NUMERICAL AND EXPERIMENTAL LOADS ANALYSIS ON A HORIZONTAL-AXIS WIND TURBINE IN YAW

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The yaw behaviour of horizontal-axis wind turbines has been recently attracting an impressive attention in the wind energy literature. This is motivated by the fact that the active control of the yaw is the keystone of wind farm control for wake steering, in order to improve the energy production and to mitigate mechanical loads.

On these grounds, the main topic of this work is the numerical and experimental study of a three-bladed horizontal-axis wind turbine prototype in yaw. The wind turbine prototype has 2 meters of rotor diameter; the nacelle mass is 40 kg; the blades are in polymer reinforced with glass fibers and have fixed pitch angle; the maximum producible power is 3 kW. The numerical simulations are performed using the open-source aeroelastic code FAST (Fatigue, Aerodynamics, Structures and Turbulence), developed at the NREL (National Renewable Energy Laboratory). The experimental analysis is performed at the wind tunnel of the University of Perugia: it is an open test section with turbulence intensity lower than 0.5%. The prototype wind turbine has been subjected to steady wind time series, with varying yaw angles.

This work is focused on the analysis of the mechanical loads, especially as regards how they change depending on the yaw angle. A triaxial accelerometer and a load cell have been employed, for measuring the fore-aft vibrations and the force on top of the tower. The measured vibration and acceleration spectra are compared against the numerical simulations: peculiar attention is devoted to monitoring the cyclic contributions through the order-spectrum analysis. In particular, the contribution from the first blade passing frequency 3P provides meaningful information about how the blade-tower interaction varies depending on the yaw angle. The time-synchronous averaging TSA of the signals allows studying the dependence of the thrust on the azimuth angle and it arises that, above a critical velocity of the order of 10 m/s, the effect of the blade deflection on the tower dam (thrust cyclic fluctuations) can't be disregarded and therefore should be included in the numerical simulations for a reliable comparison against measurements.

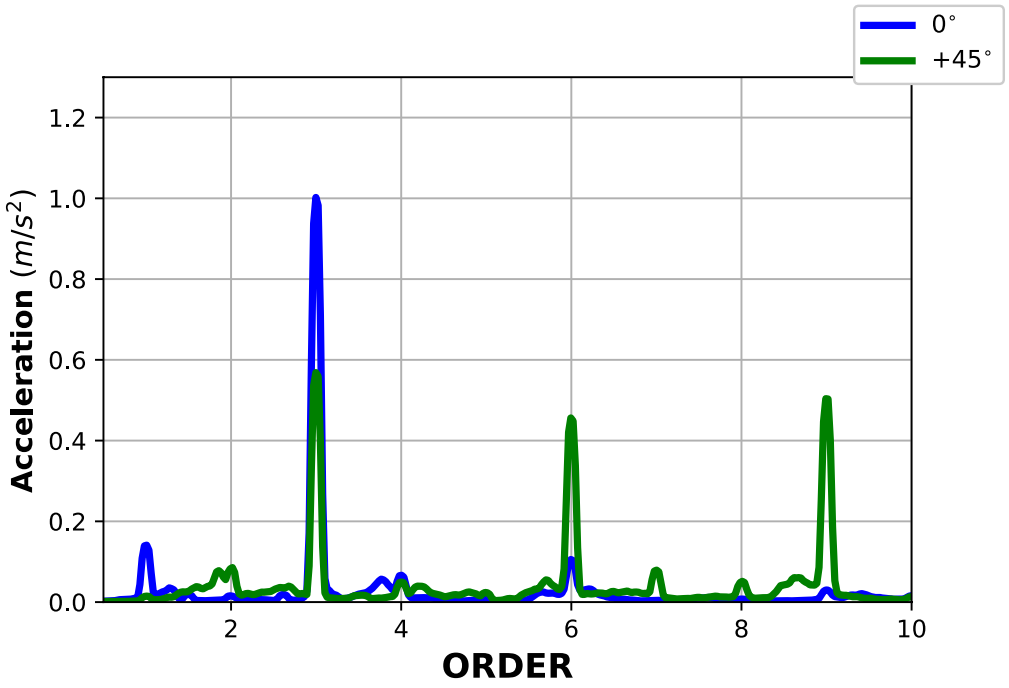

Figure 1 Experimental normalized order spectrum of the acceleration (fore-aft component normalized on the amplitude of the 3P component with zero yaw).

Figure 2 Experimental normalized order spectrum of the forces (fore-aft component normalized on the amplitude of the 3P component with zero yaw).

The general outcome of the present work regards on one side the comprehension of the limits of low-fidelity numerical models in reproducing the mechanical behaviour of horizontal-axis wind turbines in yaw, even under steady conditions; on the other side the monitoring of mechanical loads under controlled conditions might be inspiring for the comprehension of the behaviour in real (turbulent) environments and for the development of reliable control yaw control strategies.