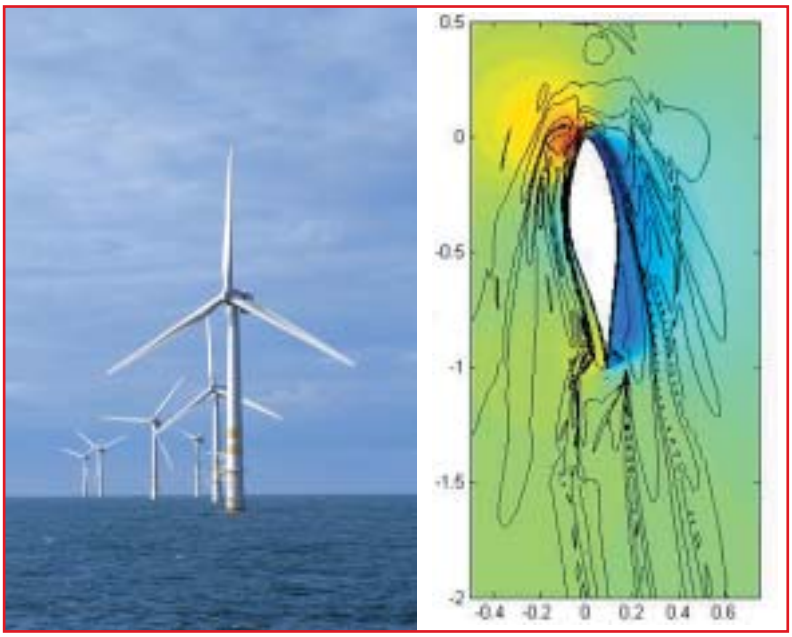
Unsteady effects in wind turbine aerodynamics

Through a Global Research Award, the Royal Academy of Engineering has enabled Dr Wolf Früh from Heriot Watt University, Edinburgh, to work on unsteady phenomena in wind turbine aerodynamics for 4 months at the Institute of Turbomachinery and Fluid Dynamics of the University of Hanover. This study has shown that the interaction between the turbine tower and the rotor blade affects the lift force on the blade even if the rotor is upwind of the tower.

The trend for wind energy is towards increasingly larger turbines, where the latest turbines for offshore installation are rated at around 5MW and have a rotor diameter in excess of 100m. This increase in power rating and size leads to new challenges in materials and structural mechanics as well as aerodynamics.

The aerodynamics of wind turbines are the same as for propellers but with the crucial difference that wind turbines often operate near stall conditions, and always operate at sizes and speeds comparable with the spatial and temporal fluctuations of the wind in the atmospheric boundary layer.

Dynamic stall occurs for two reasons: firstly the wind shear, because the wind increases with height across the rotor area and, secondly, the presence of the turbine tower. The wind upstream of the tower is modified as the air is diverted around the tower. This results in a brief change of the power output whenever a blade passes in front of the tower. Such a pulse could lead to sudden load fluctuations with implications for structural vibrations, material loading and fatigue.



(Left) *Arklow Bank Offshore Wind Power Facility, Ireland, consisting of seven GE 3.6-megawatt (MW) wind turbines (courtesy GE Energy)*
(Right) *Snapshot of a model run showing the pressure field (colours) and some vorticity contours.*

A preliminary estimation showed that the interference between the tower and the blade is likely to be noticeable. This problem was investigated in a pilot study using the computational fluid dynamics (CFD) software package NUMECA, which showed a number of features. While the lift force on the blade did not seem to vary much on the time scale of the pulse from passing the tower, the average lift was reduced by up to 30%. This pilot study is now being extended in further CFD calculations, in wind tunnel experiments on a scale-model of a full rotor in Hanover, and on a turbine blade section subjected to pulses in the flow direction, modelling those of the tower-blade interaction.

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