changes under the change in wind speed. This result corresponds to reality.

Discussion. Our research allows us to create methodological foundations for the most effective choice of the type of wind turbine, depending on the goals. Also, it is necessary to take into account the specific features of the equipment used, economic feasibility, and environmental safety. In this regard, certain nuances must be taken into consideration. One of the main issues is the cubic dependence of the power of almost any modern wind generator on wind speed. With a decrease in speed by 2 times, the amount of energy decreases by 8 times. Solving the problem requires increasing the height of the mast, which entails additional financial costs.

Like any technical product, a wind rotor requires professional maintenance, as well as repair and replacement of components. It also requires additional financial costs.

Conclusions. Thus, as a result of our research, the following fundamentally important conclusions can be noted:

1. The power of the wind generator is directly proportional to the third power of the wind speed. Based on this, it follows that doubling the wind speed will increase the power by eight times.
2. It is necessary to develop efficient structures for regions where the wind speed does not exceed 7 m/s.
3. The most efficient are wind turbines with a vertical axis of rotation, in particular rotary or carousel type.

To solve these problems, it is necessary to conduct scientific research and development work by scientists around the world. A pivotal role in these studies is occupied by the methodology of using wind turbines. The methodology will make it possible to optimize the parameters of wind turbines and create optimal technological designs.

All this together allows you to choose the right model of the device, the right number of units, and the power of the stations. The indisputable fact is that the development of new types of wind rotors is a very promising direction, as wind turbines allow you to maintain an ecological balance, with a minimum of construction and operating costs.

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ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Директор отдела издания научных журналов НАН РК *А. Ботанқызы*
Заместитель директор отдела издания научных журналов НАН РК *Р. Жәлиқызы*
Редакторы: *М.С. Ахметова, Д.С. Аленов*
Верстка на компьютере *Г.Д.Жадыранова*

Подписано в печать 14.10.2022.
Формат 70x90 1/16. Бумага офсетная. Печать – ризограф.
20,0 п.л. Тираж 300. Заказ 5.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-19