DETERMINATION OF ENERGY CHARACTERISTICS OF TWO-ROTOR WIND POWER INSTALLATION

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Abstract. The methodology of determining the energy potential of the wind at the location 145,39 kWh·m^{-2} of the two-rotor wind power installation for further use in agricultural producers far from the power supply networks is substantiated. The wind power potential of the area and the site, on which the two-rotor wind power installation is installed, allow to conduct full-scale tests for the operability and reliability of the developed installation. A description of the metrological support for determining the energy characteristics of a two-rotor wind power installation (RWPI) is given, including the experimental setup scheme and its general view. A methodology for processing experimental data has been developed and the results of full-scale tests of a two-rotor wind power installation in conditions close to real terrain are presented. The calculation of the power of the two-rotor wind power plant varied from 0.015 to 27.401 kW using the characteristics of the wind potential confirms that it produces sufficient power to charge the batteries included in the battery fleet of agricultural producers. The results of full-scale tests of a two-rotor wind power installation showed that it can be used by separate energy consumers with a wind flux utilization factor of at least 0,32 and allows further selecting power and operational parameters of mechanisms and machines using mechanical energy of a vertically rotating rotor shaft of the wind power installation.

Keywords: energy supply, testing,, methodology wind power, wind turbine.

Introduction

For assessment of wind power potential in the specific region for the purpose of effective use of its energy it is necessary to know the annual average speed of wind determined as average rate of wind for the certain multiannual time frame. Meteorological stations, which by results of long-term observations make wind inventories for the certain area [1], deal with this issue.

For the purpose of assessment of degree of openness of the installation site of the wind turbine V.Yu. Milevsky's classification recommended in the Russian Federation, obligatory for all meteorological stations [2], is accepted. On this classification, degree of openness of the area – the scale of openness is equal M7b that means: the area open – 7 points, – the area flat.

At stay for this area of average rates of wind we will use data of the Hydrometeocenter of Stavropol krai, according to which in the neighborhood of Stavropol average values of speed of wind are 4.706 m·s^{-1} in winter, in spring – 4.677 m·s^{-1}, in summer – 3.83 m·s^{-1}, in the fall – 4.076 m·s^{-1} and annual average speed 4.322 m·s^{-1}, density of energy of the wind flow in the neighborhood of Stavropol at height of the average line of the vetroagregat, equal 8 m is 0.001 kW·m^{-2}, and specific annual average kinetic energy 68.07 kWh·m^{-2}, specific technical energy resource at the height of 8 m makes 145.39 kWh·m^{-2} [3].

The provided data demonstrate that the wind power potential the site on which naturally tested the rotor wind power installation(RWPI) quite corresponds for assessment of rationality of its use in technology processes of power supply for the removed isolated power consumers what, for example, mini-farms of the dairy direction in the region are.

According to the source [3], wind speeds within the year at which RWPI begins to work, that is from 2.5 m·s^{-1} and more are 86.62 % in the neighborhood of Stavropol, do not coincide with wind potential in many areas of Stavropol territory and also steppes of Kalmykia, Kargalinsky steppes and many other regions of the Southern Federal District.

It demonstrates ample opportunities of use of the wind power installation by the removed isolated power consumers. Such opportunity is confirmed though not numerous, but nevertheless, by the available set wind electrical installations (WEI) of propeller type, which starting speed exceeds RWPI speed.

The most perspective areas of Stavropol region for the carried-out analysis of wind potential provided in work [3] on the specific annual average technical energy resources expressed in kWh·m^{-2} are considered:

Turkmen – 34.84; Neftekumsky and Levokumsky – 10.72; Ipatovsky – 13.26; Andropov – 49.84; Stavropol – 145.39, the installations of the average line of the windwheel taken at height, equal 8 m that quite corresponds to the RWPI average line.

The provided data [3] allow to define annual development of RWPI having the area of the active surface equal to 8 sq.m set on the polygon of the Stavropol State Agrarian Universityon the site with the scale of openness of M7 (b) for which annual average technical wind energy resource makes 145.39 kWh·m^{-2} [3]. For the rotor wind turbine the efficiency of wind power determined by the analytical method is not less than 0.32.

It should be noted that RWPI does not demand orientation to the direction of wind. It uses wind from any direction and uses its energy irrespective of instant change of the corner of the direction on the blade at any speeds.

Materials and methods

Let us use the annual average speed of wind equal for neighborhoods of Stavropol 4.332 m·s^{-1} [3]. In that case the average annual developed power of installation N_{in}, (kW), is determined by the formula (1):

$$N_{in} = \frac{\rho \cdot F \cdot \upsilon^3}{2} \cdot \xi \,, \tag{1}$$

where ρ – density of air, 1.29 kg·m^{-3};
F – area of the active surface, equal 8 m^2;
υ – annual average speed of air, equal 4.332 m·s^{-1};
ξ – efficiency of energy of the wind flow equal (on design data) 0.32.

The power developed on the shaft of RWPI will be equal:

$$N_{in} = \frac{1.29 \cdot 8 \cdot 4.332^3}{2} \cdot 0.35 = 146.8\ \mathrm{W} = 0.15\ \mathrm{kW}$$

The power developed on the RWPI shaft at the rated speed of wind equal 9 m·s^{-1} will be:

$$N_{in} = \frac{1.29 \cdot 8 \cdot 9^3}{2} \cdot 0.35 = 1316.574\ \mathrm{W} = 1.32\ \mathrm{kW}$$

It must be kept in mind that for charging of the rechargeable batteries it will be required to attach to the rotating RWPI shaft the electric generator through the reducer for increase in frequency of rotation that will lower the delivered power on electricity production for AB charging. The option of use of the multipole electric generator is possible. In that case, losses of energy on the reducer will considerably be reduced [4].

At the rated speed of wind 9 m·s^{-1} of power on RWPI rotating to the shaft taking into account losses on the reducer and efficiency of the electric generator it is quite enough for rechargeable battery charging. At connection to the shaft of RWPI of mechanisms directly, for example, of the water piston pump, mechanical energy is spent only for water supply taking into account the efficiency of the pump and the developed mechanical energy there is quite enough even at small speeds of wind.

It is necessary to stop on use of RWPI, which are not applied because of their low efficiency of wind power equal to 0.1-0.2. It is not true and is disproved by the set of examples [5] in which it is specified that this coefficient at RWPI makes 30-40 %, and annual power generation in 1.5-3 times is more, in comparison with the propeller VEU, because they use wind power from any direction, as well as in wind gusts, which considerably exceed its average energy [6].

The main lack of many samples RWPI executed full-scale and which passed tests at different speeds of wind is the insufficient mechanical reliability leading to breakdown of the shaft, destruction of support bearings, etc. These design faults were successfully overcome in the RWPI developed and made in the conditions of the Stavropol GAU.

Determination of power characteristics of the rotor wind power installation was carried out on the experimental sample the double-rotor wind turbine with the vertical shaft of rotation. The scheme of experimental installation is shown in Figure 1.

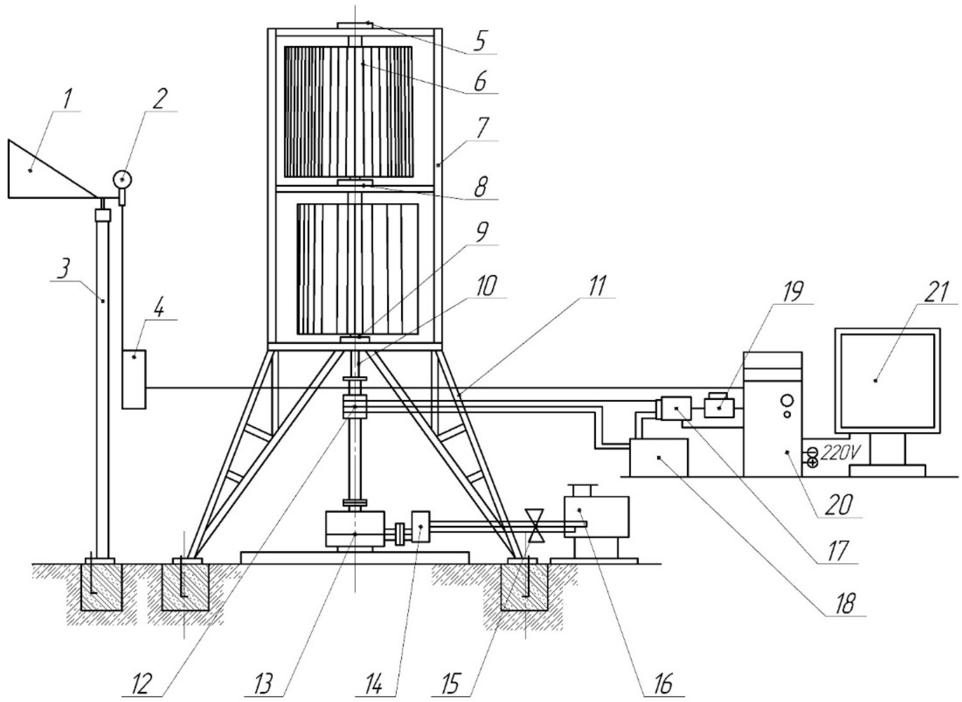

Fig. 1. **Scheme of experimental installation for determination power characteristics of double-rotor VEU:** 1 – weather vane; 2 – anemometer impeller; 3 – mast; 4 – block of approval of the anemometer; 5, 8, 9 – bearing support; 6 – blades; 7 – frame; 10 – shaft; 11 – support; 12 – dynamometer coupling; 13 – angular reducer; 14 – oil pump; 15 – adjusting valve; 16 – capacity for oil; 17 – amplifier of the signal of TDA; 18 – shop of resistance; 19 – Sigma USB ATsP DAC module; 20 – The PC with the software of ZetLab and UNI-T; 21 – monitor

Power on the shaft of the double-rotor wind turbine was measured by the dynamometer coupling [7]. Calibrating of the dynamometer coupling was executed as follows.

The dynamometer coupling was previously connected through the shielded wires in the scheme with the Sigma USB ATsP DAC module, the preliminary amplifier, shop of resistance and the system unit of the computer. The coupling was fastened to the vertical level bolts. The flange is perceiving force of untwisting of the spring of the coupling by means of suspension applied effort from 10 to 2 000 N. The brush node fixed on the flange accepted the electric signal from change of resistance of the tungsten spiral of the measurement resistor depending on effort and the angle of untwisting of the spring of the coupling, which by means of the amplifier of the signal of TDA and the analog-to-digital converter Zet-210 Sigma USB, was fixed on the personal computer with creation of the calibration diagram of the torque created on the flange of the dynamometer coupling.

By means of the dynamometer coupling it also the frequency of rotation of the vertical shaft was measured due to interruption of electric current on the current clamp ring of the coupling, which by means of the software of Zet-210 was fixed on the PC with creation of the diagram of frequency of rotation of the shaft of time at present.

Speed of the air flow was also fixed on the screen and in memory of the PC by means of the UT362 anemometer installed on the weather vane of the 8th meter mast, and the software to it at the expense of USB of connection to the PC. Having indications of the value of torque, frequencies of rotation of the shaft of the rotor and the speed of the air flow, the opportunity to determine the power on the wind turbine rotor shaft depending on the speed of the air flow by the formula (2) was provided:

$$N = M_t \cdot 2\pi \cdot n / 60, \tag{2}$$

where N – shaft power, W;
M_t – torque, Nm;
n – frequency of rotation of the shaft of the rotor, revolutions per minute.

The described technique and the developed device allowed to determine the power to the wind turbine shaft at different speeds of wind.

At production of the double-rotor wind turbine its three-blade rotors on the axis rotation are displaced by 60 degrees that allowed to make the torque on the shaft more uniform at the influence of the wind flow. The wind turbine shaft connected to the oil pump via the dynamometer coupling and the angular reducer perceived loading from the adjusting valve, which increased or reduced the section of the output pipeline through passage, depending on the speed of the wind flow. Natural tests were carried out to the wind periods, when the average rate of wind was equal 2-25 $m \cdot s^{-1}$. The speed of wind was measured by the vane anemometer of UT362 brand.

The data array of torque and frequency of rotation of rotors received at the same time were analyzed and selections on stability of the speed of the wind flow were obtained. On each speed there were ten selections, and there was the average value.

Results and discussion

Using the formula (2), we find the power on the wind turbine shaft. Average results of tests of the double-rotor VEU during its work only on the drive of the oil pump, which is switched on in the hydraulic system at the speed of wind of 2-25 $m \cdot s^{-1}$, are presented in Table 1.

Table 1

Power on the shaft of the double-rotor wind turbine at the speed of wind flow of 2-25 $m \cdot s^{-1}$

Speed of the wind flow, υ, $m \cdot s^{-1}$	Torque on the shaft, M_t, Н·м	Frequency of rotation of the shaft, n, revolutions per minute	Power on the shaft of the rotor, N, kW
2	18	8	0.015
5	120	19	0.239
9	360	34	1.281
13	780	47	3.839
17	1100	75	8.639
21	1650	94	16.242
25	1780	147	27.401

At increase in the speed of the air flow from 2 to 9 $m \cdot s^{-1}$ its power operating on the double-rotor wind turbine increases from 15.1 W up to 1281.1 W. Increase in the speed of wind led to increase in the pressure of the oil created by the pump. It is necessary to consider that the oil pump is the peculiar regulator of speed of the wind turbine, because with increase in the pressure the power consumed by it increases cubed, and at increase in the change of the throttleable opening the valve on the output pipeline of the pump – in the square. As a result, use of wind power on pumping of oil depends on these factors.

For the analysis of the received results we will use the concept “efficiency of power of the wind flow”:

$$\xi = \frac{N_{wf}}{N_{rwp}}, \tag{3}$$

where N_{wf}– theoretical power of the wind flow, W;
N_{rwp} – power developed on the shaft by the rotor wind power installation, W.

Power of the wind flow, W, is determined by the formula:

$$N_{wf} = \frac{\rho \cdot F \cdot \upsilon^3}{2}, \tag{4}$$

where ρ – density of air 1.29 $kg \cdot m^{-3}$;
F – square which the wind flow of 8 m^2 influences;
υ – speed of air, $m \cdot s^{-1}$.

Let us count the theoretical power of the wind flow influencing the wind turbine at the speed of wind equal to 9 m·s^{-1}

$$N_{wf} = \frac{1.29 \cdot 8 \cdot 9^3}{2} = 3.762 \text{ W} .$$

On the obtained experimental data the power at 9 m·s^{-1} with was:

$$N_{wr9} = M_{t9} \cdot 2\pi \cdot n_9 / 60 = 1.281 \text{ W} .$$

Let us use the formula for determination of the efficiency of power of the wind flow of the double-rotor wind turbine, which will make:

$$\xi = \frac{1.281}{3.762} = 0.34 .$$

As a result of natural tests of interaction of speed of the wind flow for the double-rotor VEU at the permanent constructive sizes of the rotor dependences of power, frequency of rotation and quantity of rotors on the different speed of the wind flow are received.

Conclusions

1. Wind power capacity of the platform 145.39 kWh·m^{-2}, on which the experimental double-rotor VEU is set, allows to carry out natural tests for determination of power characteristics of the construction of the offered installation.
2. At increase in the speed of the air flow from 2 to 9 m·s^{-1} its power operating on the double-rotor wind turbine increases from 15.1 W up to 1281.1 W.
3. The carried-out calculation of power of RWPI with use of the characteristics of wind potential confirms that the double-rotor installation on the power developed by it quite provides charging of AB and can be used by the isolated power consumers with the efficiency of power of the wind flow not less than 0.34.

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