ISSN 2181-8622

Manufacturing technology problems

Scientific and Technical Journal Namangan Institute of Engineering and Technology

NAMANGAN MUXANDISLIK-TEXNOLOGIYA INSTITUTI

INDEX COPERNICUS INTERNATIONAL

Volume 8
Issue 4
2023

Google Scholar

Crossref doi

SLIB.UZ Scientific library of Uzbekistan

20. Tashmetov K. et al. Expert system for diagnosing faults railroad switch of automation and telemechanic systems //AIP Conference Proceedings. – AIP Publishing, 2022. – T. 2432. – №. 1.

PROSPECTS FOR THE APPLICATION OF VERTICAL AXIS WIND TURBINES IN THE JIZZAKH REGION

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Abstract:

Objective. Foreign and local researchers analyzed the wind energy potential, technical and economic indicators of Bukhara, Navoi, Karakalpakstan, Kashkadarya and Tashkent regions. However, the information obtained as a result of the study about the potential of wind energy in the Jizzakh region, its direction and technical indicators is insufficient. In this article, analyzing the potential of wind energy in the Jizzakh region, the prospects for the use of small vertical wind energy devices are explored. Wind speed and its energy potential are the main factors in the production of electricity using wind energy devices. When using a wind energy device, it is necessary to find a point in this area with high wind speed and potential.

Methods. Data from NASA Power, Global Wind Atlas, and Windy international climate platforms were used to estimate the potential of wind energy.

Results. As a result of the research, average annual wind speeds were determined for each district of the Jizzakh region and areas with the highest wind speeds within the areas. At the same time, the coordinates of points with high wind energy potential were found in areas with high wind speeds. A brief description of small-power vertical type wind turbines that can operate at low wind speeds produced by various companies is given. An optimal wind power device has been selected that can operate at low wind speeds.

Conslusion. When analyzing the wind energy potential of the Jizzakh region using international climate platforms, the wind speed in the Farish, Gallaral and Sh. Rashidov districts among the districts located in the Jizzakh region is higher compared to other regions. In the above districts, the use of small wind power plants is more efficient compared to other districts.

Keywords: Wind power device, wind speed, wind energy, Weibull distribution function, small-power vertical wind turbines.

Introduction. The population of the Earth is increasing from year to year, and the amount of electricity consumed by them is also increasing. To meet the ever-increasing energy consumption, extensive use of renewable energy sources in addition to existing fuels is the need of the hour. The source of energy of the world since 1970 and its trained until 2040 is shown in Fig. 1. It can be observed that oil, gas, and coal were the main source of energy for the last five decades and similar trend is projected for the coming decades.

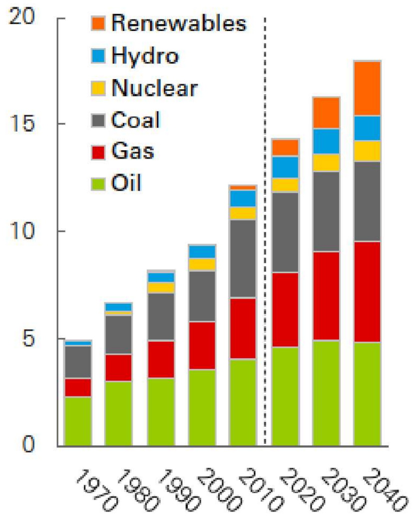

Fig.1. Use of energy source and its transition (Renewable includes solar, wind, biomass, etc.)[1]

Annual renewable capacity additions are forecast to increase continuously over the forecast period, reaching a record 460 GW in 2027 in the main case, 60% higher than last year's growth. At the end of the forecast period, solar PV and wind provide the vast majority of global renewable capacity additions in 2027, accounting for nearly 95% as technology-specific challenges and limited policy support hamper faster expansion of hydropower, bioenergy, geothermal, CSP and ocean technologies Fig.2.

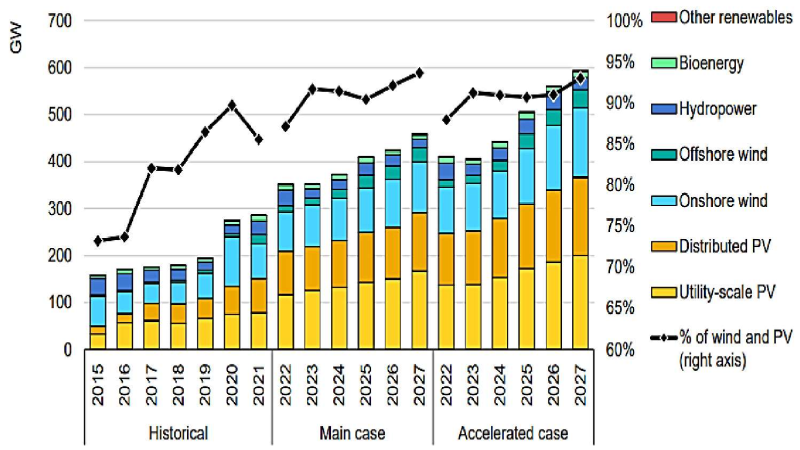

Fig.2. Renewable annual net capacity additions by technology, main and accelerated cases, 2015-2027[2]

The increase in demand for energy resources on a global scale has given a great impetus to the development of wind energy. Wind power capacity in operation around the world contributed an estimated 7% of total electricity generation in 2021 fig 3. 93.6 The top five global markets for new installations in 2022 were: China, USA, Brazil, Germany and Sweden. Overall, they accounted for 71% of global installs last year, down 3.7% from 2021. This was primarily because the world's two largest markets, China and the US, lost a combined market share of 5% year-over-year, the second year in a row that both countries lost market share.

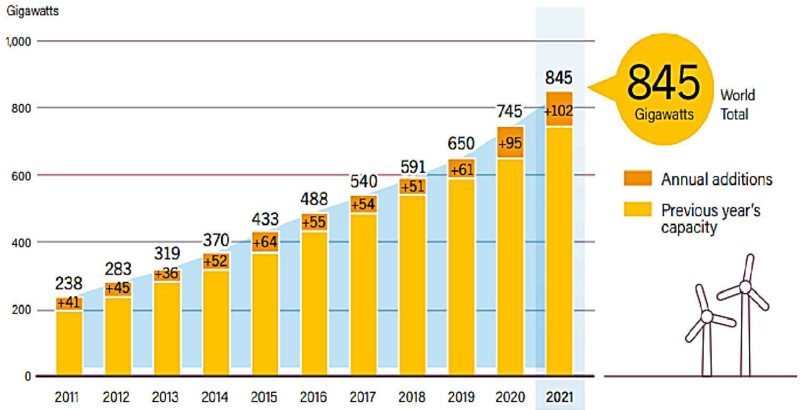

Fig. 3.Wind Power Global Capacity and Annual Additions, 2011-2021

Given the fact that water sources in the Central Asian region are declining, it is important to accelerate the use of alternative energy. Uzbekistan has the opportunity to use wind energy, but previously this renewable energy sector was not among the priority areas for the development of local energy. At the beginning of the 21st century, national and foreign experts summarized previously known information, conducted a new series of observations necessary to assess the local and regional environmental situation, the risks associated with the movement of air masses (about 90 meteorological stations operate on the territory of the country, which provided the results of systematic observations for 1994 -2004 and other periods, mainly at altitudes up to 10 m). As a result, in the mid-2000s, the gross potential was estimated at 2.2 million toe. per year, technical - 0.4 million toe. per year (five times less), and economic - as "insignificant". Below in the figure 4. one of the variants of the wind map of the Republic of Uzbekistan is shown. Its analysis allows a general idea of the nature of the distribution of wind energy potential within the territory of the country.

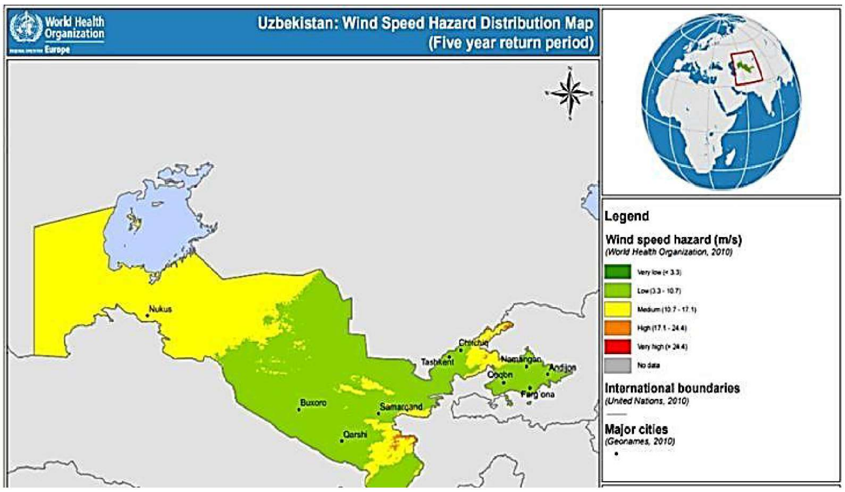

Fig.4. Uzbekistan: Wind Speed Hazard Distribution Map[4]

The first wind turbine with a capacity of 170 kW and a cost of more than 2 million US dollars was built in 2010 near the Charvak reservoir. Design documentation was prepared by Hydroproject OJSC, equipment was supplied by Doojin Co. (The Republic of Korea). The second (experimental, but the first large on the scale of Central Asia) Chinese-made wind turbines was installed in 2012 in the Yubileiny settlement of the Bostanlyk district (Tashkent region). Its power is 750 kW, the diameter of the wind wheel is 50 m, the height of the tower is 65 m. In 2012, based on the experience gained, Uzbekenergo JSC planned to create a wind farm with a capacity of 100 MW, generating about 170 million kWh of electricity per year. Subsequently, the implementation of the plan was delayed by ten years for various reasons, including the lack of reliable comprehensive indicators of wind energy potential. According to experts, the gross potential of wind energy has exceeded 520 GW (this is the possible total capacity of wind turbines), which theoretically allows generating 1,077,651 GWh of electricity per year. Promising development areas include the Navoi region and sites located in the Republic of Karakalpakstan near remote settlements and the small industrial zone "Muynak" (created in 2017 on the territory of the former "Muynak fish cannery" and the largest in Central Asia). From a technical point of view, according to the recommendations of the researchers, the most optimal solution is the use of wind turbines with a capacity of 3 MW and a rotor diameter of 100 m. specific capital investments in the creation of 1 MW of wind power capacity were estimated at 1 million US dollars (comparable to the same indicator for thermal power plants), the cost of wind power was approximately 5.5 q/kWh. In the Republic of Uzbekistan, in cooperation with international financial institutions, feasibility studies have been carried out in the field of widespread use of wind energy and the "Concept of Electricity Supply of the Republic of Uzbekistan for 2020-2030" has been developed. One of the main goals is the construction of wind power plants with a capacity of 3000 MW by 2030 in the republic. Today, several projects on the construction of SPPs have been launched in Uzbekistan. Including:

Based on an agreement signed on April 1, 2021, Masdar Clean Energy of the United Arab Emirates and the Ministry of Energy of the Republic of Uzbekistan reached an agreement on the construction of a 500 MW wind farm in the city of Tomdi district of the Navoi region. With a project cost of $600 million, the wind farm will generate 1.8 billion kWh of electricity per year at full capacity. Two more large projects are being implemented by ACWA Power Company of Saudi Arabia, and one of these projects, according to the contract signed between ACWA Power Company and the Ministry of Energy on January 23, 2021, provides for the construction of two wind power plants with a total capacity of 1 GW in Gijduvon and Peshkun districts of Bukhara region. The second project with the participation of this company is based on the agreement signed between the Ministry of Energy and ACWA Power (Saudi Arabia) on December 23, 2022 with the financial support of the European Bank for Reconstruction and Development, and works on the construction of another wind power plant with a capacity of 1500 MW in Beruni and Karauzyak regions of Karakalpakstan. When this wind farm is operational, it will produce 350 million kWh of electricity per year. On March 28, 2023, a memorandum of understanding was signed between China's CNEEC (China National Electric Engineering Company), China Huadian Overseas Investments, SANY Renewable Energy and the Ministry of Energy to study the possibilities of building wind power plants with a capacity of up to 1000 MW in Jizzakh region. According to this memorandum, 1 billion

US dollars will be directly invested in the implementation of the project[5].

Methods. *Analysis of wind potential of the region.*

Uzbekistan, a double landlocked country with no coastal area, consists of 25% mountainous valleys and 75% desert covered oasis. Therefore the average yearly wind speed on the whole territory of the country is estimated between 2-2.5 m/sec, which indicates a non-promising future for wind power engineering in Uzbekistan, especially for wind turbines of middle and high power.

Consequently the wind energy potential in Uzbekistan is relatively less exploitable in comparison withthe solar and hydropower potential (table1)[6].

Even in the provinces with areasonable potential wind resource is very seasonal and it is necessary to study the coincidence between peak wind months and the electricity demands.

Table 1

№	Province	Area of wind resource km^2	Gross potential W/m^2	Gross energy GWh/year
1	Karakalpakistan Rep.	1649	93	10752.20
2	Andijan	42	20	60.00
3	Bukhara	294	90	2421.80
4	Jizzakh	205	49	649.60
5	Kashkadaryo	284	58	1162.00
6	Navoi	1108	104	7931.40
7	Namangan	79	28	155.40
8	Samarkand	164	61	690.60
9	Surkhandaryo	208	30	434.80
10	Sirdaryo	51	58	212.00
11	Tashkent	156	100	1066.00
12	Fergana	71	34	49.60
13	Khorazm	63	55	264.00
	Total	4474	84	25849.00

Jizzakh region is located in the center of Uzbekistan. The region borders on the Republic of Kazakhstan in the north and northeast, Syrdarya region in the east, the Republic of Tajikistan in the east and southeast, Samarkand region in the south and southwest. and Navoi region in the west[7]. Air currents that affect the climate of the region are predominantly northwestern and southwestern air currents. The northwesterly air flow comes from the north from the western part of Russia and Kazakhstan and is 34.5 days a year. The south-west air flow also has a great influence on the climate of the region and is 63.2 days a year. Fig. 5. shows the direction of the north-western air flow entering the territory of the Jizzakh region[8].

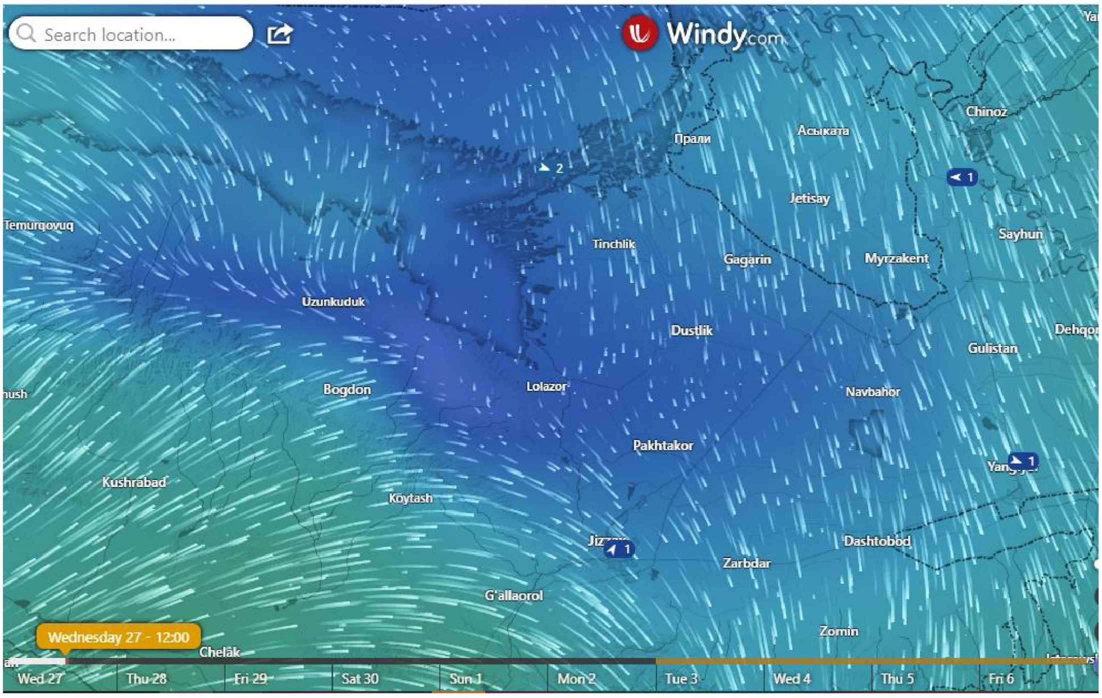

Fig.5. The direction of the north-west air flow[9]

Based on the data obtained from the NASA POWER international geographic database and the MERRA-2 satellite, annual average and monthly average wind speed in districts located in Jizzakh region at a height of h=10 m shown in Fig.6.

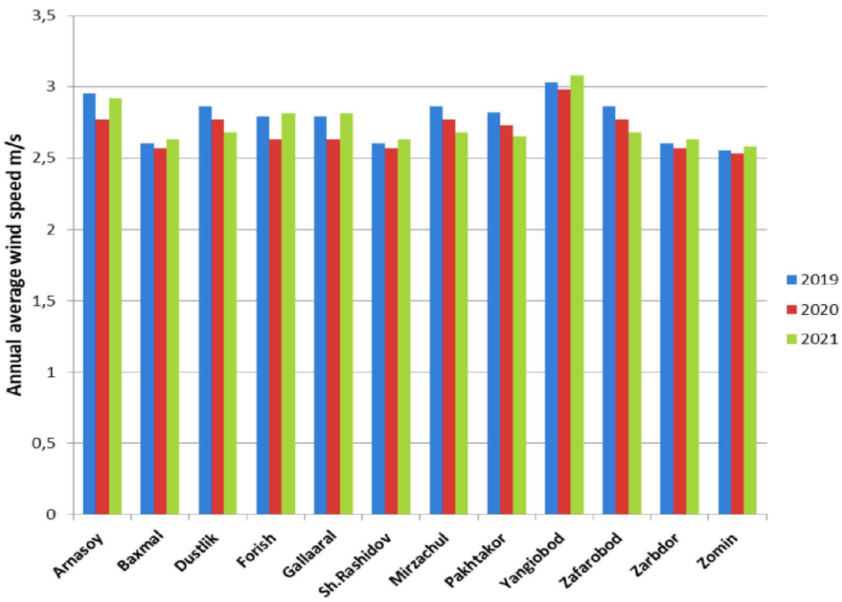

Fig.6. The average annual wind speed at height of h=10 m

It can be seen that the wind speed is higher in Arnasoy and Yangiabad districts of Jizzakh region compared to other districts. In particular, the wind speed in Yangiabad district will change from 3.03 m/s to 3.08 m/s in 2019-2021, and from

2.95 m/s to 2.92 m/s in Arnasoy district. Also in 2019-2021, the wind speed in the Forish district changes from 2.79 m/s to 2.81 m/s, and in the Gallaorol region - from 2.79 m/s to 2.81 m/s. The wind speed is low in Zomin district, the average annual wind speed in 2019-2021 is 2.55-2.58 m/s(Table 2).

Table 2

Districts	Latitude(°)	Longitude(°)	Annual average wind speed (m/s)		
			2019	2020	2021
Yangiobod	39,9	68,7	3,03	2,98	3,08
Arnasoy	40,5	67	2,95	2,77	2,92
Farish	40,04	67,4	2,79	2,63	2,81
Gallaaral	40	67,6	2,79	2,63	2,81
Dustlik	40	68	2,86	2,77	2,68
Mirzachul	40,6	68,1	2,86	2,77	2,68
Zafarobod	40,3	67,8	2,86	2,77	2,68
Pakhtakor	40,3	67,9	2,82	2,73	2,65
Baxmal	39,7	67,9	2,6	2,57	2,63
Sh.Rashidov	40	67,8	2,6	2,57	2,63
Zarbdor	40	68,1	2,6	2,57	2,63
Zomin	39,9	68,4	2,55	2,53	2,58

Based on the data presented in Fig. 8 and Table 2, it can be seen that the average annual wind speed at the points indicated in the coordinates is 2.5-3 m/s. This speed is not enough to generate electricity using a wind power plant. The operating range of the wind energy device takes values between 3 and 10 on the Beaufort scale (Table 3). Therefore, the value of the wind speed should be higher than 3.5 m/s when using a wind energy device to produce power up to the rated value. In this case, it is necessary to determine the points where the wind speed is higher than 4 m/s.

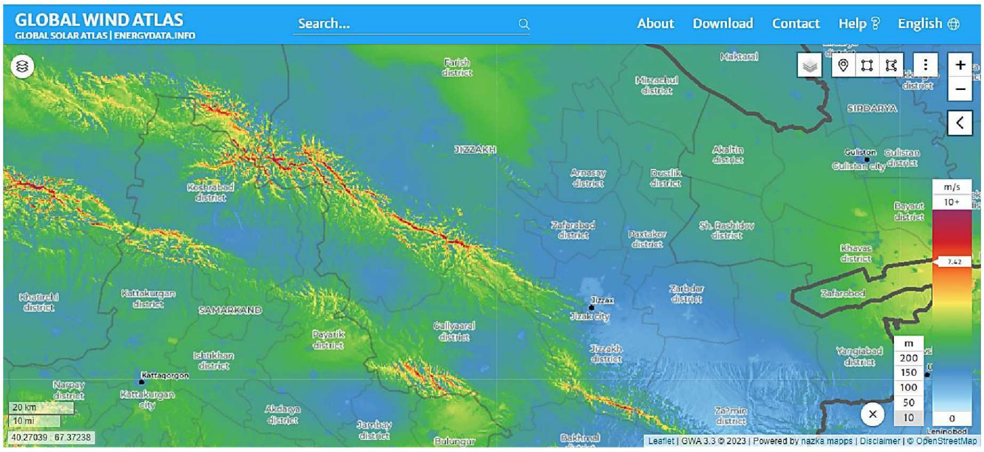

Fig.7. Points with high wind energy potential

Based on the data obtained from the Global Wind Atlas, there are points with a wind speed of 4 m/s and higher, and these points are located in the mountainous points of Forish, Gallaraal and Sh.Rashidov districts of the region(Fig 7,9)[10]. Also, the research conducted by the USAID international organization of the USA shows that the points with high wind energy potential in the Jizzakh region correspond to the territory of Farish, Gallaraal and Sh.Rashidov districts. (Fig. 8)[11].

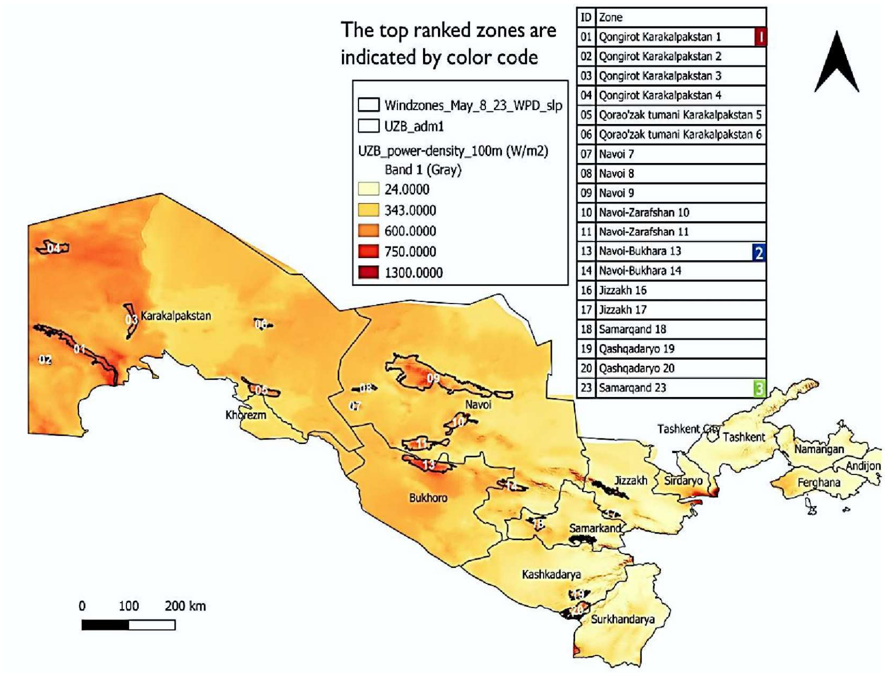

Fig.8. Updated wind energy zones by USAID/Tetra Tech. [12]

The wind speed at these selected points is given below (Fig. 10).

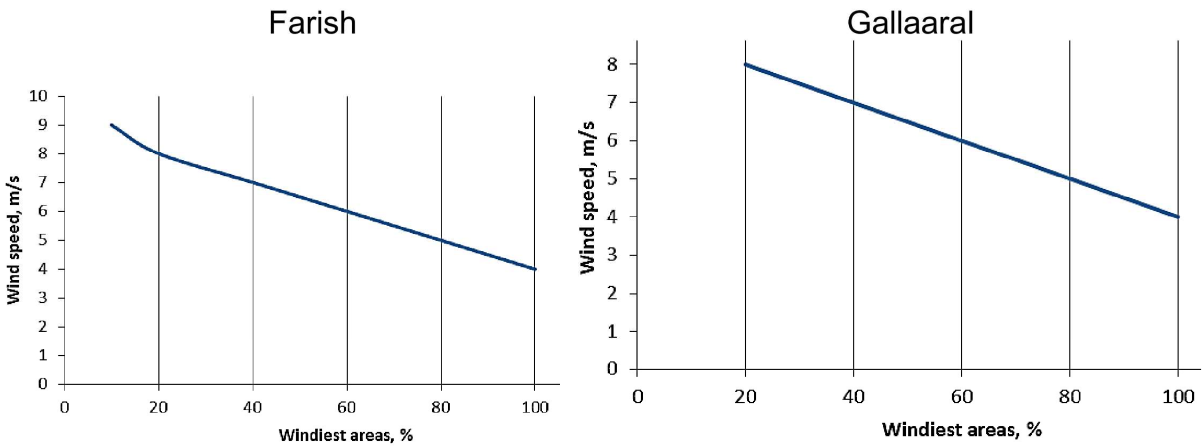

Fig.9. Wind speed at selected points

It can be seen from the data presented in Fig. 10 that the wind speed varies in the range of 6-8 m/s at the windy points located in the mountainous regions of 3 districts. This change covers a selected area in Forish district, where the wind speed is 20% at 8 m/s, and 40% when the wind speed is 7 m/s. For

Gallaraal district, it is 20% when the wind speed is 8 m/s, and 60% when the wind speed is up to 5 m/s. For Sh.Rashidov district, when the wind speed at the points located in the mountainous area is 6 m/s, the windy area is 20%, and when it is 7 m/s or higher, the values are up to 10%.

Around the world, horizontal wind turbines are mainly used in the production of large-scale electricity from wind energy. It is also possible to use a horizontal type wind power device to supply electricity to household consumers. When using a horizontal type wind power device, it is necessary to take into account the speed, direction and frequency of the wind. The use of horizontal wind turbines in areas where the direction and speed of the wind changes is technically and economically inefficient. In regions with variable wind direction and speed, it is effective to use vertical wind power devices. The advantages and disadvantages of vertical wind energy devices can be listed as follows[13]:

VAWT advantages

- No yaw mechanisms is needed.
- VAWTs have lower wind startup speeds than HAWTs.
- VAWTs may be built at locations where taller structures are prohibited.

VAWT disadvantages

- VAWTs have low efficiency.
- More blades than HAWTs.
- VAWT advantages.

Despite the existence of different constructions of vertical type wind energy devices, they can be divided into two large groups: Savonius vertical wind turbines and Darrius vertical wind turbines. Savonius turbines working on the aerodynamic drag principle and excellent in areas of turbulent wind and can self-start at low wind speed. Darrieus turbines were operating on the principle of lift. The efficiency of Savonius type wind turbines is lower than that of Darrius type wind turbines. According to Betz's law, the efficiency of the Savonius turbine is up to 20%, and the efficiency of the Darrius wind turbine is up to 40%. Fig 11.[14]

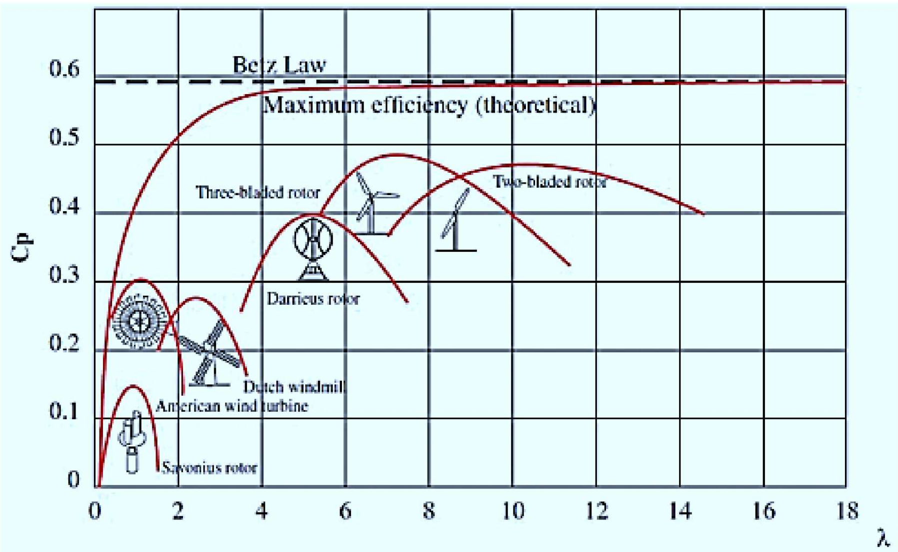

Fig.10. Betz law. Ideal turbine coefficient

Darrieus rotor can be subdivided into three categories; D – type, H – type and helix type which have been shown in Fig. 12 [15].

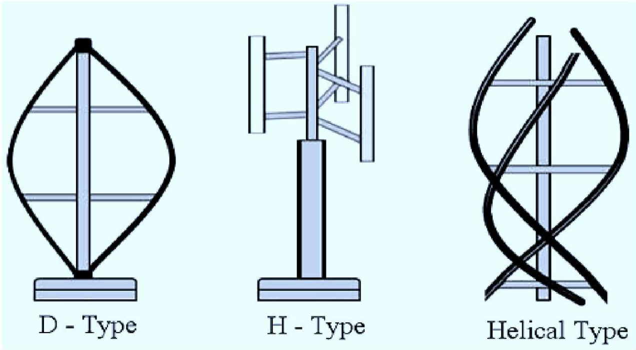

Fig.11. Different types of Darrieus wind turbine

Discussion. Unlike other energy sources, wind energy efficiency is high. Therefore, the theoretical and technical potential of wind energy is taken into account when using wind energy potential. The theoretical potential of wind energy is determined by the following expression[16]:

$$W_{theoritical}= 0{,}025\rho TS \sum_{i=1}^{n} v_i^3 t_i \ , \qquad (1)$$

here, ρ is air density, kg/m^3; T = 8760 hours during the year; S – area surface, m^2; v – i multi-year wind speed in the range; t – I approximate wind speed in the range.

Technical potential of wind energy:

$$W_{technical}= 0{,}01 \frac{N_C}{D^2} TS, \qquad (2)$$

here, N_C – the average power of the wind turbine and it is expressed as follows:

$$N_C = \frac{\pi D^2}{8} \rho \sum_{i=1}^{n} v_i^3 \, \eta_{VAWT} t_i \ , \qquad (3)$$

here, η_{VAWT} efficiency index of VAWT

$$\eta_{VAWT} = c_p \eta_{mech} \eta_{el} \ , \qquad (4)$$

here, c_p- wind energy utilization factor; η_{mech} - mechanical efficiency of the wind turbine; η_{el} – electrical efficiency of the wind turbine.

The amount of electricity produced by a wind turbine:

$$E = 0{,}01 \ T \sum_{i=v_{switch\ on}}^{v_{switch\ off}} P_{VAWT\ i} \, (k_h \text{v}) \, f_i \, (\text{v}), \qquad (5)$$

Useful power of the wind turbine:

$$P_{VAWT} = P_{flow-specific\ power} S_{VAWT} \eta_{rotor} \eta_{generator} \sigma 10^{-3}, \qquad (6)$$

Flow-specific power,

$$P_{flow-specific\ power} = 0{,}5 \ \rho \ (k_h \ \text{v})^3 \qquad (7)$$

In the production of electricity from wind energy, the working range of wind speed is used. This working range should not exceed 25 m/s. This speed is equal to 9 points on Beaufort's 12-point scale. Wind turbines generally operate between 3 and force 10 on the Beaufort scale and the rated capacity is commonly defined at forces 6/7 depending upon the wind turbine type[17].

Results. The conducted research shows that the annual average speed of the wind blowing in the Jizzakh region does not exceed 2.5-3 m/s at a height of h=10 m. It can be determined that the wind speed is 6-8 m/s in the mountainous regions of Farish, Gallaraal and Sh, Rashidov districts. Therefore, in some areas of the above 3 districts, there is a possibility of using vertical type wind energy devices.

The use of H-type turbines, which are modern modifications of the Darrieus wind turbine, is efficient compared to the Savonius-type vertical wind power plant. We will analyze some types of modern H-type vertical wind energy devices produced by different companies and their technical characteristics for regions with high wind potential. Companies that produce vertical small power wind energy devices offer wind energy devices with different capacities and characteristics. In particular, 1-Aeolos company (Great Britain) Aeolos – V5 (1), 2-3-Ice wind (USA) CW 100 and RW 100, 4-Greef New Energy Equipment Co., Ltd (Canada) GW 500, 5-**Qingdao allrun new energy co. (China) ARC 3000, 6-**United Solar Technologies (Russia) Sokol Air Vertikal-3kW(6) models are among them (Fig. 13). Table 4.[18-22] below shows the technical parameters of the vertical H-type wind energy devices named above.

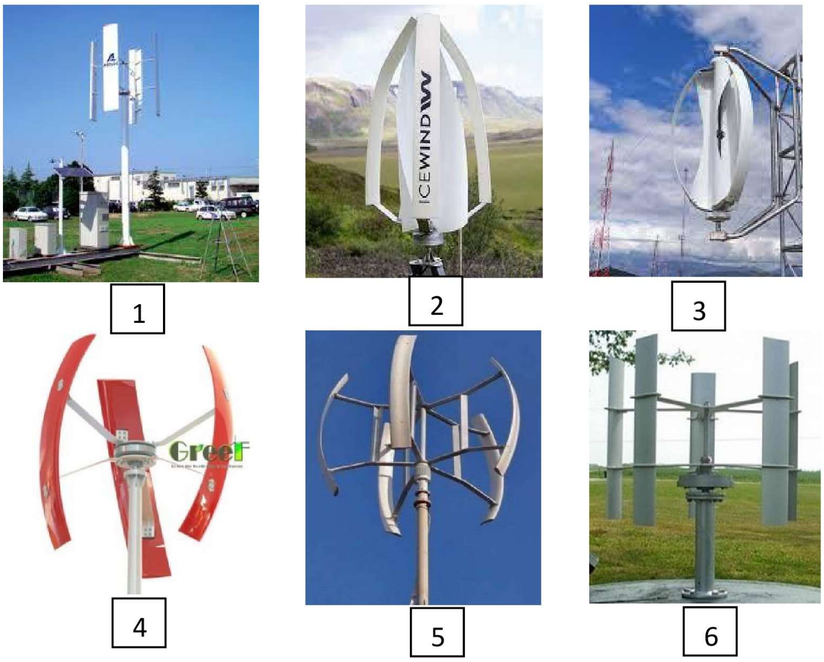

Fig. 12. Different models of vertical axis wind turbines

Table 4

Manufacturer	Model	Rated Power (kW)	Start–up wind speed (m/s)	Rated wind speed (m/s)	Working wind speed (m/s)	Survival wind speed (m/s)	Material	Output Voltage (V)
Aeolos	Aeolos V5	5	1,5	10,0	1,5-10	52,5	Aluminum alloy	220
Ice wind	CW 100	0,1	2	10	2-10	60	Fiber Reinforced Plastic	-
Ice wind	RW 100	0,16	2	10	2-10	60	Fiber Reinforced Plastic	-
Greef New Energy Equipment Co., Ltd	GW500	0,5	1	10	1-25	-	Fiber Reinforced Plastic	-

Qingdao allrun new energy co., ltd	ARC 3000	3	2,5	9	2,5-25	50	Glass Fiber Reinforced Plastic	220
United Solar Technologies	Sokol Air Vertikal	3	2	7,5	3-20	-	Aircraft-grade aluminum	220/380

Analyzing the VAWT models presented in Table 4, it is possible to make sure that the models capable of operating at the smallest initial wind speed are GW500 (1 m/s), Aeolos V5 (1.5 m/s) and Sokol Air Vertikal (2 m/s). The rated speed of these models is 10 m/s Aeolos V5, GW500 and 7.5 m/s (Sokol Air Vertikal).Also, the rated speed of the ARC 3000 vertical wind energy device is small compared to other models and is 9 m/s. Taking into account the speed of the wind blowing in the mountainous part of Farish, Gallaraal and Sh.Rashidov districts, the production of electricity using the Sokol Air Vertical wind power plant is effective compared to other models of this type.

Conclusion. This study provides information on the potential of wind energy in the world and in Uzbekistan, as well as on the projects launched to develop wind energy in the country. [10-12] by analyzing the data obtained from international databases, the wind energy potential of Jizzakh region was analyzed. Based on the conducted theoretical studies, it was determined that 3 out of 12 districts of the region have a high wind energy potential compared to other districts. The possibilities of using a vertical-type wind energy device for these districts were considered. As a result, it was theoretically analyzed that the use and Sokol Air Vertical wind energy devices in the production of electricity using the potential of wind energy in these districts is the optimal solution.

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UDC 621.77.04

PROBLEMS AND POSSIBILITIES OF LASER SYNTHESIS OF METAL POWDERS IN ADDITIVE TECHNOLOGIES

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Abstract:

Objective. To carry out research on the production technology of powder materials used in the production of products with additive technology, to apply the obtained results for the purposes of powder metallurgy.

Methods. The mechanical methods of obtaining metal powders are studied in the article, and the properties of formation without significant changes in the chemical composition of the powder material are highlighted.

Results. Depending on the aggregate state of the initial components in the reaction zone, results were obtained for three main types of the reaction process: solid-phase, non-gaseous and gaseous types. It was found that during the solid phase reaction, the metal particles in the powder mixture retain their original size. It was found that the reaction rate of gasless combustion does not depend on pressure and the constant mass of the formed particle is maintained. The dependence of the gas combustion reaction rate on pressure and the change in the mass of powder particles during the process were determined.

Conclusion. In the process of mechanochemical synthesis, it is necessary to take into account the increase in the volume fraction of the three-sided bond boundary with the decrease in the size of the particles.

In the process of preparing the powder material, its positive feature is its low temperature and high speed fusion, while maintaining its plasticity with the reduction of the particle size. The reduction of the

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