ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

ANALYTICAL STUDY OF THE PARAMETERS OF WIND TURBINES WITH VERTICAL SEMICYLINDRYCAL BLADES

Dr.Abbas Alwi Sakhir Abed

Manuscript Info

Manuscript History:

Received: 03 October 2013
Final Accepted: 17 October 2013
Published Online: November 2013

Key words:
Axial wind turbines, orthogonal wind turbines, wind turbines with vertical semicylindrical blades, energy efficiency, independent power supply, offshore oil platforms, ships.

Abstract

Axial wind turbines with maximum energy efficiency of 0.3 – 0.4 due to multiple changes in wind direction are not more than the actual efficiency of 0.15 – 0.25. Analytical dependences to determine the torque, power and efficiency of the wind turbine with vertical semi-cylindrical blades (WTVSB) are obtained. Calculations have shown that the efficiency can reach values WTVSB 0.21. Experiments have shown its ability to run at an air flow of 1.5 – 2.0 m/s and stable operation at speeds up to 7.0 m/s. The simplicity of design WTVSB blades, absence of tower and system of orientation to the wind significantly reduce the capital cost of wind turbines and reduce their payback period by 1.5 – 2.0 times. This type of wind turbine can be used for electric power and water desalination at various facilities, including oil platforms, commercial and transport ships that greatly reduces the consumption of energy resources.

Introduction

One of the possible variants of economy of fuel resources is usage of renewable power sources, including their usage both on oil and gas rigs and on fishing vessels and floating factories [1-3]. Among renewable power sources for marine objects the usage of wind power is seemed the most promising. Wind turbines can be used both in the combination of power supply packages with renewable power sources and separately for electricity generation.

The most widespread usage axial wind turbines have received, in which 2 – 4 blade wheels with airfoil blades have horizontal axis of rotation. However, except distinctive excellences including the main feature – sufficiently high efficiency (efficiency coefficient) achieving 0.3 – 0.4, such wind turbines have one negligible disadvantage – orientation on the wind. Developers and corporations consciously conceal the fact and inform consumers only about the benefits of the devices. Power of wind turbines is estimated taking into account that the wind vector always coincides with the axis of rotation of the wind rotor in other words that the wind always blows on the reference blade face. As a consequence calculated power of wind turbines is obtained. But it is known that the wind vector is not a constant.

On figure 1 the dependence of the swept surface of a wind wheel and the power of wind turbines as a consequence from the slope angle of the wind vector to the rotation axis of the wind rotor is shown.

At the power more than 1 kW the presence of a weathercock is not an efficient technique in wind orientation. As a consequence sufficiently expensive and complicated control systems of the wind wheel ought to be arranged. The existence of the control systems make wind turbines “slow” due to long feedback, but this factor cannot be reduced anyway. The control system reacts on such alteration of the wind direction which can be constant during 15 minutes. The wind can change the direction for example by 75 % and hold it during 10 minutes and then return to the previous direction. In this case the system does not set the signal to turn the rotor and as a consequence, the rotor and the whole wind turbine will provide only 10 % from the nominal rating power in other words 10 times less and the real efficiency reduces to 0.03 – 0.04. This situation can repeat many times within 24 hours and as a result the average efficiency can reduce to 0.15 – 0.25. In connection with the above matter, wind turbines with horizontal rotation axis are quite effective but only when the wind direction is clearly estimated that almost impossible. And from the power in 3 kW such wind turbines need special unwind devices meaning that they cannot start independently. It leads to the complicated start and control systems and as a consequence to value appreciation.

In this regard among the different types of wind turbines for marine objects the usage of orthogonal wind turbines seems the most efficient [4, 5]. The interest is connected to the range of the doubtless benefits including the independence from the wind direction, the possibility to start independently and the possibility to work at the slow wind velocity – 2 – 3 m/sec, but not at the speed in 5 – 6 m/sec as the majority of axial wind turbines.

The aim of the work is analytical research of the parameters of orthogonal wind turbines with vertical semicylindrical blades.

Take into account the main aerodynamic and energetical parameters of an orthogonal wind turbine with vertical semicylindrical blades. As against traditional wind turbines with Savonius rotors, wind turbines with vertical semicylindrical blades have small amounts of wind blades (n = 2 – 6), arranged on the sufficiently large distance R from the rotation axis and shadow factor of the swept surface by the wind blades is 0.3 – 0.7 (figure 2). Such wind turbine can be arranged with electrical or mechanical power generator [6, 7]. For drive-up the arbor of the power generator an increaser with the reduction ratio 3 – 6 can be used.

The value of spin moment occurring on every wind blade at the cost of aerodynamic resistant forces can be defined using the equation:

$$M_i = F_i L_i \qquad (1)$$

where F_i –hydrodynamic pressure force on the wind blade; L_i – arm of the pressure force.

Hydrodynamic pressure force on the wind blade (circumferential force):

$$F_i = \frac{1}{2} C_i \rho S_i V^2 \qquad (2)$$

where C_i – aerodynamic resistant coefficient depending on the rotation angle of the wind blade; ρ – air density; S_i – projected area of the wind blade.

So, for the definition of circumferential force and spin moment occurring on every wind blade at the cost of aerodynamic resistant forces the value of aerodynamic resistant coefficient depending on the rotation angle of the wind blade is necessary to know.

Expressing the projected surface and arm of the pressure force of the wind turbine with vertical semicylindrical blades as φ (figure 2), force resistant moment M on every wind blade:

$$M = \frac{1}{8} \rho V^2 dH(D-d)C(sin\varphi + sin^2\varphi) \qquad (3)$$

and relative spin moment, $N{\cdot}m$:

$$M^* = {}^{M}/_{M_{max}} = \frac{0.50C(sin\varphi + sin^2\varphi)}{C_{max}} \qquad (4)$$

The results of the calculation of relative spin moment of one wind blade of the wind turbine M^* depending on the rotation angle φ are shown on figure 3.

The dependence $M^* = f(\varphi)$ as in the case with the momentum value M has quasi-sinusoidal character, taking the maximum value of $M^*_{max} = 1$ at $\varphi = 90°$, zero values at $\varphi = 0°$ and at $\varphi = 180°$ and negative values at $180° < \varphi < 360°$. The value of relative spin moment of the wind turbine with n wind blades depending on the rotation angle φ

can be arranged as the sum:

$$M_{wt}^{*} = \frac{1}{C_{max}} \sum_{i=1}^{i=n} C_i [\sin(\varphi + \varphi_{0i}) + sin^2(\varphi + \varphi_{0i})] \qquad (5)$$

where φ_{0i} – phase angle considering the angle between the wind blades $\varphi_{0i} = {}^{2\pi}/_{n}$.

The dependence M_{wt}^{*} from the rotation angle φ defined by equation 5 is shown on figure 4.

This dependence has quasi-sinusoidal character with growing maximum values $M_{wt\ max}^{*}$ and reducing periods with the increase of the quantity of wind blades *n*.

The average value of relative spin moment of the wind turbine in one complete circle of the arbor can be obtained by the method of integration:

$$M_{wt\ av\ 2}^{*} = \frac{1}{2\pi} \int_{0}^{2x},\ M_{wt}^{*}(\varphi) d\varphi \qquad (6)$$

With the sufficient accuracy for practical calculations the integration by equation 6 can be replaced by the numerical integration at a pitch of $\Delta\varphi = 10° = {}^{\pi}/_{18}$. The average values of relative spin moment of the wind turbine with 2 – 6 wind blades which equal to $M_{wt\ av\ 2}^{*} = 0.42$; $M_{wt\ av\ 3}^{*} = 0.57$; $M_{wt\ av\ 4}^{*} = 0.76$ and $M_{wt\ av\ 6}^{*} = 1.13$ have been obtained by the numerical integration. On the ground of these correlations, average spin moment of the wind turbine with vertical semicylindrical blades has been determined:

$$M_{wtvsb} = \frac{1}{8} C_{max} M_{wtvsb}^{*} \rho V^2 dH(D - d) \qquad (7)$$

and power of the wind turbine with vertical semicylindrical blades considering the correlation between frequency *n* and peripheral speed *U*:

$$P_{wtvsb} = \frac{1}{4} C_{max} M_{wtvsb}^{*} \rho V^3 V^3 \frac{dH(D-d)}{D} U \qquad (8)$$

where *U* – peripheral speed of the wind wheel connecting with rotation frequency of the wind wheel *n*, r/min by the correlation:

$$U = \frac{\pi n D}{60} \qquad (9)$$

Power of the wind flow blowing on the wind wheel can be determined by the well known equation:

$$P_{wf} = \frac{1}{2} \rho H D V^3 \qquad (10)$$

So, energetical efficiency, more properly defining as efficient coefficient of the orthogonal wind turbine is:

$$\eta = \frac{P_{wtvsb}}{P_{wf}} = \frac{1}{2} C_{max} M^{*} \frac{d(D - d)}{D^2} \left(\frac{U}{V}\right) \qquad (11)$$

Equation 3 can be simplified using power-speed coefficient $Z = \frac{U}{V}$ and introducing the geometric complex:

$$K_r = d^{*}(1 - d^{*}) \qquad (12)$$

where $d^* = \frac{d}{D}$ – relative width of the semicylindrical wind blade.

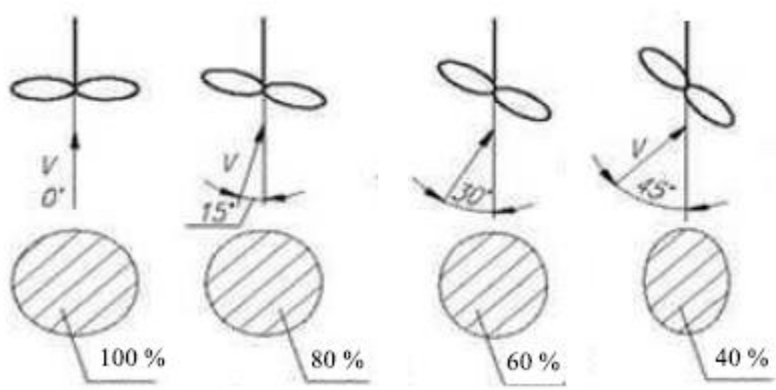
$$\eta = \frac{1}{2} C_{max} M^* KZ \qquad (13)$$

The calculations by equation 13 show that energetical efficiency of the wind turbine with vertical semicylindrical blades can achieve 0.21 which the same for axial wind turbines considering incongruity of the rotation axis orientation with the wind direction. It should be noted, however, that the obtained equations are necessary to examine practically, particularly equation 13.

In the research laboratory of the Department of equipment and devices of the oil and gas field of the Astrakhan State Technical University (from November 2012 the Department of petroleum and gas exploitation) the experimental-demonstrational model of the wind turbine with vertical semicylindrical blades has been developed which is shown on figure 5.

This device has a wind turbine 0.5 m in diameter and vertical semicylindrical wind blades 0.07 m in diameter and 0.4 m in height. The pilot experiments have shown the possibility of independent start at the wind speed 1.5 – 2.0 m/sec and the working stability until the wind velocity 7.0 m/sec. In the future it is planned to develop a larger experimental model of wind turbine with vertical semicylindrical blades equipped by the system of maintaining the rotation rate with the alteration of the wind direction, by an electrical generator to estimate the energetical efficiency and to provide more precious tests of this type of wind turbines.

The construction simplicity of the wind blades of the experimental-demonstrational model of the wind turbine with vertical semicylindrical blades, the absence of an expensive tower due to both the possibility of installation of increasers and electrical generators at the bottom and the orientation wind system, which allows to reduce the capital cost for wind turbines decreasing the payback period 1.5 – 2 times. The proposed wind turbines with vertical semicylindrical blades can be used both independently and in combination with solar hot water tanks and distilling devices [3, 6 – 8]. The developed type of orthogonal wind turbines can be used for independent electrical and heat supply and for water distillation on different marine and land objects, including oil and gas rigs (particularly for petroleum rig, for harvesting and transport vessels) that significantly reduces fuel and energetical resources' consumption for production and keeping needs.



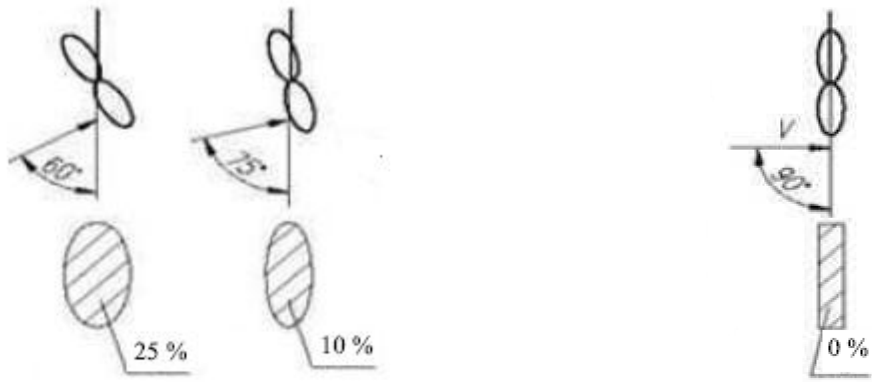


FIG. 1. Dependence of the surface swept by the wind wheel from the wind direction. The swept rotation surface at the different angles of the wind directions towards the rotation axis.

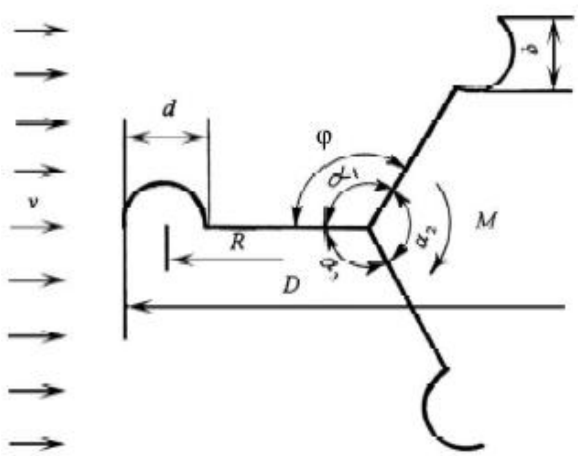


FIG. 2. Calculation model of a wind turbine with vertical semicylindrical blades, n = 3.

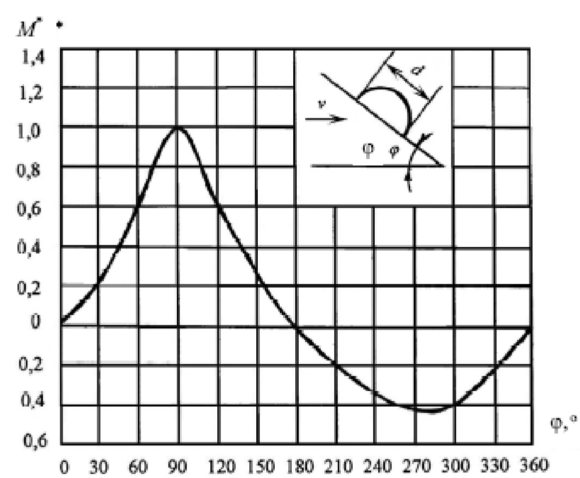


FIG. 3. Dependence of the relative spin moment of the semicylindrical wind blade of the wind turbine from the rotation angle.

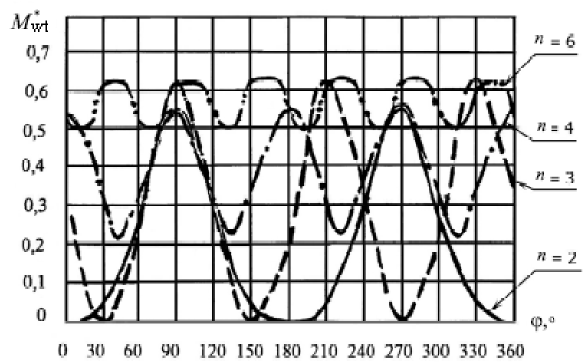


FIG. 4. Dependence of the relative spin moment from the rotation angle.

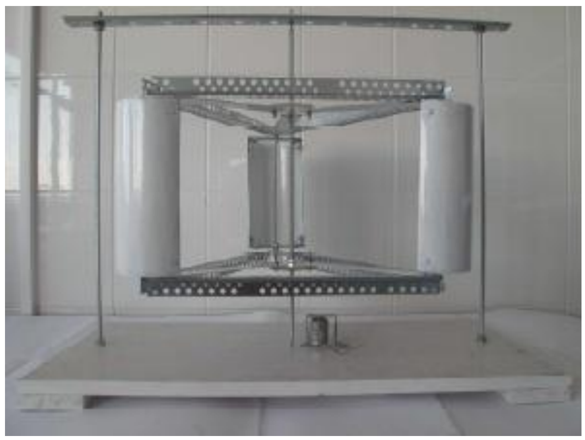


FIG. 5. Experimental-demonstrational model of the wind turbine with vertical semicylindrical blades

Conclusions

Traditional axial wind turbines with maximum efficiency 0.3 – 0.4 due to the repeated alteration of the wind direction has average efficient as far as 0.15 – 0.25. The usage of the simpler orthogonal wind turbines has been proposed to employ. The main aerodynamic and energetical parameters of the wind turbine with vertical semicylindrical blades have been observed. The analytical dependences for definition of rotation spin, power and efficiency of the wind turbine with vertical semicylindrical blades have been obtained. The calculations have shown that energetical efficiency of the wind turbine with vertical semicylindrical blades can achieve 0.21, almost the same efficiency as for axial wind turbines. The pilot experiments have shown the possibility of independent start at the wind speed 1.5 – 2.0 m/sec and the working stability until the wind velocity 7.0 m/sec. The construction simplicity of the wind blades of the wind turbine with vertical semicylindrical blades and the absence of an expensive tower and the orientation wind system allows to reduce the capital cost for wind turbines decreasing the payback period 1.5 – 2 times. This type of orthogonal wind turbines can be used for independent electrical and heat supply and for water distillation on different objects, including oil rigs, harvesting and transport vessels that significantly reduces fuel and energetical consumption.

References

1. Elistratov V.V. Energetics of renewable sources in 21st century. Proc. Of Int. sci. tech. seminar. Sochi, RIO SGUT i KD, 2001, pp. 6 – 12.

2. Korobkov A.V. Transformation ocean energy. Leningrad, Sudostroenie Publ., 1986. 280 p.

3. Shishkin N.D., Baltaniazov I.V., Gerlov V.N. Use of renewable power sources for power supply of iol drilling marine platforms // Reports of the Astrakhan State Technical University. Library: Marine equipment and technology. 2009. no. 2. pp. 251 – 255.

4. Antipov V.N., Danilevich J.B. Analysis and research of wind generators of different construction operations within rotation frequencies 75 – 300 per minute with the purpose of creation proportionate number. Electrotechnica. – 2009. no. 1. pp. 27 – 33.

5. J.B. Danilevich, V.N. Antipov, I.U. Kruchinina, U.F. Hozikiv, A.V. Ivanova, B.N. Mironov. Autonomous integrated wind installation with the use of nanostructural materials for storage and transformation of power energy. Alternative energy and ecology. 2009. – no. 4(72). pp. 81 – 89.

6. Shishkin N.D. Effective usage of renewable sources of power for autonomous power supply of different objects. Astrakhan, Izd-vo AGTU, 2012. 208 p.

7. Birulin I.B., Gostunin U.V., Shishkin N.D. Hydraulic heat generator. Patent RF, no. 2228503. Moscow, RAPTZ, 2004. 8 p.

8. Shishkin N.D., Manchenko E.A. Assessment of technical and economical indices of combined solar-wind installations for autonomous heat supply // Problems of improvement of fuel and energy complex: collection of papers: proc. of Int. sci. con. Saratov, Izd-vo Sarat. un-ta, 2011. pp. 138 – 142.