CFD Methodology for Wind Turbines Fluid-Structure Interaction

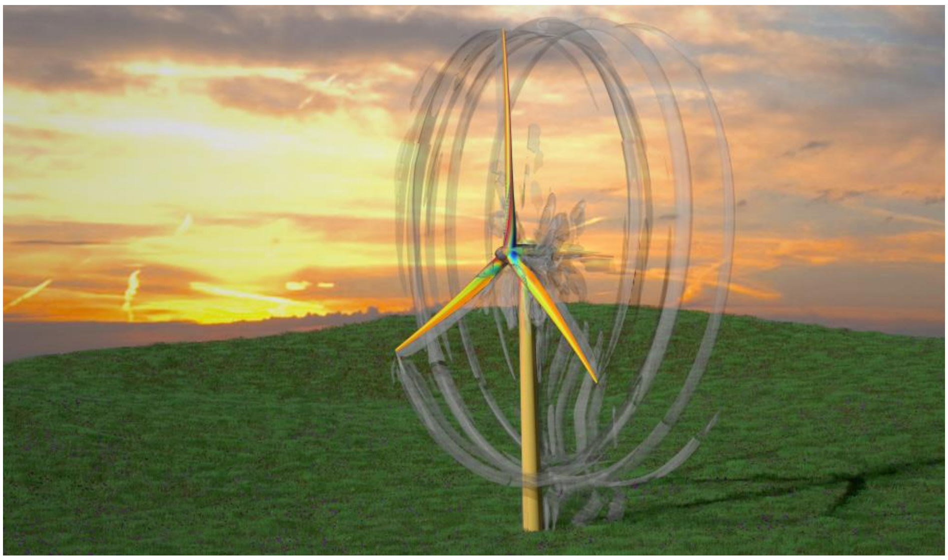
Sergio González Horcas

Horizontal axis wind turbines are one of the most efficient renewable energy sources. In order to extract the maximum power per machine and reduce the overall energy extraction cost, there is a clear design trend consisting in the up-scaling of the rotor diameter. This implies the consideration of more flexible blades, that significantly deform during operation due to the aerodynamic loading. This thesis proposes an innovative computational approach for the study of this aeroelastic problem that accounts for the interaction of both the fluid and the structure physics.

The PhD work tackles two major issues concerning efficient fluid-structure interaction simulations of large horizontal axis wind turbines. One concerning the development of a mesh deformation technology achieving a good trade-off between mesh quality, scalability, robustness and computational cost for 3D flow meshes accounting multi-million points. Another concerning the extension of a frequency domain methodology, namely the nonlinear harmonic method, to handle the 2-way coupling between a fluid in motion and a deformable elastic structure for steady and periodic unsteady aeroelastic interaction.

The resulting methodology allows to assess the rotor performance with progressive degrees of model complexity. Both isolated rotor and full machine (i.e. including the tower) calculations can be performed. Fluid modeling relies in a steady or unsteady formulation respectively. For both configurations, a structural model of the blades can be considered in order to assess the influence of aeroelasticity in the rotor performance.

The suggested approach was implemented and tested within the FINE™/Turbo software, edited by NUMECA International. It offers a higher fidelity multiphysics flow modeling than current industry standards, and its reduced computational cost enables its direct introduction into the wind energy market.



Artist impression of one result of this PhD work