Influence of the Number of Blades on the Mechanical Power Curve of Wind Turbines

summary

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Abstract. The paper describes the experimental work in a wind tunnel on wind turbine rotors having different number of blades and different twist angle. The aim of the work is to study the influence of the number of blades, the blade tip angles and twist angle of the blades on the power coefficient of the rotor. Also, the experiments evaluate to what extent the power coefficient of the turbine rotor depends on the operating wind speed.

Key words

Wind turbine, blade profile, blade twist angle, power coefficient

1. Introduction

When designing a direct drive wind turbine the interest is to obtain the highest efficiency for the wind speed range of the locations of implementation. If the average wind speed is rather low, the wind turbine should have a better behavior at low wind speeds. The blade of the rotor is the most important component with impact on wind turbine efficiency. According to the previous works, [1] and [6] the generator should be designed for maximum power transfer from turbine rotor to the load, but an appropriate design of the turbine rotor is mandatory for achieving good overall efficiency.

There are several methods of designing the blade profile[2], [3], [5] for selecting the twist of the blades and the blade tip angle for optimum power extraction of wind kinetic energy.

Generally, the design method of main characteristics of turbine rotor is based on simplifying assumptions and optimum design principles theoretically defined and verified in practice[3].

The goal of the work presented in the paper is performing experimental investigation for studying the influence of different parameters, such as number of blades, blade tip angle, twist angle of the tip of the blades on the performances of the rotor of wind turbines. Having the experimental results, the designer could have deeper knowledge of the impact of the characteristics of the rotor turbine on the final performances of the wind turbine and to know how to fit the rotor performances to a specific wind potential.

2. Experimental setup

The experiments were carried out in a closed loop wind tunnel described in previous works, [1] and [6]. The maximum wind speed for tests is actually limited to 13 m/s, due to the technical possibilities of the wind tunnel.

The blades are assembled into a rotor and mounted on a 3,5m mast for positioning the hub on centre on the wind tunnel cross section. The wind tunnel cross section, which is actually 7 m in diameter, could act as a duct and the measurements can give higher efficiency of the turbine than in open air, but the behavior of the rotors is well reproduced. This aspect is now under study.

The airflow on the cross section is uniform within 2% on the area swept by the blades.

For measuring the power curve of the rotor, a 3 phase

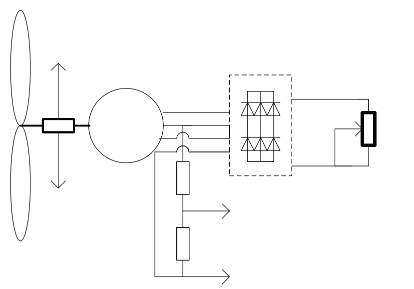

Fig. 1-Electrical layout

synchronous generator is used as variable torque break. At the output of the generator is a 3 phase

rectifier with a variable power resistor which can be continuously adjusted for setting the desired breaking torque for the rotor.
The torque is measured by a transducer inserted between rotor and generator. The rotational speed is measured through the frequency of the generator output voltage.

3. Main results

As can be seen in Fig.15, the tip speed radio, λ, decreases when blade tip angle increases.

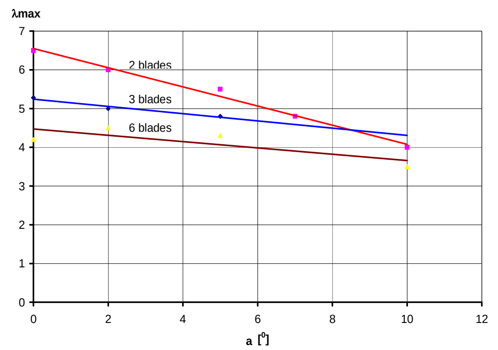

Fig. 15-Tip speed ratio at ***Cpmax*** for *a* type blades

The wind turbine is faster when the number of blades decreases[3]. Furthermore, as α increases, the speed at *Cpmax*, *λmax*, for 2 blades rotor decreases much faster than 3 or 6 blades rotor. For 6 blades, *λmax* decreases much slower. It to notice that at $\alpha=8^0$, 2 blades rotor is as fast as 6 blades one.

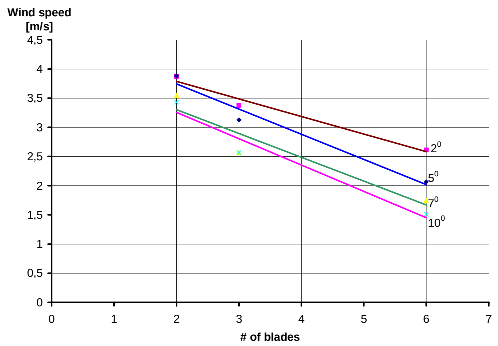

Fig. 16-Cut-in wind speed for *a* type blades

In Fig. 16 is the variation of cut-in wind speed vs. number of blades, having parameter blade tip angle, α. It is known that as the number of blades increases, the cut-in wind speed decreases. Similarly, the cut-in wind speed decreases as the blade tip angle increases.
The cut in wind speed and power coefficient have the same variation with blade tip blade angle at a given number of blades, both parameters are decreasing.

4. Conclusions

The wind tunnel experiments carried out on two different sets o blades revealed the influence of design parameters on the mechanical performances of the rotor of wind turbines.
Two type of blades have been studied, having similar aerodynamic profiles, but different blade twist angle.
The main conclusions are the following:
a) The blades have roughly the same maximum power coefficient at optimum blade tip angle; if the aerodynamic blade profile is carefully selected the power coefficient is very good;
b) The blades with increased twist should be mounted at small blade tip angles than those with lower twist angle;
c) The rotor with increased blade twist angle has higher power coefficient at lower wind speeds and the blades with optimum selected twist behave oppositely. This can lead to the conclusion that an increased twist should be used for lower wind potential, even though the variation of *Cp* with the wind speed is within 10% on whole normal operating wind speed range.
d) The *Cp* of the rotor with 2 blades is decreasing very fast with the increasing of α; at higher α, the cut in wind speed is lower.
e) The *Cp* of the rotor with 6 blades is decreasing much slower with blade tip angle than the Cp of the rotor with 2 or 3 blades; therefore, the use of increased number of blades gives a larger margin for adjusting the cut in wind speed without affecting too much the power coefficient.

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