An LES-AL Study of the DTU 10MW RWT

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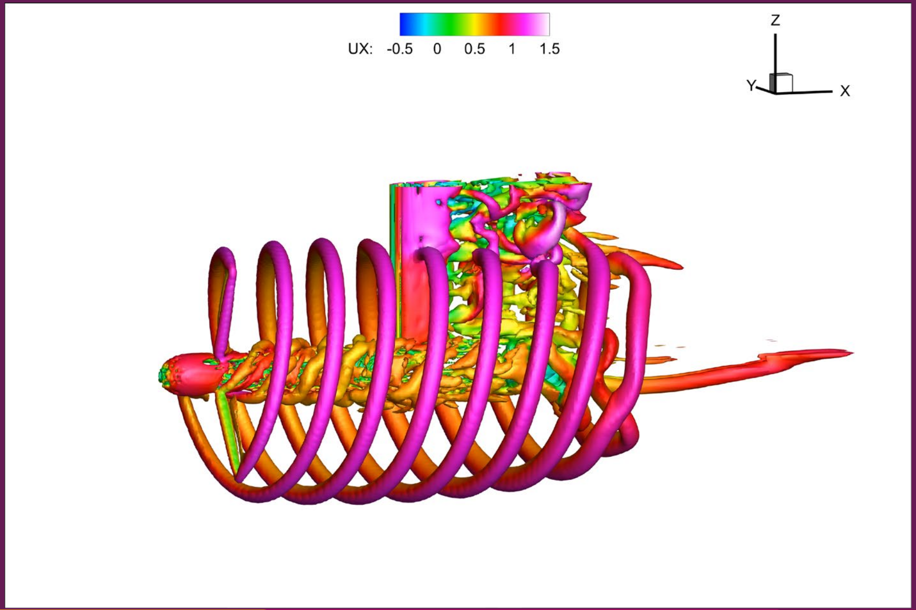
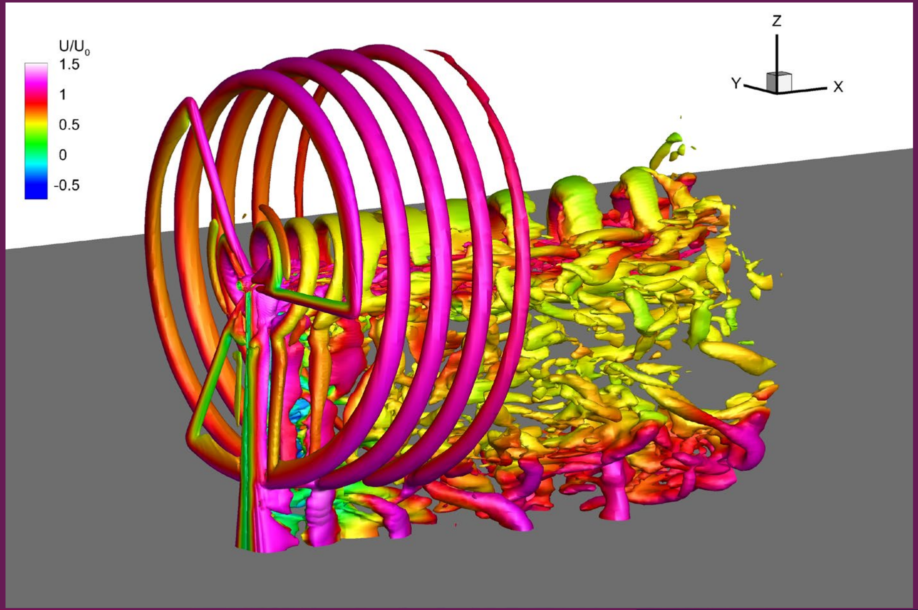


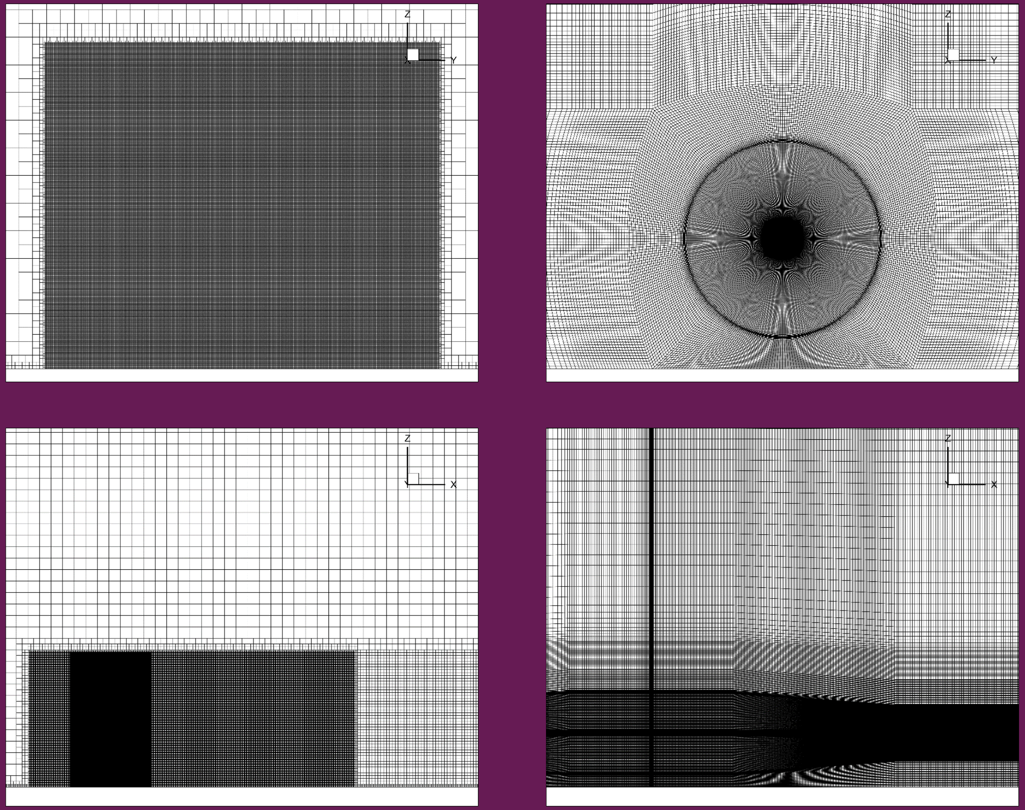


Objectives

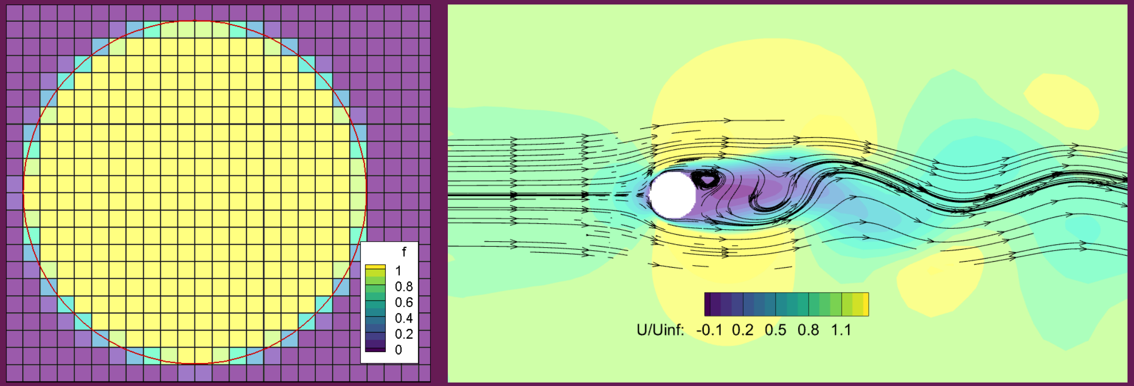
- Development of computationally efficient simulation techniques for high fidelity CFD simulations
  - Actuator Line (AL) turbine representation
  - Immersed boundary body representation
  - Efficient meshing strategies
- Detailed evaluation of wake physics
  - Velocity and turbulence profiles
  - Velocity spectra
  - Wake structure decomposition methods (e.g. POD, DMD)

Configurations

- DTU 10MW RWT at just below rated power, U_∞=10 m/s.
- Nacelle and tower represented by the immersed boundary method for computational efficiency
- Approx. 50M cells: OpenFOAM Octree and O-grid meshes
- Nacelle and tower represented by the immersed boundary method for computational efficiency
- Simulation speed (at 3600 timesteps per rotation)
  - Octree: 1.9×10^3 core-hours / rotation
  - O-grid: 14.7×10^3 core-hours / rotation



OpenFOAM Octree (left) and O-grid (right) meshes

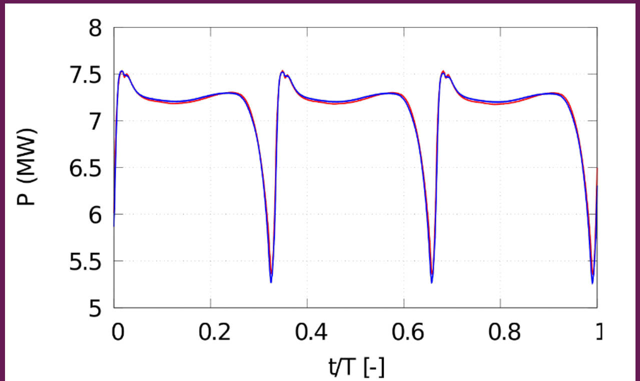


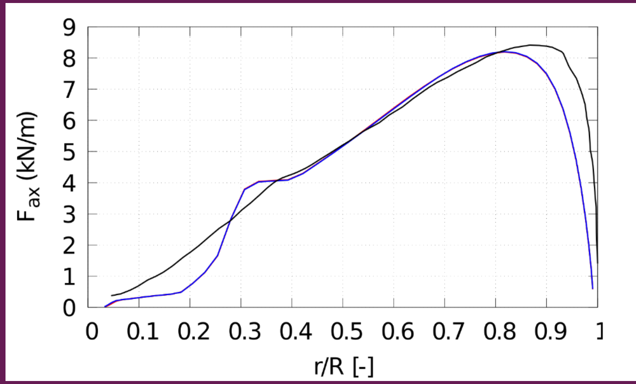
Example of the immersed boundary method and cylinder test case

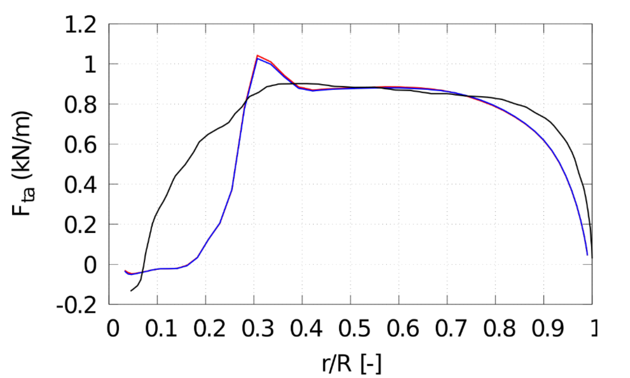
Turbine Performance

- Overall performance of LES-AL turbine compares well to blade resolved results for both meshing strategies.
- Spanwise force distributions compare well except in tip region.
- Differences between LES-AL cases and blade-resolved [1] are due to 2D lift-drag polars, tower wake effects and tip-loss correction.

	Blade-resolved [1]	Octree LES-AL	O-grid LES-AL
C_P	0.494	0.463	0.463
C_T	0.838	0.781	0.781





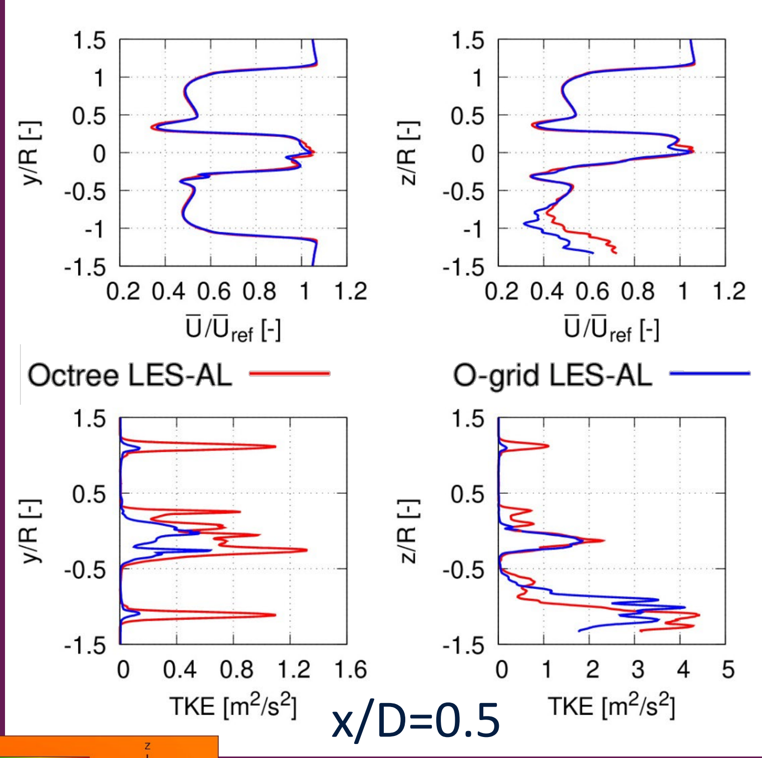


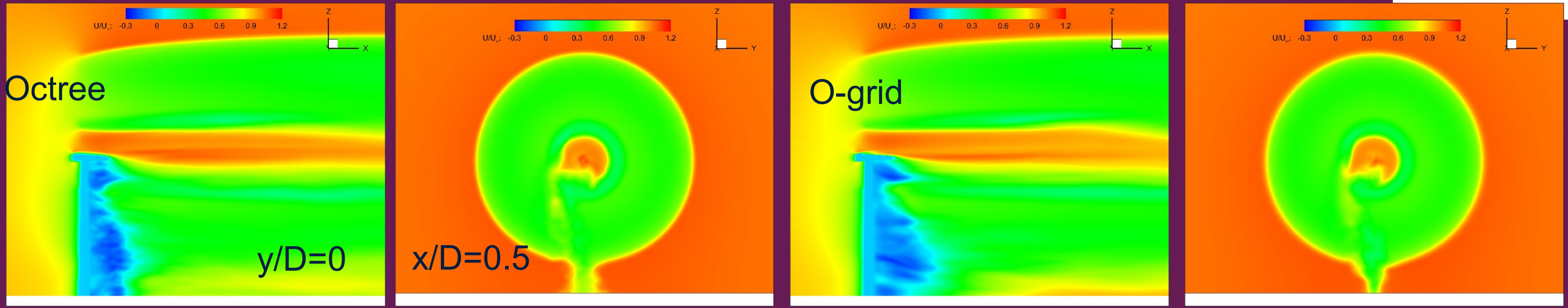
Octree LES-AL — O-grid LES-AL — Blade-resolved [1] —

[1] DTU Wind Energy Report-I-0092, C. Bak, F. Zahle, R. Bitsche, T. Kim, A. Yde, L.C. Henriksen, A. Natarajan and M.H. Hansen, July 2013, available from: https://rwt.windenergy.dtu.dk/dtu10mw/dtu-10mw-rwt

Wake Velocity

- Mean velocity and TKE field are similar between the 2 meshing strategies.
- The accelerated region towards the blade root is consistent with reduced root loads, which are due to the choice of lift-drag modelling coefficients in the AL representation of the root aerofoil sections.
- Octree case shows a reduced TKE decay rate compared to O-grid case.

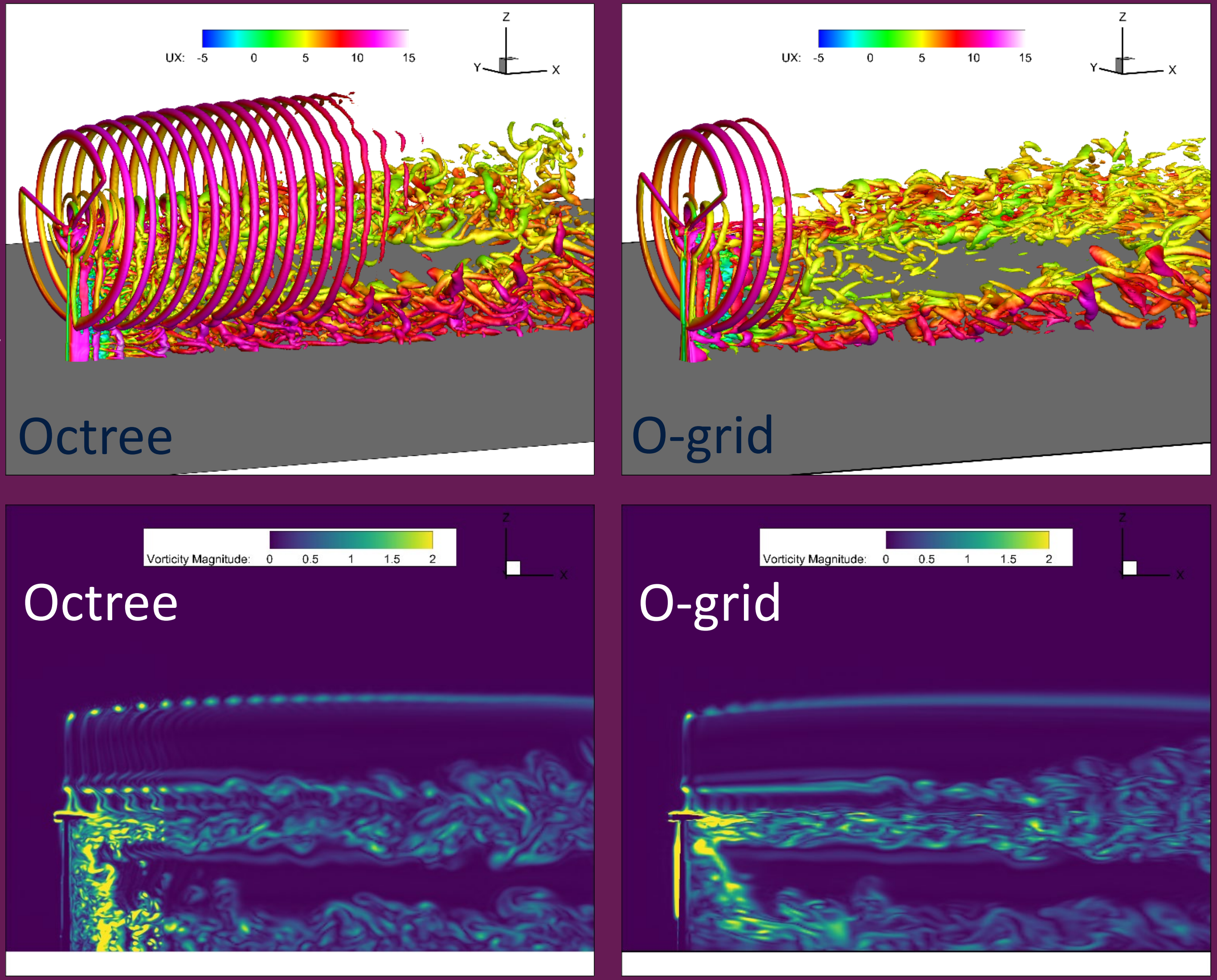




Wake Turbulence

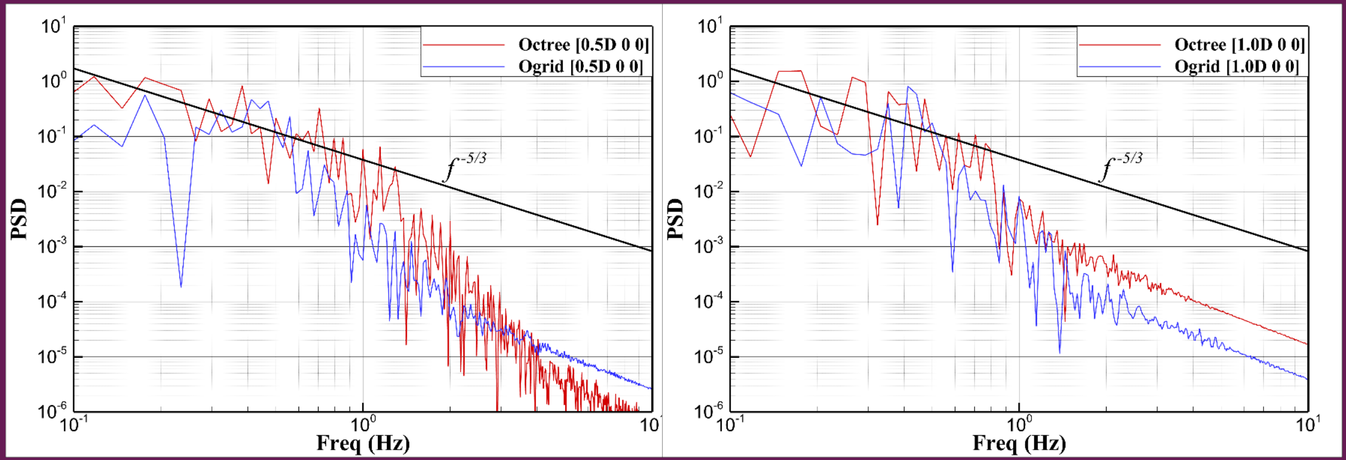
- Iso-surfaces of λ_2 coloured by velocity (top) and vorticity magnitude (bottom)

- Visualisation of the turbulent structures suggests a higher dissipation rate for larger turbulent structures, e.g. tip vortices, in the O-grid case compared to the Octree case.

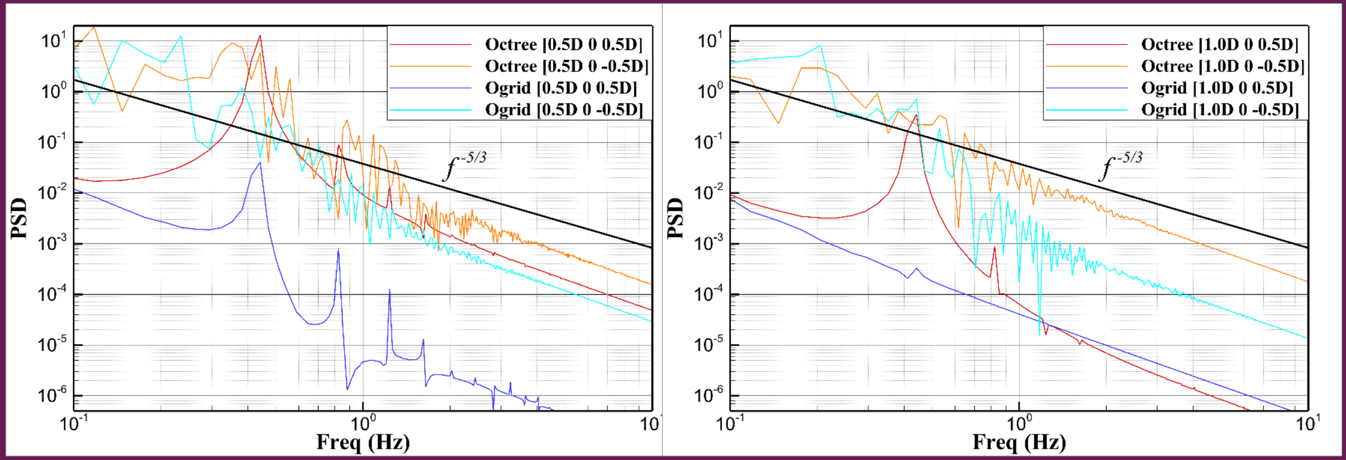


Wake Velocity Spectra

- Both meshing strategies show a similar dissipation rate in the nacelle wake.
- In the tip shear region, spectra shows that the Octree mesh preserves higher turbulence levels.



Streamwise velocity spectra in the nacelle wake region at x/D=0.5 and x/D=1.0.



Streamwise velocity spectra in the tip shear region at x/D=0.5 and x/D=1.0, z/D=±0.5

Conclusion & Future Work

- The Octree mesh has higher computational efficiency than the O-grid.
- Octree based grids are able to provide similar turbine performance, as well as mean wake flow field, when compared to O-grid techniques.
- Turbulent structures and statistics are preserved better in Octree than the O-grid.
- Future improvements including the AL method, wake flow resolution, and more analysis methodology

Acknowledgements

- The authors would like to thank the SUPERGEN ORE Hub, EPSRC (grant No. EP/S000747/1), and RWE Renewables for their support in funding this work.