WIND MILLS WITH HORIZONTAL AND VERTICAL SHAFT

Vladimir A. Dobrovolski
Director, Wind Energy Department of Moscow Aviation Institute (MAI), Director, Molinos Co. Ltd., Moscow, Russia

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Summary

This Article presents a historical summary of wind turbines of small and large power capacity with horizontal and vertical shafts. Advantages and disadvantages of Darrieus type wind turbine are described. The problems of control systems, aerodynamics, structured dynamics, fatigue and failure analysis of wind turbines are discussed.

1. General Considerations

There are two main types of wind turbines: horizontal axis wind turbines (HAWT) and vertical axis wind turbine (VAWT) see Figure1.

HAWT can be divided into two categories low and high speed. Low speed turbines usually rely on drag forces to extract the kinetic energy from the wind. Drag devices always move slower than the wind and their motion reduces rather than enhances the power extraction. High-speed wind turbines rely on lift forces and their motion is several times faster than that of the wind. The ratio of the power extracted by a lift device to that of a drag device is usually greater than 3:1 for the same swept area.

Consider a blade rotating in a plane perpendicular to the undisturbed wind flow. The relative airflow over the blade (a combination of the wind velocity and the rotational velocity of the blade) gives rise to a lift force, which is perpendicular to the direction of the relative air flow, and a drag force - parallel to the flow. The resultants of these forces can be resolved into components of normal and tangential force, perpendicular and normal to the plane of blade rotation.

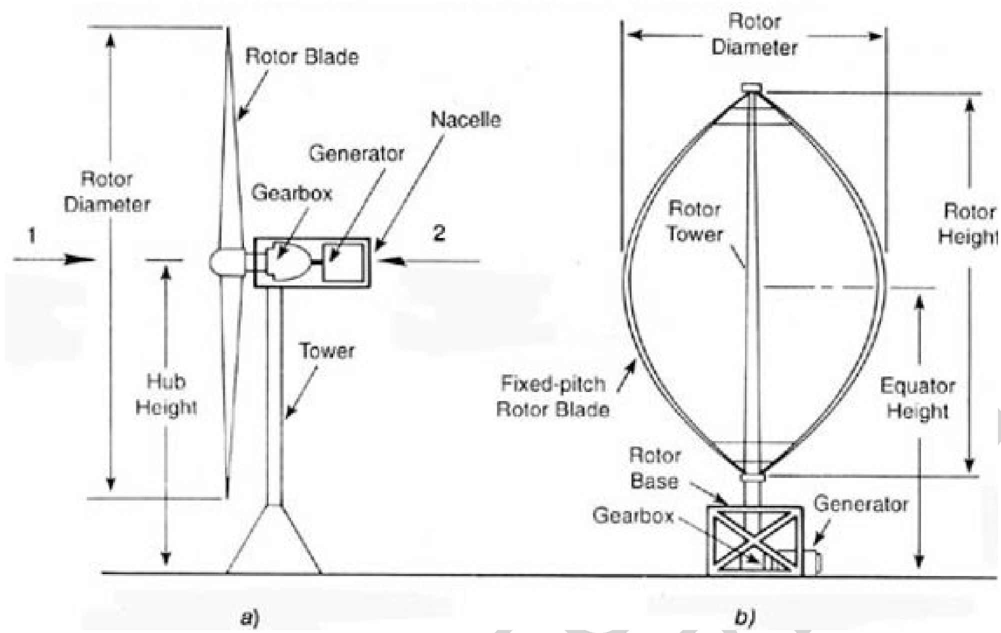

Figure 1. Main types of wind turbines
a) HAWT; b) VAWT; 1- wind direction for an upwind rotor; 2- wind direction for a downwind rotor

The results of some studies show that increasing the number of blades increases the performance due to reduced tip losses; increasing the tip speed ratio (see *Fundamentals of Energy Extraction from Wind* in EOLSS On-Line, 2002) reduces the energy loss due to wake rotation and tip losses, hence increase the performance. As a consequence the performance, at higher tip speed ratios, depends on the lift to drag ratio; the higher is the lift to drag ratio, for any blade number or tip speed ratio, the higher is the performance.

2. Development of Large Horizontal-Axis Systems

A large wind turbine is a machine with a rated capacity of 100 kW or larger. In terms of basic appearance and function, large and small turbines are similar. The greater size and weight of components in large machines demand stronger materials and special design efforts. For example, the rotor blades of very large machines could be longer than the wingspan of a jumbo jet. The latest computer technology is needed to control the pitch angle and rotational speed of these huge blades. Made of steel, laminated wood, fiberglass, or a combination of these materials, the blades must withstand a variety of stresses and loads, including cyclical fatigue loads and random wind loads associated with turbulence.

In addition to blade material, some of the technological issues currently under discussion include prediction and reduction of dynamic and fatigue loads, shape of the airfoil, number of blades, design of the transmission system, and selection of rigid of flexible towers.

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Bibliography

Johnson G.L. (1998). *Wind Energy Systems*. Prentice-Hall, INC, Englewood Cliffs, N. J. 07632.

Lipman N.H. Musgrove P.J. Pontin G W-W. (1982). *Wind Energy for the Eighties*, Peter Peregrinus Ltd.

Wind Energy Information, Guide (1996). U.S. Department of Energy, April 1996.

Biographical Sketch

Professor Vladimir A. Dobrovolski, Ph.D. was born in Moscow, Russia in 1936. He graduated from Moscow Aviation Institute in 1960 and Ph. D. Degree in 1968.

1960-1963 - test engineer, the USSR Civil Aviation

1963-1970 - researcher, Thermodynamics department of Moscow Aviation Institute

1970-1973 - head of department, Central Aerohydrodinamics Institute

1973-1977 - adviser, International Civil Aviation Organization (Montreal, Canada)

1977 - head of department, Moscow Aviation Institute. His present position is a director of Wind Energy Department of Moscow Aviation Institute and director, Molinos Co. Ltd. Main activities: Development and production of small scale wind mills.