

Developing the Next Generation 12+ MW Offshore Wind Turbine for Clean and Competitive Electricity

Vortex-induced vibrations of wind turbines: From single blade to full rotor simulations

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Abstract

Vortex-induced vibrations (VIVs) of wind turbine blades cannot be predicted by low fidelity methods. High fidelity methods, such as computational fluid dynamics (CFD) coupled to a structural solver, come at a high computational cost. For single blade cases, the so-called forced-motion method of prescribing the blade motion according to structural modeshapes has proven effective. In this work, VIVs of the IEA 10 MW reference turbine is studied in a fluid–structure interaction setup. This study is limited to only a single case at 18 m/s wind speed with the rotor in bunny configuration, 80 degrees pitch and 90 degrees yaw. A significantly larger limit cycle amplitude was obtained than what would be reached in a corresponding isolated single blade simulation. Forced-motion simulations combining three single blades are found to be feasible. Details of the work can be found in [1].

Simulation setup

The IEA 10 MW reference turbine is simulated using a coupled fluid-structure interaction setup.

The structural part of the full turbine is modeled in the aeroelastic simulation code HAWC2, which uses Timoshenko beam elements in a multibody formulation, that allows for nonlinear deflection. The aerodynamics are simulated using the flow solver EllipSys3D. The rotor is placed within a spherical domain, with a domain boundary at ~750 m from the rotor center. The mesh consists of 51.1 million total cells.

The structural and aerodynamics solvers are loosely coupled, exchanging information once per time step.

Results

After an initial forcing, vibrations in the rotor yaw mode were building up, eventually reaching a limit cycle oscillation (LCO) amplitude of 17m. The vortex shedding at LCO is visualized in Fig. 1.

At low amplitudes, blade B1, pointing into the wind, was injecting most power into the oscillation, but at a large amplitude of 12 m, the aerodynamic power injection at B3, pointing downwind, takes over, Fig. 2. Blade 2 always shows a small, but positive aerodynamic damping.

The structural damping in the FSI simulations matches the structural damping according to the standstill first yaw mode in vacuum, as predicted by HAWCStab2, closely, Fig. 2.

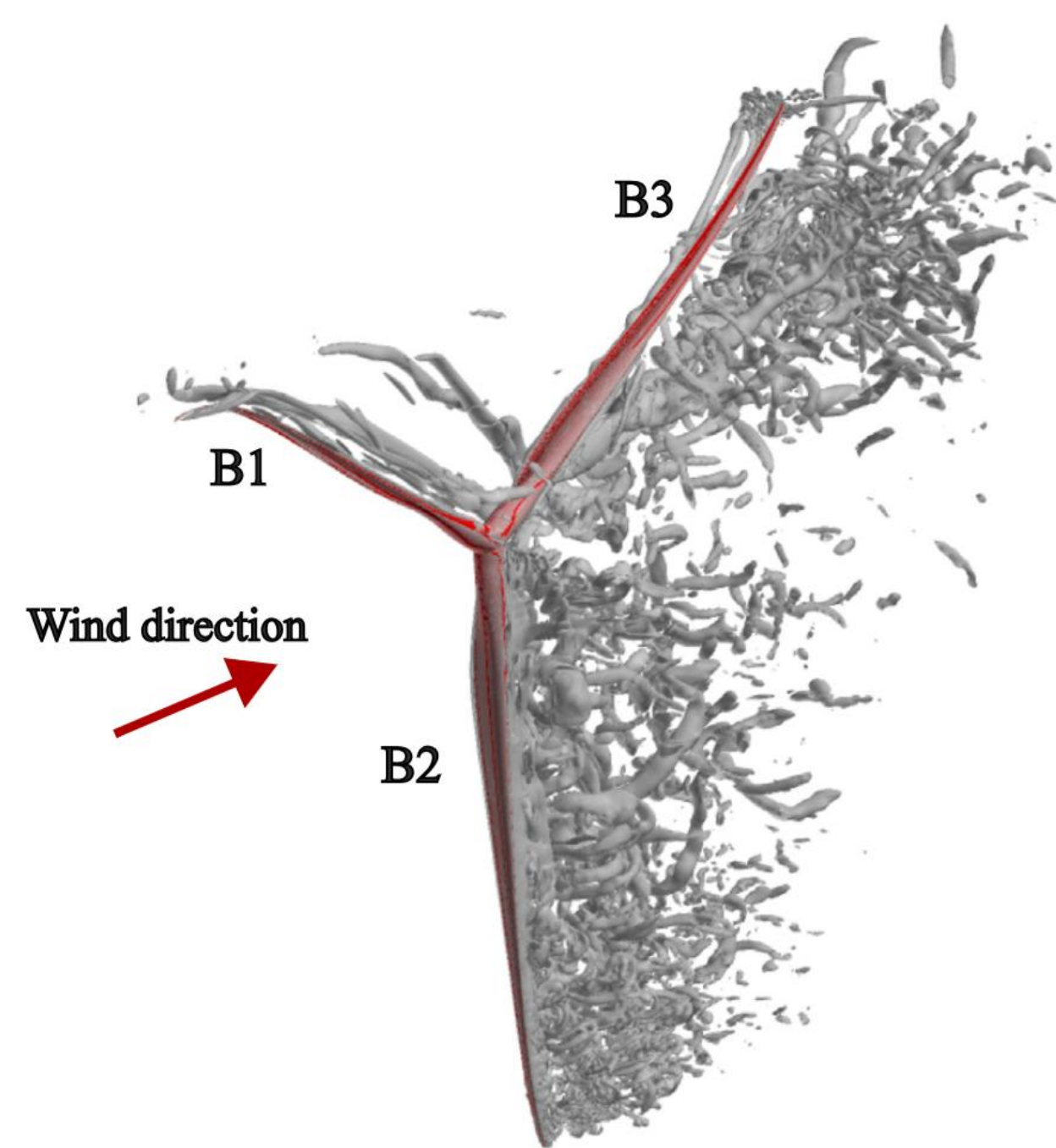


Fig. 1: Flow visualization of vortex shedding during limit cycle oscillations

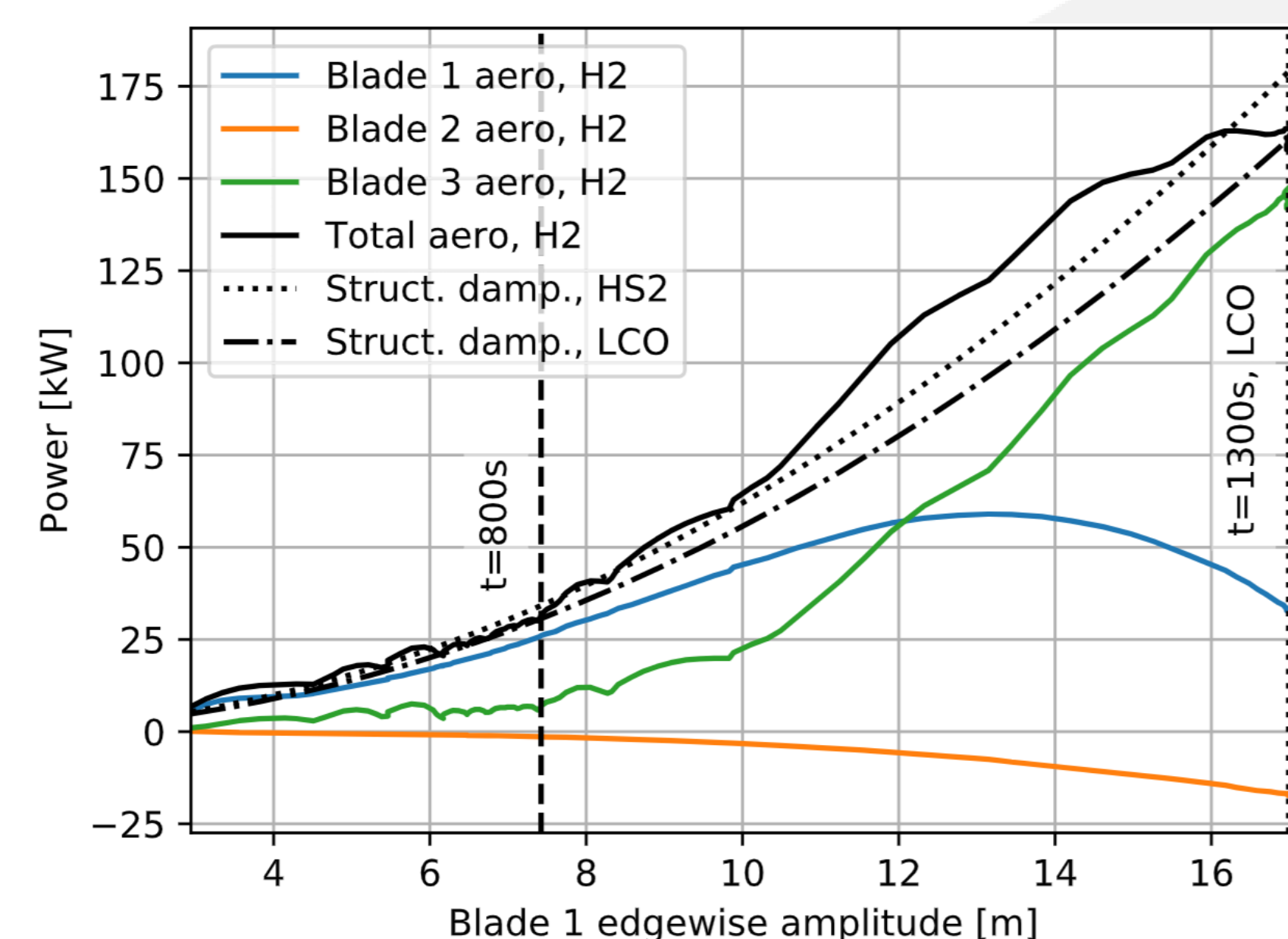


Fig. 2: Aerodynamic work of the three different blades as function of blade 1 tip amplitude

Conclusions

In the present case, the first rotor yaw mode could reach a far greater limit cycle amplitude than what was expected from previously conducted clamped single blade simulations. The observed deflection shapes were in good agreement with the structural mode shape, and therefore the structural damping seen in the FSI simulations matched well the structural damping obtained by a purely structural computation in HAWCStab2. Additional computations (not shown here for brevity) showed that the wake of the upstream blade had negligible impact on the aerodynamic power injection at the downstream blade. This indicates that a combination of forced motion computations of individual blades vibrating according to the rotor mode could predict the total aerodynamic power injection.

Source

1. Pirrung, G.R., Grinderslev, C., Sørensen, N.N., Riva, R., Vortex-induced vibrations of wind turbines: From single blade to full rotor simulations, Renewable Energy (2024), <https://doi.org/10.1016/j.renene.2024.120381>

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