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Programme Area: Marine

Project: ReDAPT

Title: ReDAPT:Development of a CFD Model of the TGL Turbine at the EMEC Site

Context:

One of the key developments of the marine energy industry in the UK is the demonstration of near commercial scale devices in real sea conditions and the collection of performance and environmental data to inform permitting and licensing processes. The ETI's ReDAPT (Reliable Data Acquisition Platform for Tidal) project saw an innovative 1MW buoyant tidal generator installed at the European Marine Energy Centre (EMEC) in Orkney in January 2013. With an ETI investment of £12.6m, the project involved Alstom, E.ON, EDF, DNV GL, Plymouth Marine Laboratory (PML), EMEC and the University of Edinburgh. The project demonstrated the performance of the tidal generator in different operational conditions, aiming to increase public and industry confidence in tidal turbine technologies by providing a wide range of environmental impact and performance information, as well as demonstrating a new, reliable turbine design.

ReDAPT MD1: Development of a CFD model of the TGL turbine at the EMEC site.

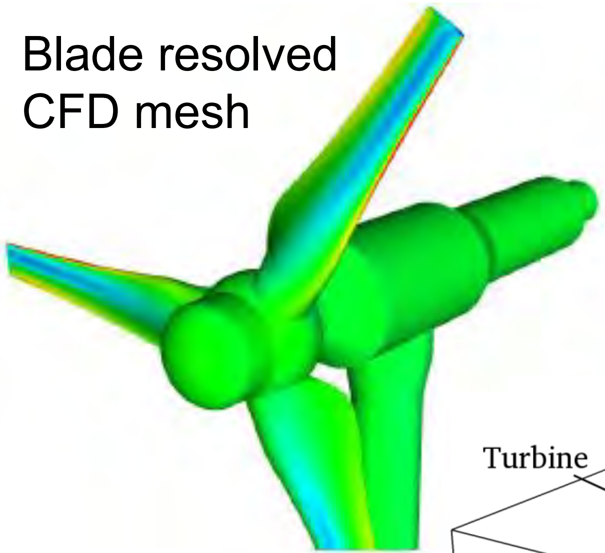
Tim Stallard, Peter Stansby, David Apsley, Imran Afgan,
Umair Ahmed, Stefano Rolfo, James McNaughton

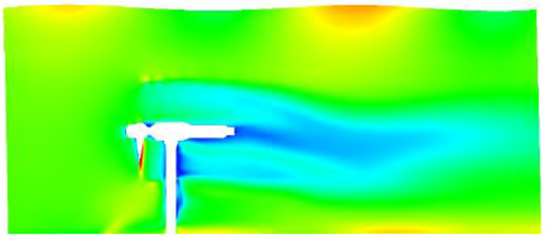
The University of Manchester

MD1: Development of a CFD model of the TGL turbine at the EMEC site.

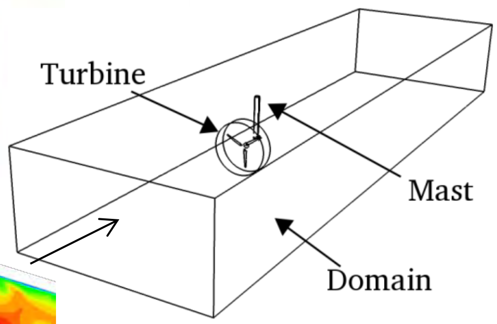
AIM: detailed study of transient flow and loads, including effect of turbulence and waves

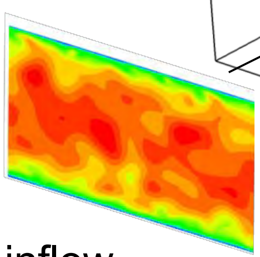
Blade resolved CFD mesh





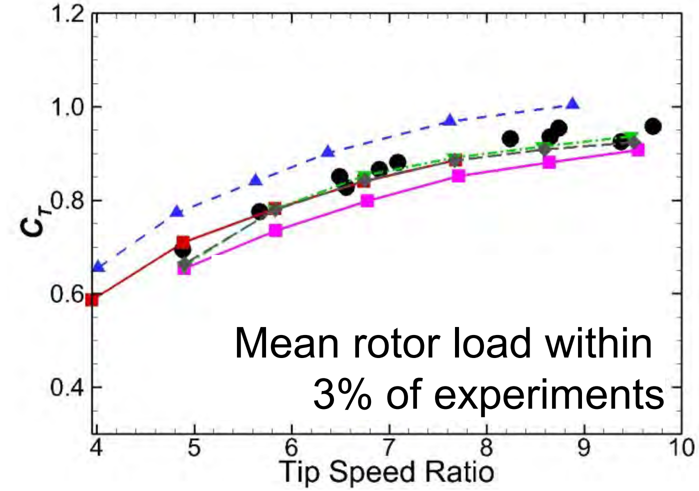
Free surface by ALE method

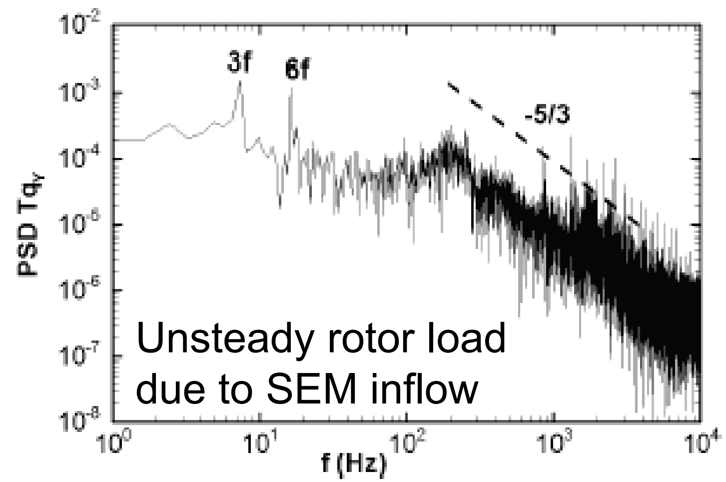




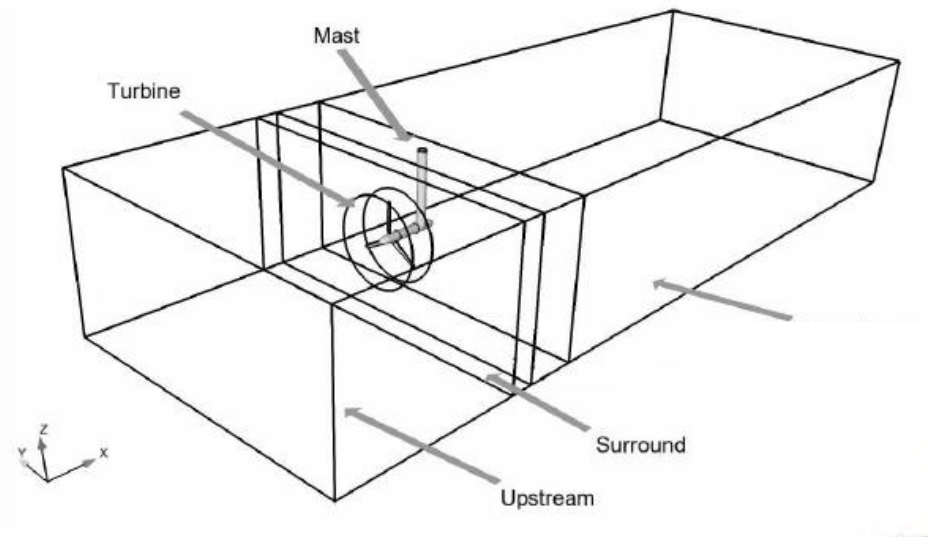
Turbulent inflow by Synthetic Eddy Method (SEM)

RANS and Large Eddy Simulation (LES) using EDF Code_Saturne.

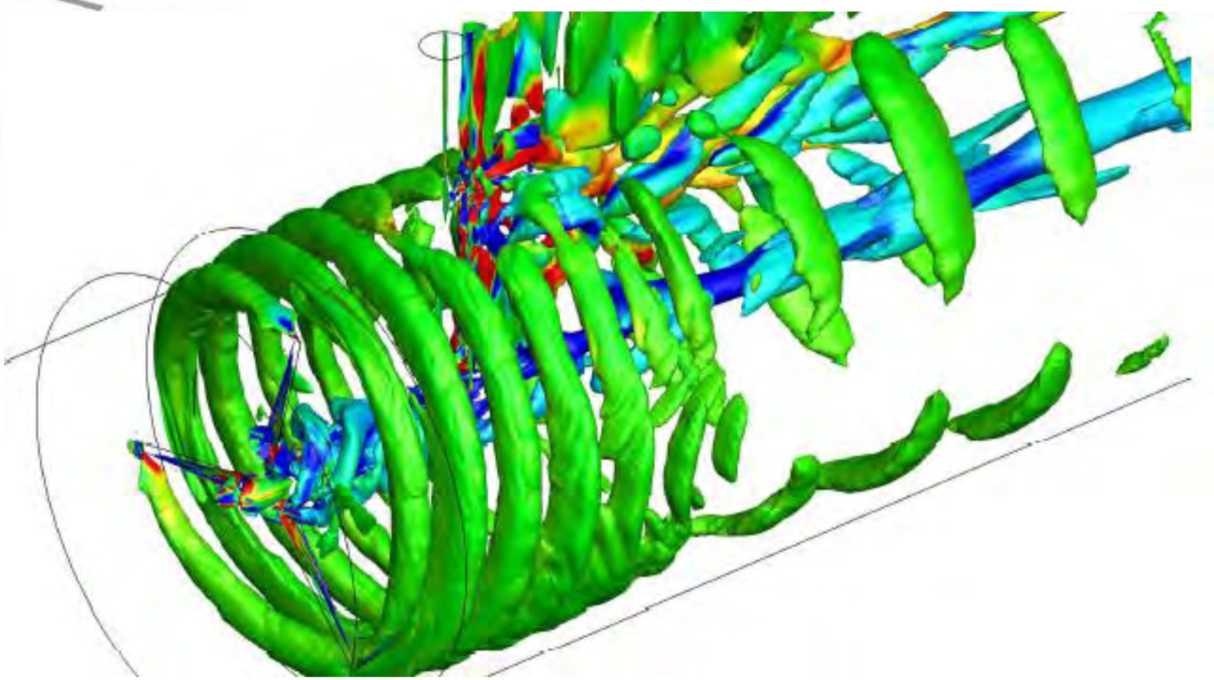




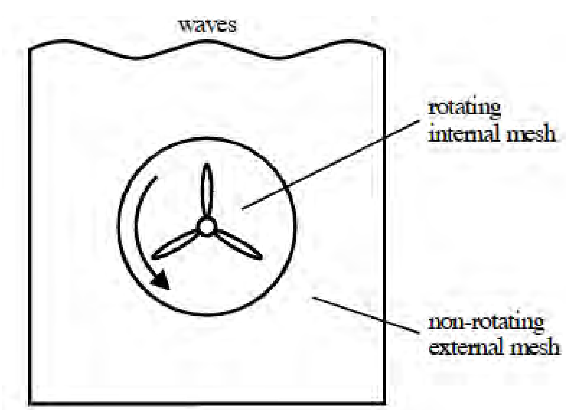
Method: Sliding Mesh Method developed for RANS and LES



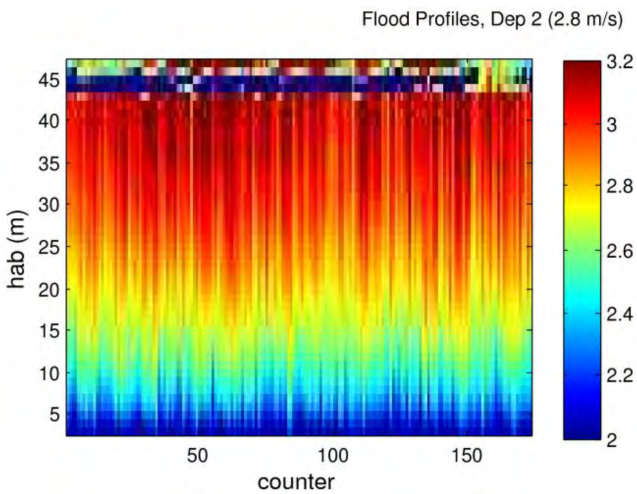
LES of Generic Rotor



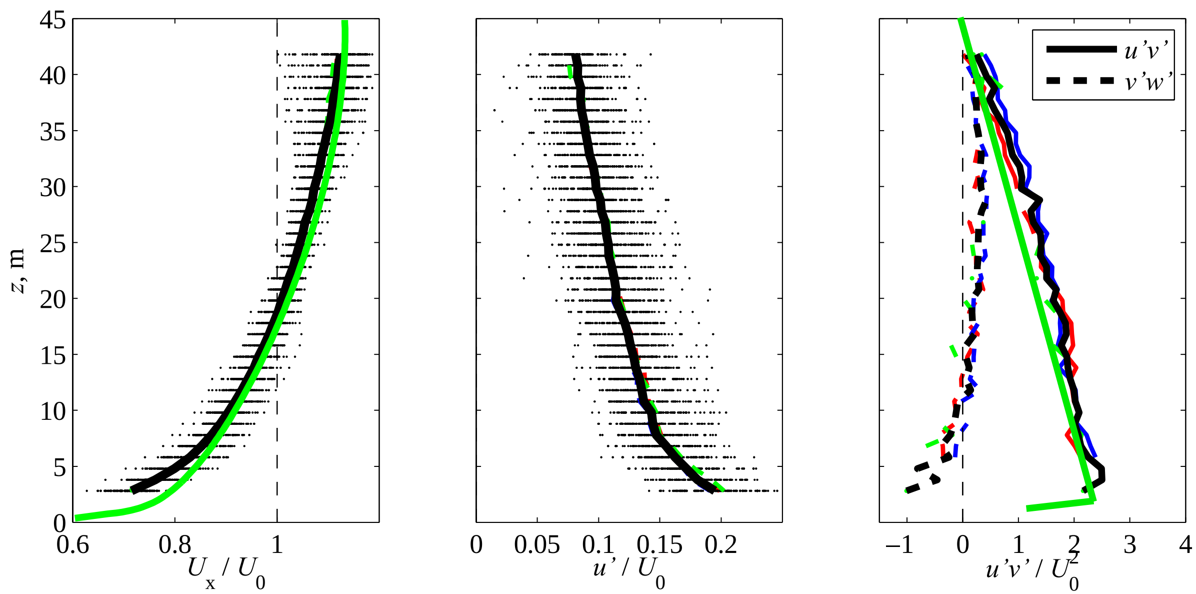
Sliding interface method



Method: Synthetic Eddy Method used to represent depth profile of mean and unsteady flow



ReDAPT MD3 EMEC flow measurements by ADCP and turbine mounted instruments at EMEC



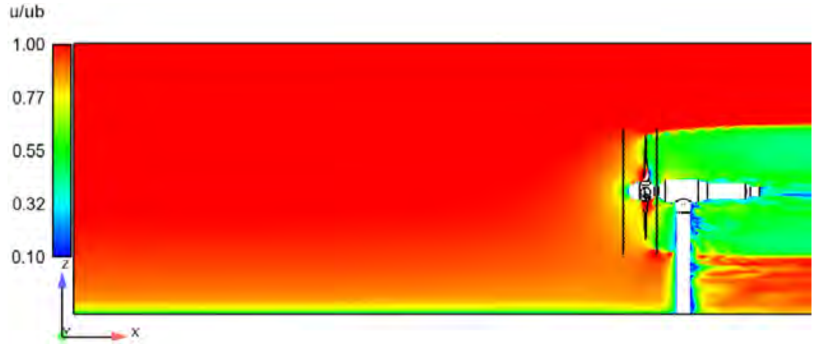
EMEC flood profiles and fully developed LES channel simulations used to define SEM inflow to LES turbine simulations. Reynolds stress distribution and measured lengthscales scaled from simulations.

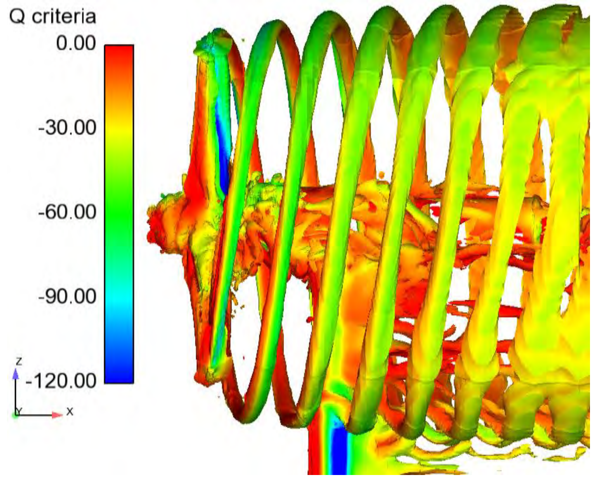
Sellar et al. ReDAPT MD3

Ahmed et al. ReDAPT MD1 reports

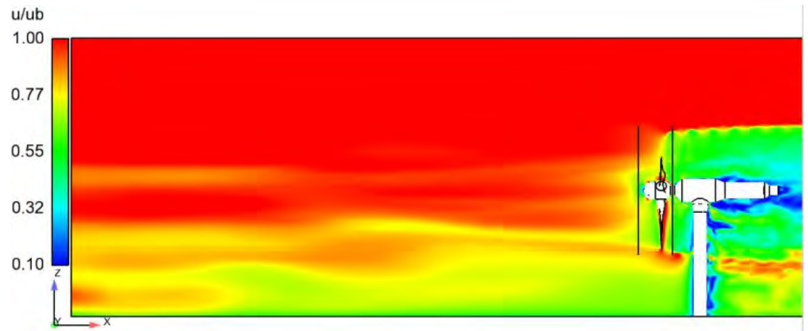
Method: LES with sliding mesh method and SEM inflow to predict 1 MW turbine loads

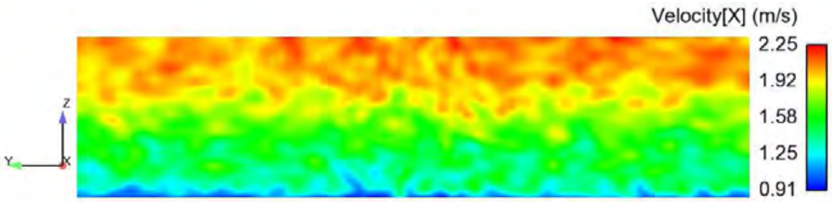
Zero turbulence inflow

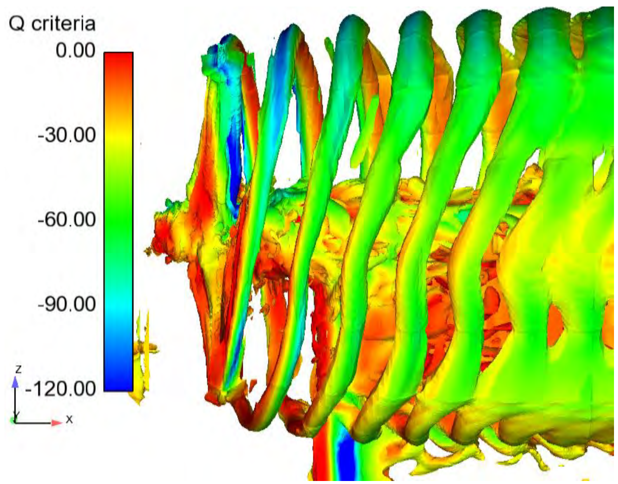




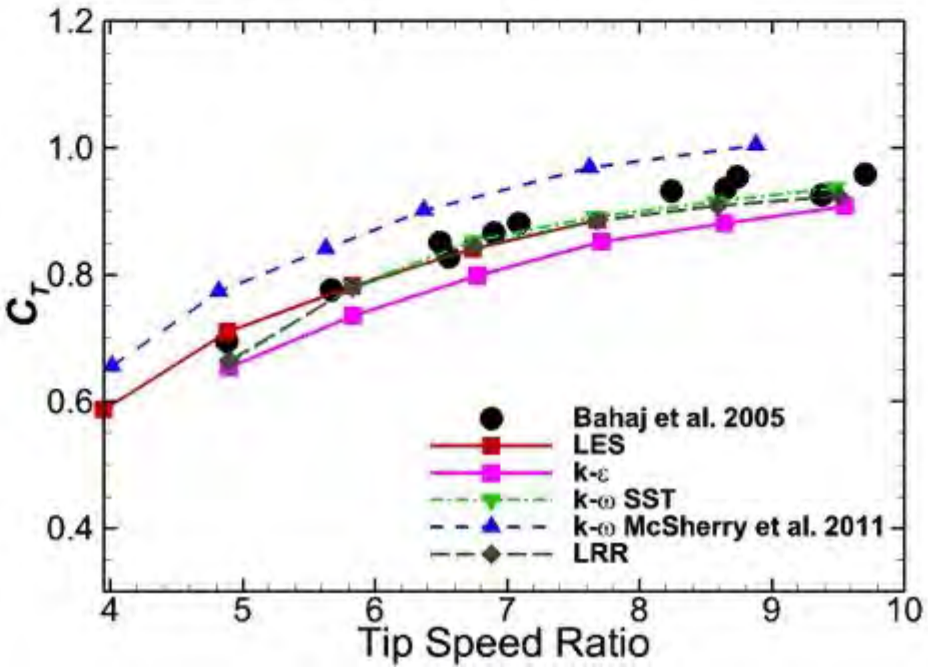
Synthetic turbulence at inflow

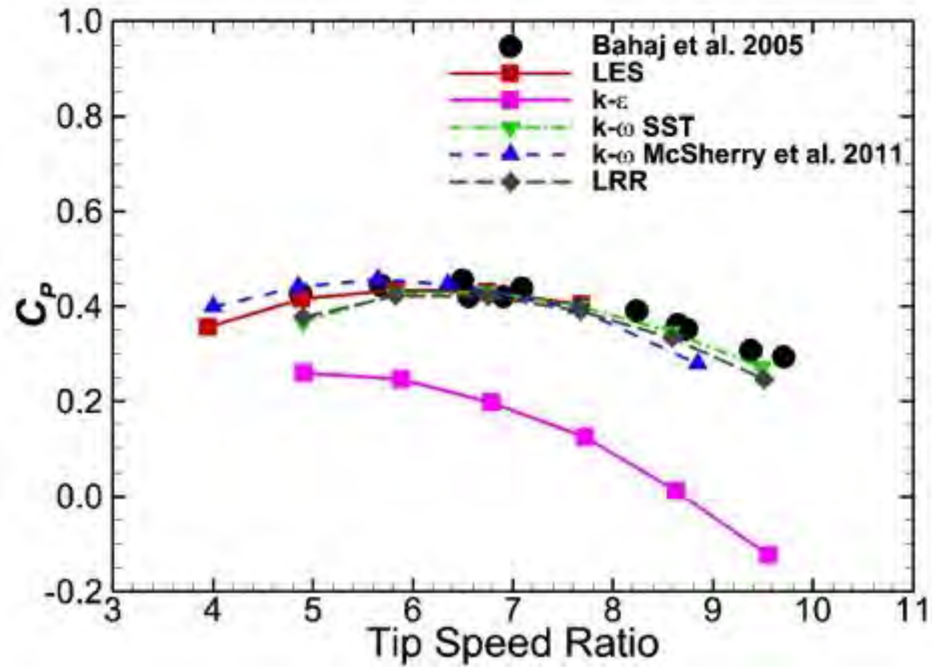






Finding: Accurate prediction of power and thrust





<u>Mean</u> loads within 3% of experiments by LES and RANS
LES prediction accurate to lower TSR than RANS

Afgan et al. IJHFF 2013 and McNaughton et al. AWTEC 2013

Finding: Measured shear significantly affects cyclic blade loading

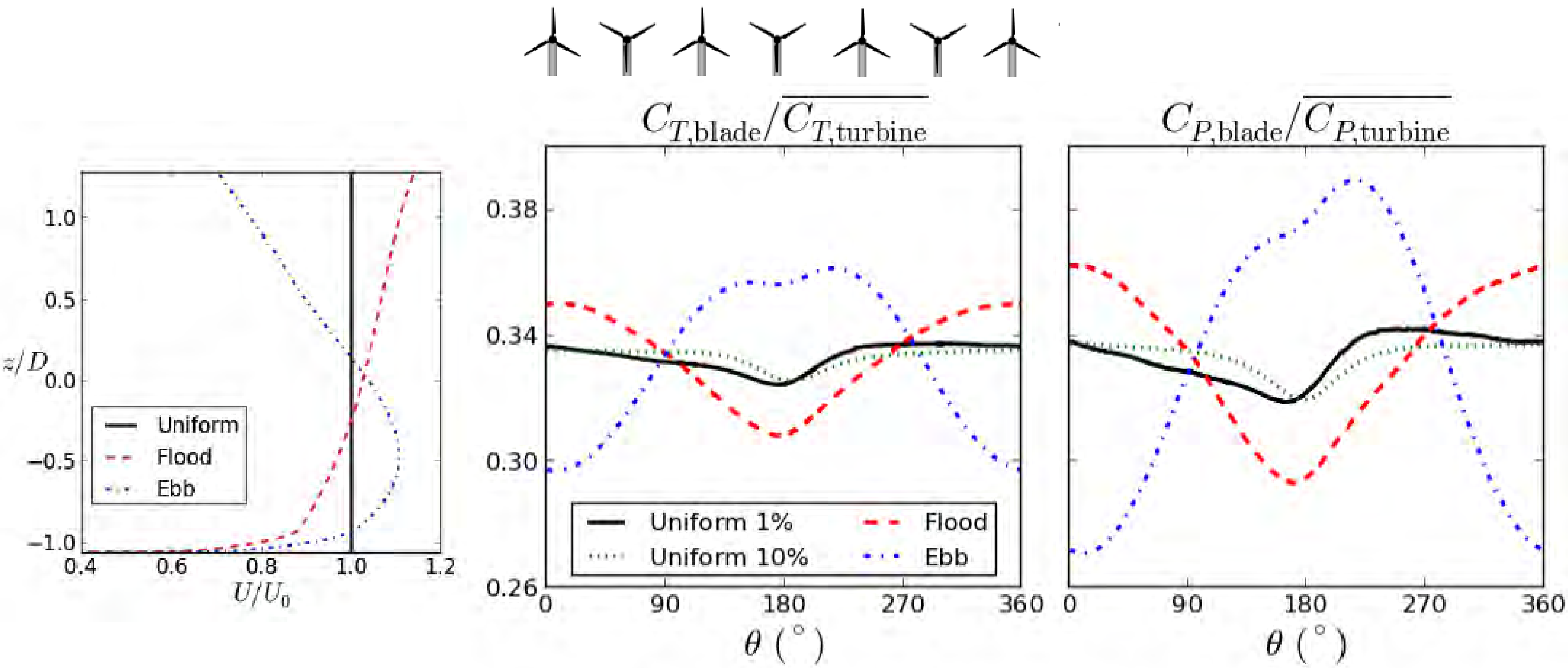
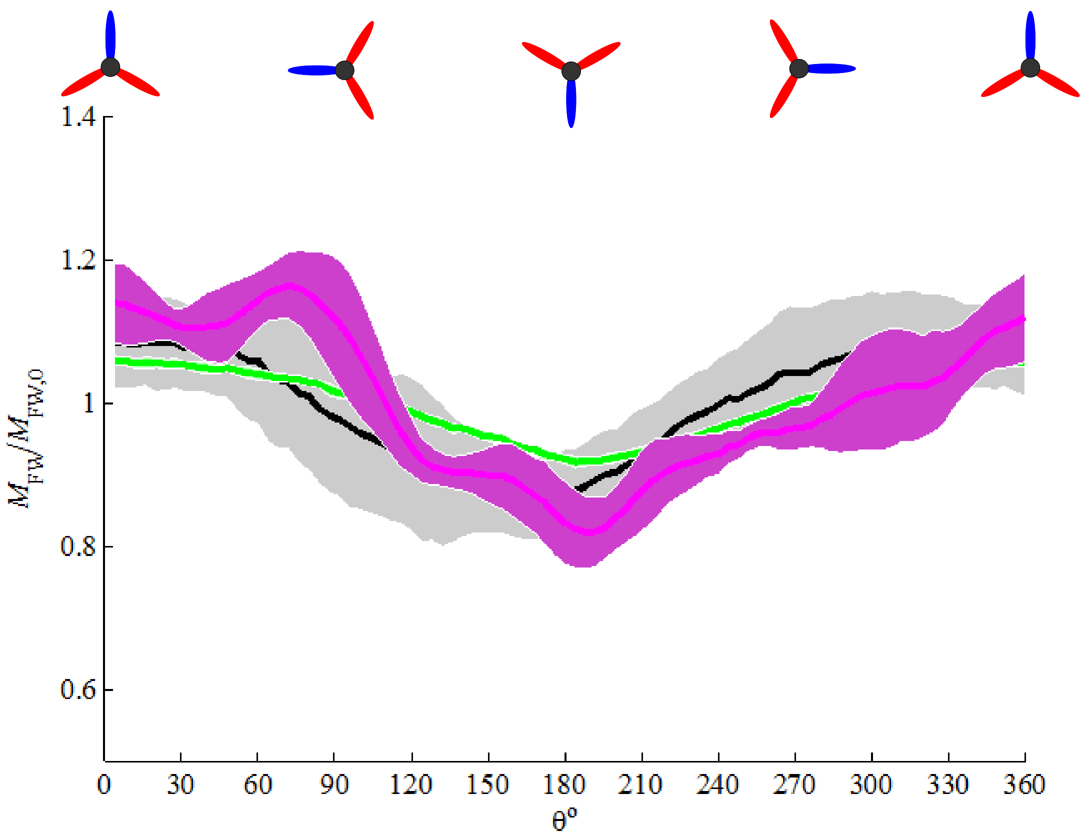


Figure 2.5: Phase-averaged thrust and power coefficients for each velocity profile.

McNaughton, Rolfo, Apsley, Stallard, T., Stansby, P.K. CFD power and load prediction on a 1MW tidal stream turbine with typical velocity profiles from the EMEC test site. *Proc. 10th EWTEC*. Sep 2013

Finding: LES with SEM inflow predicts blade root bending moment affecting fatigue design.



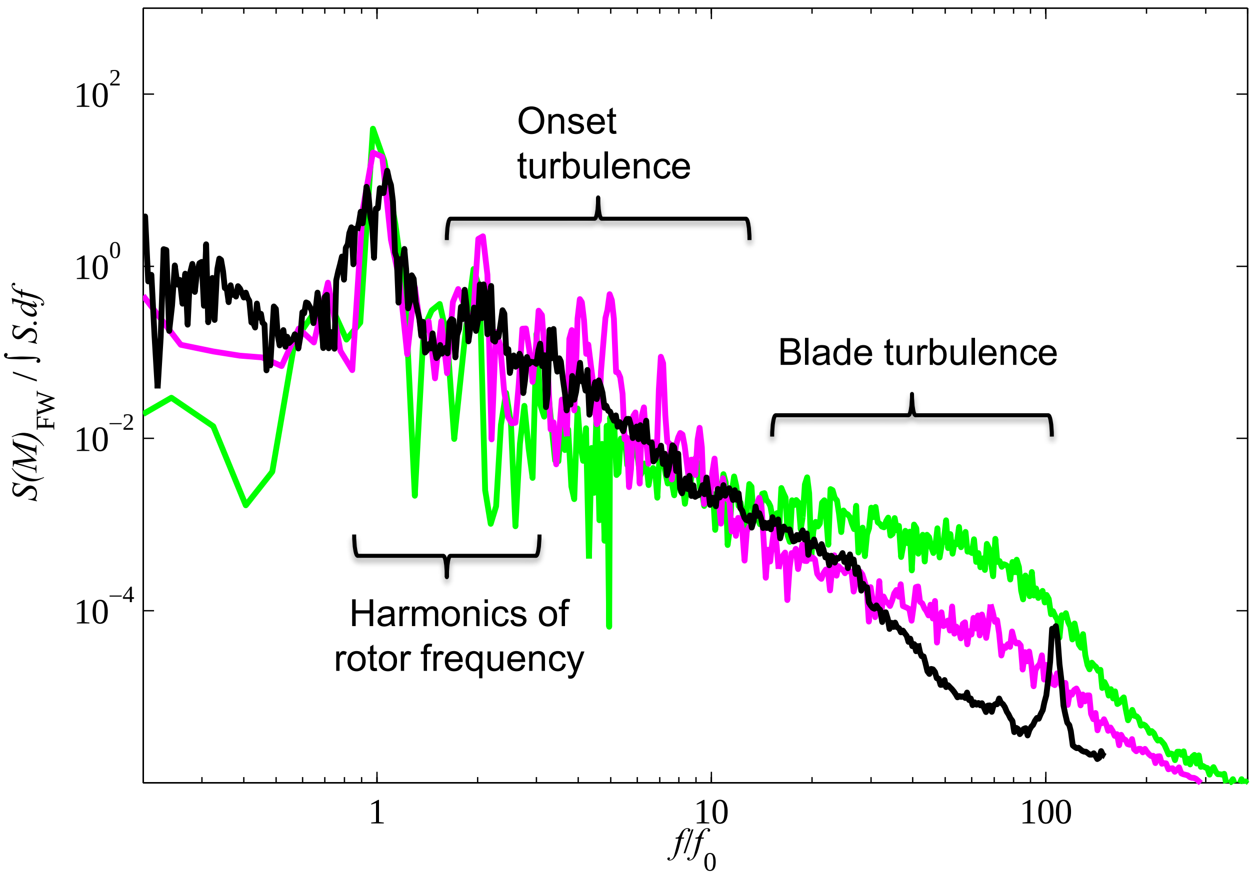
1 MW Turbine

Case 1: LES only

Case 4: Represents full-scale

Finding: LES with SEM inflow predicts blade root bending moment affecting fatigue design.

Normalised to unit area – comparison of trend not magnitude



1 MW Turbine

Case 1: LES only

Case 4: Represents full-scale

Reasonable agreement of LES ***with inflow turbulence by SEM*** to 1 MW data

MD1 Aim: To establish capability of CFD for unsteady load prediction in realistic flows.

Achieved:

1. **Developed and evaluated** blade-resolved RANS and LES simulations of a lab-scale rotor and a 1 MW turbine.

2. **Represented full-scale measurements** of profiles of velocity and length-scales and Reynolds stresses at inlet for operating speeds.

3. **Assessed influence of inflow turbulence on blade loads**

4. **Assessed alternative CFD turbulence models** for blade load prediction:
   - RANS k-ω SST and LES each without onset turbulence
   - LES with onset turbulence by Synthetic Eddy Method
   - Load measurements from full-scale 1 MW turbine

Lessons and Next Steps

Established capability of presently available CFD methods for ***design optimisation of turbines in realistic flow***.

- In low onset turbulence, LES and RANS (k-w SST) produce similar:
  - phase-averaged loads
  - low-frequency fluctuations, due to support tower and velocity shear

- Turbulence has a small effect on mean power

- LES necessary to predict high-frequency fluctuations due to blade-generated turbulence

- SEM provides a basis for representing measured flow

- Need a realistic turbulence representation at inlet to predict load spectrum over full range of frequencies.

Publications

- Afgan, I, Rolfo, S., Apsley, D.D., Stallard, T and Stansby, P.K. 2014. A Simple Sliding-Mesh Interface Procedure and its Application to the CFD Simulation of a Tidal-Stream Turbine. **Int. J. Num. Meth. Fluids** 74 (4) 250-269.

- Afgan, I, McNaughton, J, Rolfo, S., Apsley, D.D., Stallard, T and Stansby, 2013. P.K.Turbulent flow and loading on a tidal stream turbine by LES and RANS. ***Int. J. Heat and Fluid Flow*** 43, pp 96-108.

- Ahmed, U., Afgan, I., Apsley, D., Stallard, T., Stansby. P.K. CFD Simulations of a Full-Scale Tidal Turbine: Comparison of LES and RANS with Field Data. **Proc. 11th EWTEC**, 7-10 Sep 2015, Nantes, France.

- McNaughton, J., Rolfo, S., Apsley, D., Stallard, T., Stansby, P.K. 2013 CFD power and load prediction on a 1MW tidal stream turbine with typical velocity profiles from the EMEC test site. ***Proc. 10th EWTEC***. 2-5 Sep 2013, Aalborg, Denmark.

- McNaughton, J., Rolfo, S., Apsley, D.A., Stansby, P.K. and Stallard, T. Comparison of three turbulence models for RANS modeling of Tidal Stream Turbine loading and wake. In **Proc. 1st AWTEC**, Oct 2012.