International Journal of Mechanical And Production Engineering, ISSN: 2320-2092, Volume- 3, Issue-11, Nov.-2015

REVIEW OF VERTICAL AXIS WIND TURBINES

[1]D.I. ERYOMIN, [2]N.I. YAGFAROVA

Magister, magister
E-mail: denis.e@bk.ru, nadiya1006@gmail.com

Abstract- The purpose of this article was to review vertical axis wind turbines. There were observed distinctive features of vertical axis wind turbines in comparison with horizontal axis wind turbines. The result of conducted study was the collection of the vertical axis wind turbines benefits. There were also observed different types of vertical axis wind turbines, such as Savonius rotor, Gorlov rotor, and Darrieus rotor.

Index Terms- Horizontal Axis Wind Turbines, Vertical Axis Wind Turbines.

Currently, on the global market of wind turbines horizontal axis or so-called propeller units amount to more than 90%, and several thousands of enterprises are engaged in their mass production. Delay in mastery of vertical axis wind turbines is caused by several reasons. Vertical axis wind turbines were developed later than horizontal axis propeller ones (Savonius rotor – in 1929, Darrieus rotor – in 1931, Musgrove rotor – in 1975). Besides, until recently, it was wrongly believed that the main drawback of vertical axis wind turbines consisted in impossibility to obtain for them the rate of peak value of operating element linear speed (blades) to the wind speed that could be more than one (this rate reaches more than 5:1 for horizontal axis propeller wind turbines). [1]

This assumption is true only for low-speed rotors, using different resistance values of blades as they move with the wind and against the wind. This lead to incorrect theoretical conclusions that marginal coefficient of wind power usage is lower for vertical axis wind turbines than for horizontal axis propeller ones, which is why this type of wind turbines has not been developed for almost 40 years. Only in the 60s – 70s first Canadian and later American and British specialists proved experimentally that these findings do not apply to the Darrieus rotors that use lift force of the blades. [2]. For such rotors afore mentioned rate of peak value of operating element linear speed to the wind speed is 6:1 and more, and coefficient of wind power usage is not less than horizontal axis propeller wind turbines.

It also plays a part the fact that the volume of theoretical researches of fundamentally new issues of rotor aerodynamics and experience in the development, optimization and operation of vertical axis wind turbines is much less than horizontal axis propeller ones.

Vertical axis wind turbines have been intensively developed since the beginning of the 80s, and the range of their capacities is constantly expanding. So far, almost all countries use vertical axis wind turbines with Darrieus rotor. Moreover, in Canada, the USA, and the Netherlands the preference is given to classical scheme with curved blades, and in the UK and Romania rotors with straight blades which are parallel to the axis of rotation are considered to be the basic scheme. [3]

Vertical axis wind turbines are almost fundamentally different from horizontal propeller devices. Apart from insensitivity of vertical axis wind turbines to the airflow direction, as a positive quality, there are many other key points and construction solutions which are no less important.

One of the most significant differences of vertical axis wind turbines is the wind orientation. The maximum efficiency of horizontal propeller wind turbines is only achieved on condition of constant collinearity of wind wheel axis and the wind direction. The need to focus on the wind requires the presence in the wind turbines of mechanisms and systems for the continuous monitoring of wind conditions, the search of direction with the largest possible wind potential, the wind wheel turning in this direction and its hold in this position. The presence of wind orientation system in the construction of wind turbines complicates the wind unit and reduces its reliability. According to operating experience of foreign wind turbines, up to 13% of failures falls on orientation systems. [4]

Besides of that, with constant changes in wind direction it is almost impossible to orient wind wheel effectively because of delayed action of orientation mechanisms. For the units of megawatt class with wind wheel diameter over 30 m efficiency of its wind orientation decreases because of non complanarity and differences in the speeds of wind current on the diameter of blades span that makes it impossible to install the wind wheel in the optimal direction of orientation. Because of this, due to the reduction of the wind current energy being used, electricity production and economic efficiency of wind turbine decreases.

To design deficiencies of horizontal propeller wind turbines system can be attributed to the fact that it is necessary to break rigid link between nacelle with the wind wheel and the tower, which brings about the appearance of self-excited vibrations and the difference in frequency-response characteristics of moving and stationary parts of the device and ultimately decreases the reliability and increases operating costs. The place of rigid link break between the nacelle and the tower also require attention in terms of power transmission from the generator rotating with the nacelle to the out-reaches to customers, which are on the ground. To avoid twisting of power bus lines they either limit the turning angle of the nacelle with its subsequent unwinding or use a current collector. In both cases in the design there are introduced additional complexities reducing its reliability. Thus, the efficiency of horizontal propeller wind turbine decreases as a result of the nacelle with the wind wheel orientation system delay when the wind current direction changes and the rotation axis of wind wheel constantly mismatches the direction of the wind speed. Secondly, the systems of the nacelle rotation for the wind orientation and of the blades rotation require appropriate drive components, i.e. while working horizontal propeller wind turbines constantly consume a certain quantity of power for their own needs, which ultimately reduces the annual power output into the mains of the wind turbine. [4]

The efficiency of vertical axis wind turbines principally does not depend on wind direction, for which reason there is no need in all wind orientation systems and mechanisms. Rigid fixation of rotor major node on the tower of vertical axis wind turbine eliminates self induced vibrations and simplifies the dynamics of construction.

On the basis of afore-mentioned distinctive features of vertical axis wind turbines we can make a conclusion that horizontal propeller wind turbines are inferior to vertical axis ones in the following characteristics:

- need of wind orientation of the windwheel reduces the efficiency of wind turbine by means of the nacelle turnings delay against the wind constantly changing direction and noncollinearity of windwheel axis and the wind speed direction, complicates the design and reduces the reliability of the wind turbine due to the introduction of special systems and mechanisms;
- the work of wind turbine with a constant rotation speed of the windwheel, which provides the largest power output in a tight range of wind operating speeds and, consequently, decreases the efficiency of the wind turbine;
- placement of the generator and multiplying gear in the nacelle on the top edge of the tower complicates the demands to their dimensional and mass characteristics, also complicates the operating conditions of constructions due to the appearance of additional vibrations, bumps and, consequently, increase of load level of the tower, multiplying gear, generator, worsens the conditions of equipment installation and operation due to its location on the height of the tower, complicates the transmission of electrical energy from the rotating nacelle to the stationary tower;
- extra specific speed of the windwheel increases the demands to its dynamic stability, balancing, strength and reliability;
- extra specific speed of the wind wheel results in extra impact on the environment in consequence of the high level of aerodynamic and mechanical noise, long range of the ice crust and blade fragments distribution in case of its destruction. Besides, rotating wind wheel makes insurmountable obstacle on the way of birds.

Thus, our analysis has shown that due to such fundamental features such as no need for wind orientation, work with variable speed of rotation, under mount of generator and multiplying gear, rotor self-starting at any wind direction, no rotation of the blades, the constancy of length section of blades, low speed, minimal environmental impact, independent vertical axis wind turbines with H-rotor Darrieus compares favourably with traditional horizontal axis wind turbines in such features as efficiency, simple design, reliability, ecological cleanliness, ease of maintenance.

Vertical axis wind turbines are most effective at a low (up to 10 kW) power. It coincides with the concept of independent and extra power supply systems. The most sophisticated types of vertical axis wind turbines are:

– Savonius rotor;
– Gorlov rotor;
– Darrieus rotor. [5]

Figure 1 – Savonius rotor

Savonius rotor.

The torque moment occurs at the airflow of Savonius rotor due to the different resistance of convex and concave harts of the Savonius rotor. The advantages of wind-driven power plant of this type are low noise level, small occupied space, and excellent work at low winds (3-5 m/sec). Windwheel is extremely simple, but material costs are proportional to the efficiency. This turbine is the most low speed, and as a consequence, has a very low wind power efficiency – just 0,18 - 0,24 and efficiency of 17-18%. The usage of these turbines is economically and technically impractical.

Gorlov rotor.

The rotor consists of several airfoil blades. The turbine is high speed, power-speed coefficient is over 3, and efficiency is more than 38%. The manufacture of such blades is difficult due to the complicated blades shape. The Gorlov turbine is characterized by the increased level of noise and infrasound frequency of 4-8 Hz, which is formed by the blades tilt and separation of flow from the ends of the blades. The usage of these turbines is economically and technically impractical.

Darrieus rotor.

It is a symmetrical structure consisting of two or more aerodynamic wings, which are attached to the radial girders. There is lifting strength that affects each wing moving with respect to the flow. Its magnitude depends on the angle between the vectors of the current velocity and the instantaneous speed of the wing. Maximum lifting strength is achieved when these vectors are orthogonal. Taking into consideration that the vector of the instantaneous speed of the wing changes cyclically during the rotation of the rotor, moment of force developed by the rotor is also variable. As far as there must be wings movement for the lifting strength, the Darrieus rotor is characterized by poor self-starting. Self-starting improves in case of using three or more blades, but in these circumstances preliminary acceleration of the rotor is needed.

The Darrieus rotor is classified as a wind-receiving device using lifting strength, which occurs at the concave blades with a wing profile in the cross-section. The rotor has a relatively small starting moment, but good specific speed, and because of this – a relatively high specific capacity referred to its weight or cost.

Performance of Darrieus rotor does not depend on the current direction. Consequently, based on it turbine does not require an orienter. Darrieus rotor is characterized by high power-speed coefficient at low current speed and also by high current power efficiency, and the rotor wing-swept area can be large enough.

Among the disadvantages of Darrieus rotor are also low mechanical strength and extra noise generated during the performance.

The most technologically advanced is H-shaped Darrieus rotor. The turbine of this type is fast-speed (power-speed coefficient ≥ 3), the efficiency reaches 0,38. H-Darrieus rotor is characterized by the lowered noise level and a total absence of infra-sound. Wind-driven power-plant of this type has a simple design and high reliability.

Figure 2 – Darrieus rotor

Therefore, vertical axis wind turbines are simpler and have a range of advantages over horizontal axis wind turbines. Lower wind power capacity factor and efficiency are compensated by the absence of power waste when the wind changes its direction. In case of buffer electric power storage it is possible to level down the demands to the quality of the out voltage and apply the simplified construction solutions of the wind current modulation into the shaft rotation mechanical power (e.g., non-adjustable blades, etc.). At the same time the required quality of the electricity in the electric power supply channel can be provided by conventional electric power conversion units (e.g., UPS-type uninterruptible power supply) with an electric battery of appropriate capacity.

REFERENCES

[1] J. Tvaydell, A. Weir. Renewable energy: Translation from English. Moscow: Energoatomizdat, 1990

[2] Solomin Ye. “SRC-Vertical” wind turbines. Alternative Energy and Ecology, 2010 № 1.pp. 10-15

[3] Internet resource // http://vetrodvig.ru/?page_id=432

[4] Internet resource // http://www.ecoteco.ru/?id=1198

[5] Voronin S., Babina L. Wind turbine performance at the wind direction change. Alternative Energy and Ecology, 2010 № 1. pp. 98-100

★★★