ON THE POTENTIAL LOAD REDUCTION ON WIND TURBINES BY FLAP CONTROL USING MEASUREMENTS OF LOCAL INFLOW TO THE BLADES

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Summary A number of research studies within the last ten years have shown that the potential load reductions using controllable trailing edge flaps on MW wind turbine blades are considerable. However, two major issues also have to be explored and solved in order to obtain the considerable reduction of loads; 1) what flap technology should be used ?; and 2) what sensor inputs should be used to control the flaps ? The present paper will focus on the sensor inputs and in particular the focus will be on sensors measuring the local flow in a small distance from the blade, e.g. with a five hole pitot tube measuring the flow in a distance of less than one chord length in front of the leading edge of the blade. Results will comprise load reduction potential as function of number of sensors and also the influence of necessary filtering will be explored.

INTRODUCTION

The considerable load reduction potentials by using controllable flaps on MW turbines have been shown in a number of theoretical and numerical studies over the last ten years [1], [2]. However, the studies also have revealed that the load reduction potential is strongly dependent on detailed control input which could be blade acceleration, bending moments or inflow data (local inflow data or relative velocity). Furthermore studies [3], [4] show, that the flap actuator time constant can reduce the load alleviation potential considerable as shown in Figure 1.

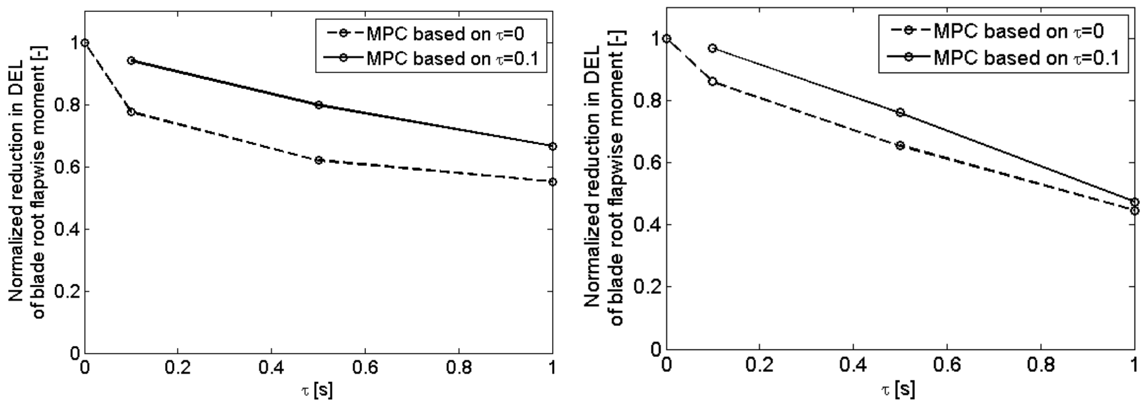

Figure 1 Computed reduction in load alleviation potential due to flap actuator time constant. Figure from [4]

However, further delay in the flap control loop can be due to the type of signal that is used for control. An illustration is shown in Figure 2, where inflow measurements on the Nordtank 500 kW turbine operating at 15m/s are shown in

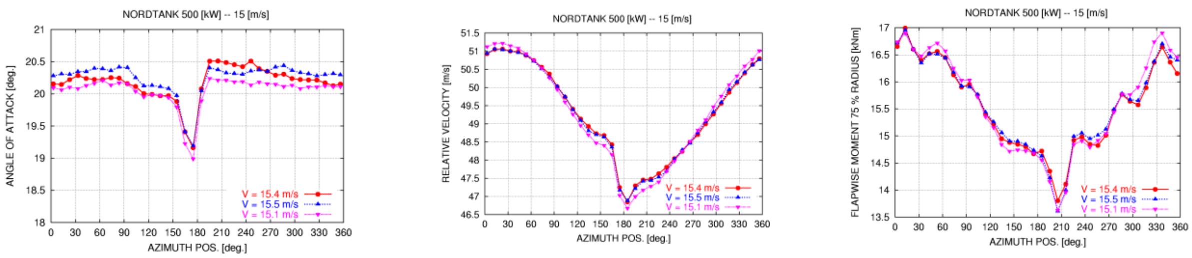

Figure 2 Example of inflow measurements with a five hole pitot tube on the Nordtank 500 kW turbine. To the left is the local inflow angle binned on azimuth positions for three 10min. Series. In the middle the local relative velocity is shown and to the right the flapwise blade root moment.

comparison with the flapwise response. Both the measured local inflow angle and the relative velocity show a minimum at an azimuth of 180 deg. caused by the tower influence on the flow but the minimum in the flapwise response is seen to occur somewhat later at 210 deg. This delay will depend on the damping in the system but is also due to the five hole pitot tube measuring the inflow about 1m in front of the leading edge of the blade. This illustrates that it can be an advantage to include flow measurements in the input for control in order to reduce the influence of time delay.

Approach and results

The analysis will be based on aeroelastic simulations with the HAWC2 code on the 5 MW NREL reference rotor, however, with a stiff turbine structure to avoid aeroelastic effects but with turbulent inflow. Important parameters that will be investigated are; 1) the load alleviation potential as function of number of inflow sensors; 2) the requirement to filtering of the inflow signal and 3) influence of limitations in flap response amplitude and time constant. Analysis of real measured inflow signals from the DAN-AERO experiment will also be included in the analysis. Derived aerodynamic loading , Figure 5, from inflow, Figure 4, is shown below and compared with the measured flapwise blade root moment in Figure 6. A good correlation is seen between the derived load from inflow and the measured flapwise moment.

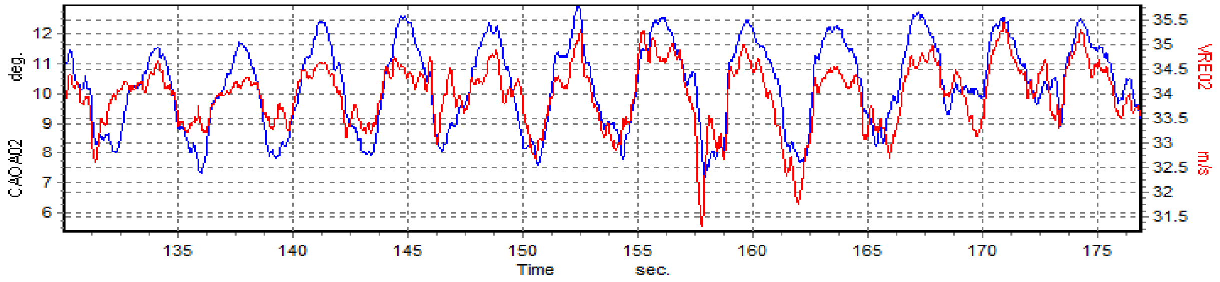

Figure 3 Local inflow angle at radius 20m (blue line) and relative velocity (red line) measured on the 80m rotor in the DAN-Aero project.

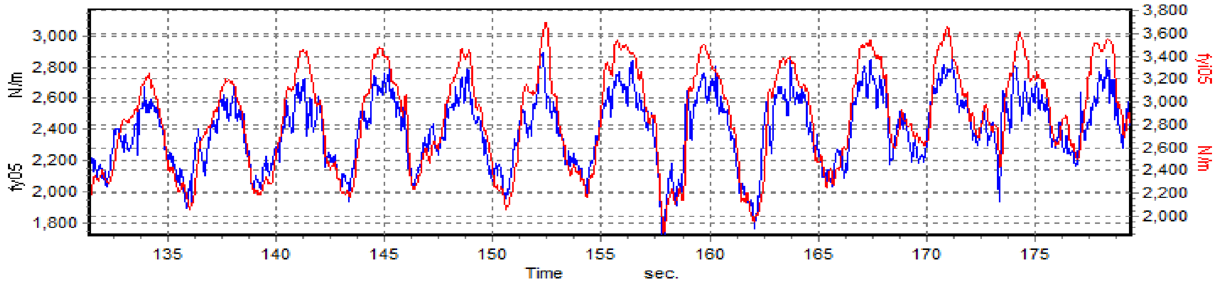

Figure 4 Local aerodynamic loading perpendicular to the chord (blue line) measured on the 80m rotor in the DAN-Aero project in comparison with the load (red curve) derived from inflow measurements of local inflow angle and local relative velocity.

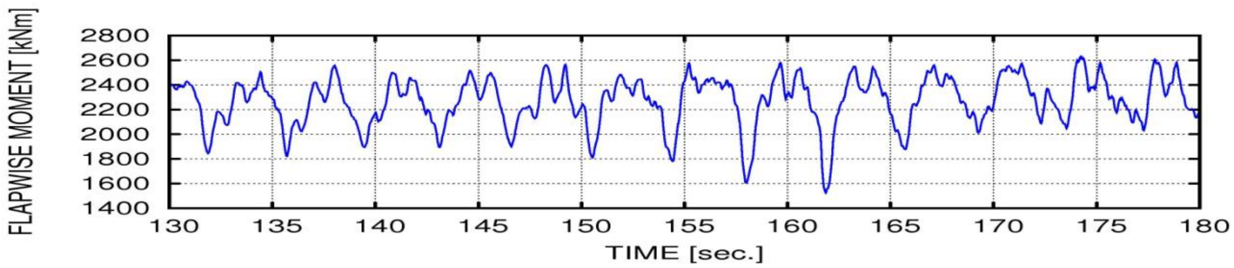

Figure 5 Measured blade flapwise moment for the same blade as shown above and for the same period.

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