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Commentary

Regarding the number of blades in the rotor of the wind turbine

M Shykhailov* and V Kokhanevich

Renewable Energy Institute of NAS of Ukraine, 02094, Metrolohichna, 50 St., Kyiv, Ukraine

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***Corresponding authors:** M Shykhailov, Renewable Energy Institute of NAS of Ukraine, 02094, Metrolohichna, 50 St., Kyiv, Ukraine, Tel/Fax: +38-044-206-28-09, +38095 697-37-64; E-mail: info@ive.org.ua; markel2005@ukr.net, nicksun328@gmail.com

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Abstract

When developing a wind turbine, sooner or later the designer is faced with the problem of the number of blades. After all, the purpose of the wind turbine and its cost depends on this. The criteria were determined and an analysis was carried out regarding the appropriate number of blades in the rotor of the wind turbine.

So, how many blades should any wind turbine (WT) have?

During the design of a wind turbine of any kind purpose, first of all, the question arises of choosing the number of blades in the rotor and, as a result, the criteria that should be used to determine their number. There is no clear and unequivocal answer to this question in the available sources of literature. Let's analyze this issue based on the following criteria, such as the functional purpose of the higher education institution; material capacity and cost of manufacturing a set of blades, loads, environmental friendliness, and visual design.

At first glance, everything is very simple. Suppose that there are two WTs of the same diameter, which are installed at the same height from the earth's surface. At the same time, one has a rotor with many blades, the other has a rotor with the number of blades many times less. It is clear that the power of the wind flow, which is perceived by the rotors of both wind turbines, is the same and is determined by the formula:

$N=M\cdot\omega$, (1)

Where N is the power on the WT rotor;

M - Torque on the rotor of the WT;

ω - Angular velocity of the rotor.

Obviously, a larger number of blades creates a larger torque. Then we conclude that a larger number of blades leads to a decrease in angular velocity so that the product in expression (1) remains unchanged.

Thus, if we need a large torque, then the number of blades should be larger. This is relevant for performing mechanical work (for example, pulp crushers, silo cutters, mills, wind pump installations with piston pumps, etc.).

But for power generation, a high angular velocity is crucial to avoid the use of multi-pole high-cost electric machines.

Let's think further. It is obvious that there are energy losses on each blade (inductive, terminal losses, etc.). It is clear that the smaller the number of blades, the less energy loss on the rotor and, accordingly, the higher the coefficient of wind energy utilization (CWEU).

In addition, the blade is a high-tech, rather expensive product, and the more of them, the more expensive the WT.

And the last. For power generation, as already mentioned above, high angular speed is crucial, which means that the

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number of blades should be minimal. Ideally, it is one blade. Known designs of a single-blade rotor with a counterweight, for example, a wind engine according to [1]. This is a single-blade rotor with a counterweight, the blade of which is a hollow structure and hinged on the shaft. In the hub of the unit, there is a valve actuated by centrifugal weights. Therefore, when the rotor reaches an angular speed higher than the nominal value, under the action of centrifugal forces, the valve opens and the air begins to move along the cavity of the blade. At the same time, Coriolis forces arise, which lead to the braking of the rotor.

Everything seemed simple. The shovel is balanced by a counterweight, but it is static balancing. When the rotor rotates, the picture is somewhat different. It is known that the wind speed depends on the height above the earth's surface. On the surface of the earth, it is practically zero, and with height, it acquires a certain value. So, when the blade is in a vertical position, its end can be either in the lowest or in the highest position. It is obvious that the wind speeds in these extreme positions are different, so the values of the aerodynamic forces are also different. At the same time, the counterweight has relatively small geometric dimensions, and therefore the aerodynamic force acting on it has a more or less constant value. Therefore, when the rotor rotates, we have a constant change in the aerodynamic force acting on the rotor. This fact leads to the occurrence of fluctuations that cannot be counteracted.

If you take a two-blade rotor, the picture will not be so bright, but similar. On the sections of the trajectory of the ends of the blades, which are different from the vertical position, we will have a variable character of the aerodynamic force, which means oscillations, although of a lower intensity. So, we come to the conclusion that 3 should be close to the optimal number of blades.

These considerations are confirmed by the graphic materials (Figure 1) presented in the work [2-4].

A few more obvious facts can be added to the previous conclusions.

First, in many bladed WTs, the main shaft must be increased due to the greater value of the torque.

Secondly, in WT with a smaller number of blades, the rotation frequency is increased. Therefore, quite simple centrifugal regulators of direct action can be used quite effectively to regulate the angular speed of the rotor.

Thirdly, the increased angular speed of the rotor makes it necessary to take this fact into account when calculating the rotor orientation system in the direction of the wind flow. This refers to the gyroscopic moment that occurs when the rotor is oriented in the direction of the wind. It is proportional both to the angular speed of the rotor itself and to the angular speed of rotation of the nacelle around the support.

And the last. Visual and psychological perception. The two-bladed rotor constantly either increases or decreases its volume due to rotation. The perception of the three-blade setup has a more calming effect on the environment, including people.

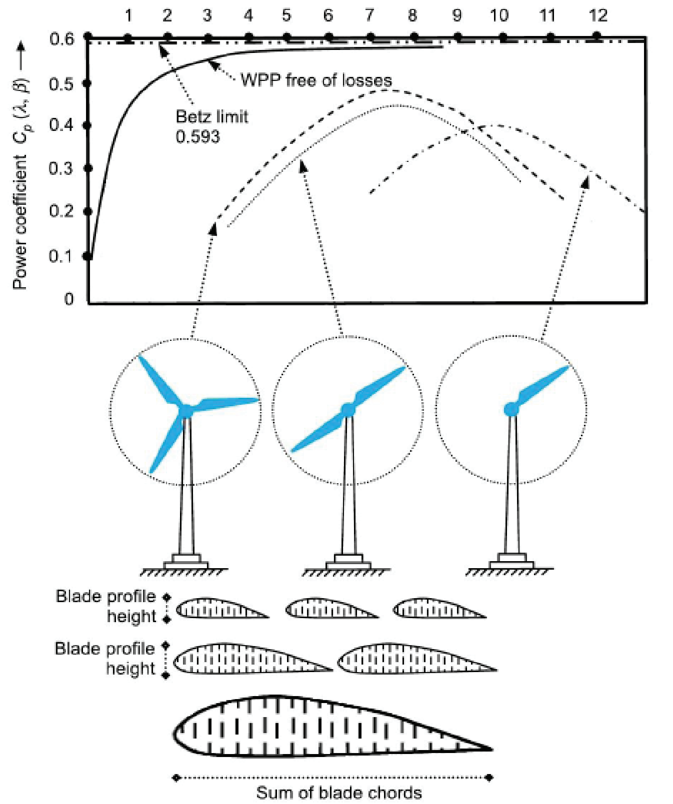

Figure 1: Characteristics of C_p and dimensions of profiles for WT with different number of blades.

Conclusion

1. For the class of slow-moving wind turbines, it is decisive of torque provided by a significant amount of blades - from 6 to 24.
2. For the class of high-speed wind turbines, the rotor revolutions are decisive, for which 1–3 blades are sufficient.
3. The analysis of the number of blades of high-speed wind turbines showed that three-blade turbines are preferred in terms of efficiency, material capacity and visual design. According to other criteria, it is impossible to clearly determine the optimal number of blades for of this class of wind turbines.

Therefore, it is up to the developer to draw conclusions, and the consumer will show the results of their correctness. All these reflections are well correlated with well-known sources.

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