Highly resolved Large-Eddy Simulation of wind turbine wakes

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The interaction of a wind turbine with a free stream generates a complex vortical wake that ultimately leads to transition to turbulence [1]. In order to predict performances (e.g. power production, fatigue loads...) of wind turbines in wind farms, it is essential to accurately characterize these wakes and their impact on the downstream turbines. Large-Eddy Simulation (LES) is well adapted to this problem as the considered flow is 3D, complex and strongly unsteady. The state-of-the-art approach for taking into account the effect of the turbine on the flow is the Actuator Line (AL) method [2, 3]. This method enables the use of Cartesian grids, which brings numerous advantages but prevents space adaptivity and limits the shape of the flow domain.

In the present work, the AL approach was implemented in a massively parallel high-order finite-volume LES solver named YALES2 [5]. This code offers good scalability and is able to handle unstructured meshes up to billions of elements. We propose here to assess this approach on the Tjaereborg wind turbine case [4]. In particular, the quality of the results obtained using Cartesian and fully unstructured tetrahedral meshes will be compared.

The strategy is then applied to a realistic 1MW wind turbine designed by the Adwen company. Fully unstructured grids with local refinement are used here. Figure 1 presents the simulated wakes by plotting iso-contours of Q-criterion $Q = 1\,\mathrm{s}^{-2}$ at three different Tip Speed Ratios $\lambda = \omega \mathrm{R}/\mathrm{u}_\infty$. The figure shows that the tip blade vortices are faster destabilized as the TSR increases leading to a faster transition to fully developed turbulence.

This work demonstrates the ability to perform massively parallel scale-resolving simulations where both near and far turbine wakes are accurately modeled. These simulations may be further exploited to validate design tools based on simpler models.

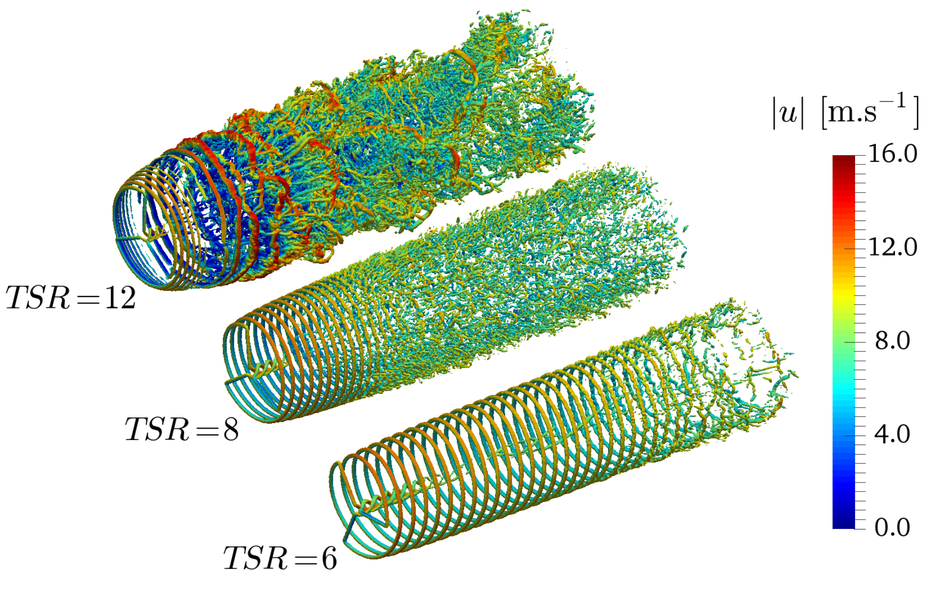

Figure 1: Iso-contour of Q-criterion $Q = 1\,\mathrm{s}^{-2}$ colored by the norm of velocity for three Tip Speed Ratios.

Références

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