Evaluation of the possibility of replacing pitch control by active trailing edge flaps in wind turbines

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State of the art wind turbine rotors are getting larger and with it the weight of the whole system. It is of extreme importance to reduce the structural loads of the wind turbine to make wind energy more reliable and competitive.

One possibility to reduce loads is the usage of trailing edge flaps in wind turbine blades, similar to the concepts of the aerospace industry. However, what about using them in order to get rid of the pitch control system? This paper shows an aerodynamic study which analyzes the impact of the flaps in the power output.

A rigid trailing edge flap with \( c/c = 0.2 \) is introduced in the rotor blade of the reference turbine [1] of the Smart Blades project [2], cf. Fig. 1. With various span lengths of the flap and a range of flap angles, the impact on the power output under steady conditions is investigated.

This paper does not contain a control strategy for the use of flaps as power limitation system. The focus is merely to show a first study of the potential of trailing edge flaps as an alternative system to classical pitch control. Thus it is of main interest the existing relationship between the flap configuration and the power output for overrated conditions.

The first step of the study is the generation of the aerodynamic characteristics of the profile placed at the outer part of the reference blade. The corresponding calculations are performed with the well known software XFOIL.

The reference turbine has a rated power of 7.5 MW and a rotor diameter of 164 m. Each blade is 80 m long and the flaps are implemented between span positions of 44 m and 76 m. Various lengths of the flaps are used for the calculations, from 12 m up to 32 m.

The rigid trailing edge flaps introduced in the rotor blades have a chord length of 0.2 times the chord length of the corresponding cross section. The hinge point is always placed in the middle point between the suction side and the pressure side of the airfoil. The flap is moved upwards, in order to get load reduction and power limitation, and the maximum flap angles chosen is -9°, as higher flap angles lead to stall for very small angles of attack.

The aerodynamic calculations are based on the BEM theory with usual corrections and do not take into account dynamic effects. The rated wind velocity is 10.7 m/s, which is the starting point of the calculations.

From this wind speed on the pitch control would be used under normal working conditions of a state of the art wind turbine. Instead of that, we do not pitch the blade but we move the flap in order to get 1.05 of rated power, as losses in the gear box and generator are taken into account. The aerodynamic characteristics of the flaps are modeled in the calculations using the polars of the corresponding flap configuration. For different constant wind speeds, the flap angle which limits the power to the rated value is looked for.

The main goal of the study is to find out for which range of wind velocities the use of the flap system is feasible for power limitation.

Figure 2: Lift coefficient, lift to drag ratio, moment coefficient and hinge moment coefficient of airfoil with rigid trailing edge flap, \( c/c = 0.2 \)

The BEM calculations show that the range of wind speeds where the flap could replace the pitch control system is significantly small, cf. Fig. 3. With the biggest flap (32 m long) and maximum deflection (-9°) the highest wind velocity for which the power can be limited to its rated value is 11.2 m/s, which is very close to rated wind speed. This means, that for higher wind speeds, the flap should be longer or reach higher deflections, which is neither desirable (stall) nor feasible.

Figure 3: Relationship between normalized wind speed and length of flap

The present study shows that:

- The range of velocities where the flap is able to limit the power is very small. Therefore, it is not possible to replace the pitch system.
- The trailing edge flaps could be used to limit power and alleviate fatigue loads in the region close to rated conditions.
- Flap systems could be an alternative to or at least could assist classical pitch-controlled peak shavers.

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References

[2] Smart Blades, a coordinated cooperative research project between ForWind, the German Aerospace Center and Fraunhofer Institute of Wind Energy & Energy Systems Technology, www.smartblades.info
[3] Institute of Turbomachinery and Fluid Dynamics (TFD), Leibniz Universität Hannover