AERODYNAMIC LOADS OF LARGE HORIZONTAL-AXIS WIND TURBINES

zEPHYR Marie Skłodowska-Curie project: towards a more efficient exploitation of on-shore and urban wind energy resources

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CONTEXT

Wind energy has become a major technology in power production, and in EU it is currently the most successful renewable source of **electricity** (see Fig.1). Among the many technical advancements that led to such a result, the increase in **rotor size** is one of the most important. Large rotor sizes allow to reduce the **Levelized Cost of Energy** (see Fig.2), and this is essential for the competitiveness of wind energy with fossil fuel energy sources.

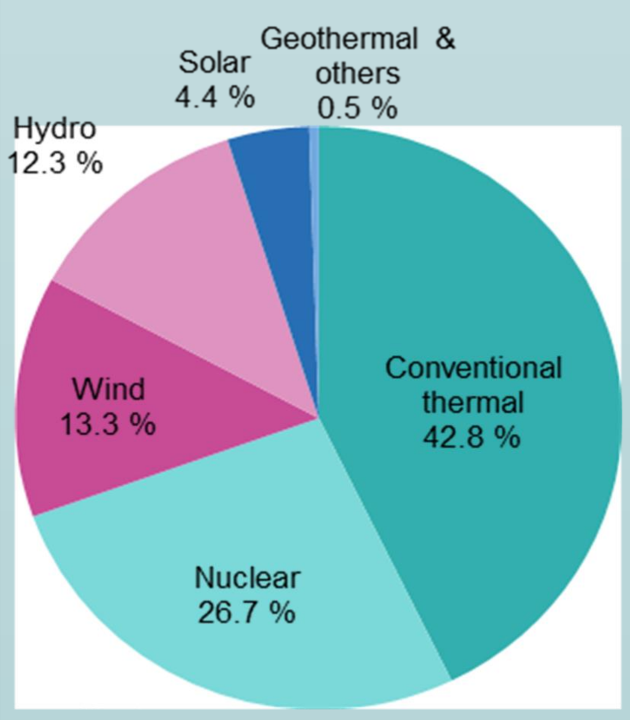

Fig 1. Electricity production by source, EU-27, 2019 (%). Source: Eurostat

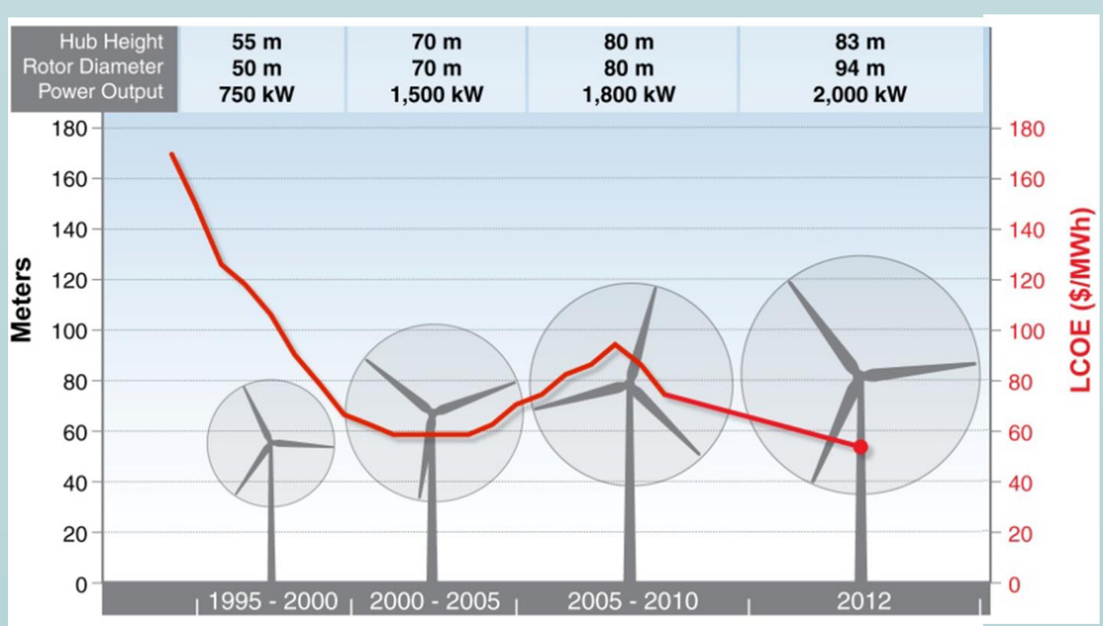

Fig 2. Relation between average onshore wind turbine rotor size and Levelized Cost of Energy (LCOE) from 1995 and 2012 in the US [1].

PROBLEM DEFINITION

The large rotor size of **Horizontal-Axis Wind Turbines** (HAWT) introduces two main issues:

- **Large blade deformations** (see Fig.3) reaching even 10% the blade length along the rotation axis direction [2].
- Increased **non-uniform time-dependent inflow conditions**, as the rotor size is comparable with the size of atmospheric turbulent eddies [3].

For **structural** and **aerodynamic modelling**, both aspects can be treated separately. However, they are strongly coupled in physical terms leading to relevant **aeroelastic effects**. Accurately predicting such effects is essential to **design** safe and efficient wind turbines. This is achieved by reliable **simulation methodologies** coupling structural and aerodynamic models.

Fig 3. The large bending deformation experienced by a wind turbine blade during a structural test.

Source: www.compositesworld.com

WIND TURBINE AERODYNAMIC MODELLING

The **Blade Element Moment Theory** (BEMT) is currently the state-of-the-art for industrial applications due to its low simulation cost [3]. However, its basic assumptions require **engineering corrections** to address non-uniform time-dependent inflow conditions. These corrections efficiently retain global first-order effects, but often neglect second-order local effects undermining the reliability of BEMT predictions. Conversely, **Computational Fluid Dynamics** (CFD) is a high-fidelity (see Fig.4) but prohibitively expensive approach for design cycles. Therefore, current research efforts aim at exploiting CFD simulations to improve both our understanding of the **wind turbine aerodynamics** and engineering models.

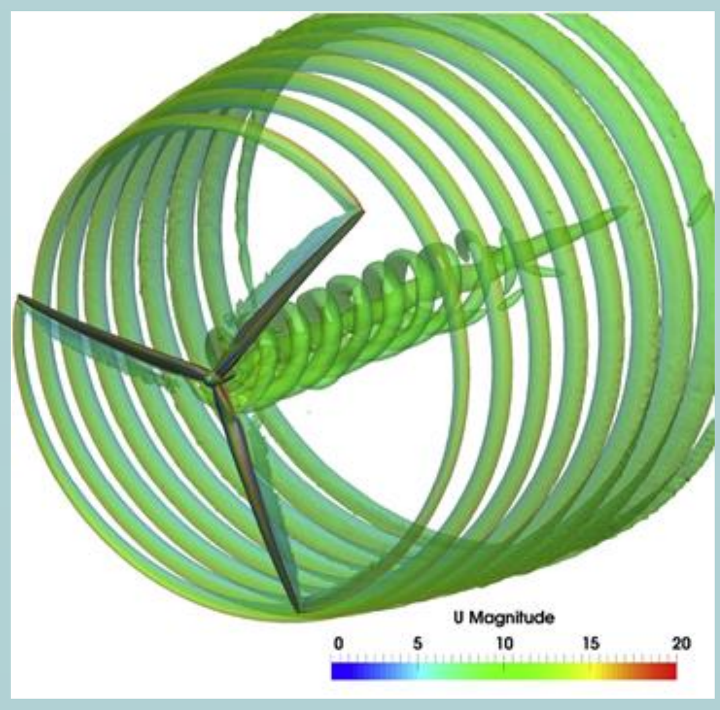

Fig 4. CFD solution of the wake shed by an isolated wind turbine rotor. The wake structure is shown in terms of iso-surfaces for the vortex Q criterion colored by velocity magnitude. [4]

OBJECTIVES

- Assess the prediction accuracy of state-of-the-art industrial simulation methodologies on large HAWT experiencing realistic inflow conditions.
- Investigate the flow physics of large HAWT under non-uniform time-dependent inflow conditions by CFD simulations.
- Develop new engineering aerodynamic models.
- Validate and assess the proposed new methodologies.

METHODOLOGY

This research uses the **Simcenter** environment by Siemens Digital Industries Software (see Fig.5), in particular:

- Samcef for Wind Turbines
- Samcef Mecano
- StarCCM+

In addition, also academic research codes will be used.

Fig 5. Simcenter release 2020.1. Source: www.blogs.sw.siemens.com

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