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Numerical Investigation of the Near Wake Velocity of Floating Wind Turbine Using Free-wake Vortex Model

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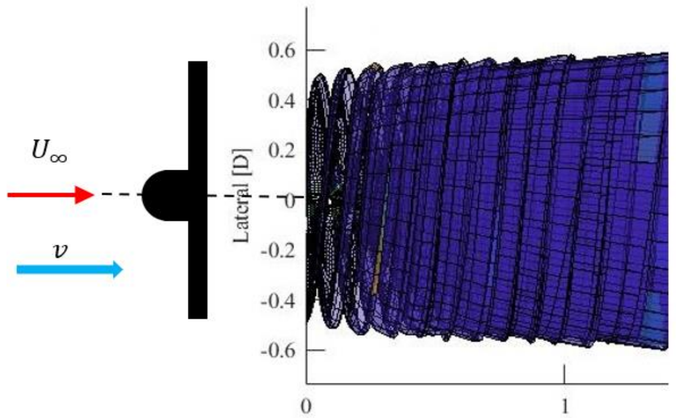
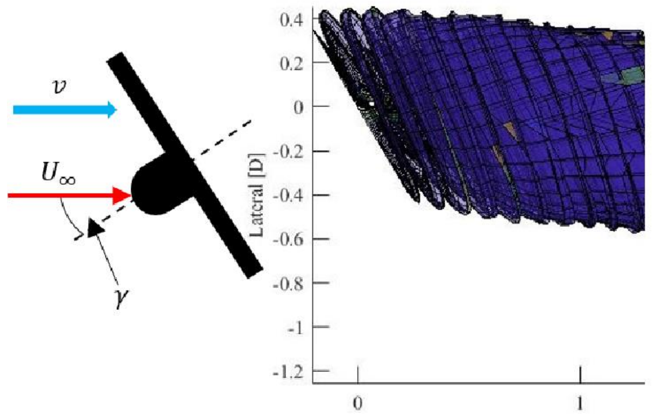
Introduction

- Motivation
  - Lack of literature associated with the near wake characteristics of floating wind turbines under axial and yawed conditions
- Research Objective
  - To utilise the Free Vortex Wake (FVW) method to investigate the near wake of offshore floating wind turbines under both axial and yawed rotor conditions
    - Near wake was considered up to twice the rotor diameter (D) downstream
    - Yaw angle (γ) of 30° , floating conditions were limited to sinusoidal surge motion
- Method utilized
  - Free Vortex Wake (FVW) Method: Wake Induced Dynamic Simulator (WInDS) (UMASS, *Sebastian et al, 2012*)



Axial



Yawed

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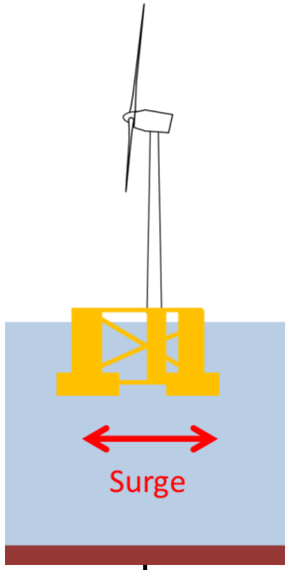
Approach

- Modelled Wind Turbine
  - NREL 5 MW wind turbine: rotor diameter 126 m and hub height 90 m
- Operating Conditions
  1. Fixed and axial (baseline study)
  2. Fixed and yawed
  3. Surging and axial
  4. Surging and yawed
- To observe the effect of the rotor position, the last three operating conditions were studied under four different blade azimuthal angles ψ = 0°, 90°, 180° and 270°
- Parameters
  - Freestream velocity for all conditions acted in the direction perpendicular to an axial rotor
  - Freestream velocity fixed with time, no wind shear
  - Floating case - Wave surging frequency equal to frequency of rotor
  - Floating case – sinusoidal surge motion prescribed as a function of time

Freestream Velocity (U_∞) (m/s)	Tip Speed Ratio	Ramsamy- Leishman Constant (a_1)	Wake expanding downstream
11.4	7.55	6.5x10^{-4}	7 D
Sea Wave Parameters			
Wave Amplitude, A (m)		Wave Frequency, f (Hz)	
1.2		0.22	



Free-wake vortex model

Generate flow field in near wake

Analyse Windward velocities in the near wake

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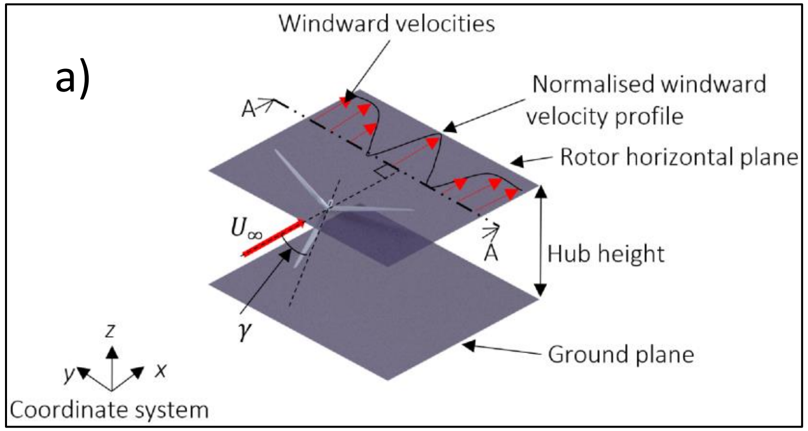
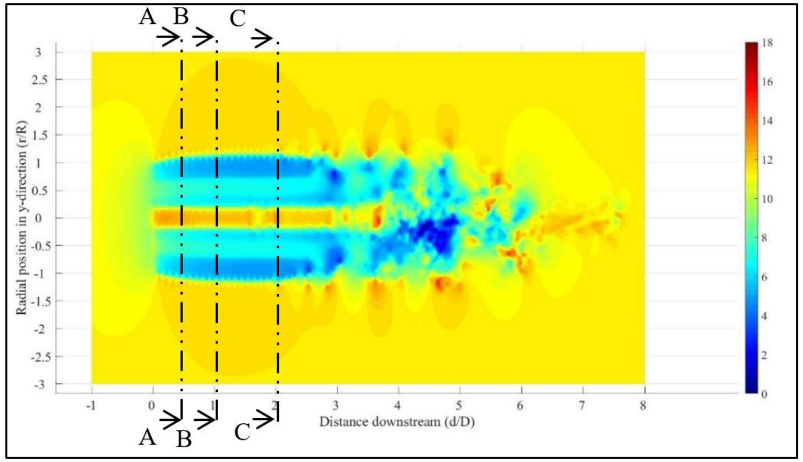
- Near Wake Analysis
  - Windward velocities (v): the wake component parallel to the freestream velocity
  - On a horizontal plane, parallel to the ground at rotor hub height (Figure a)
  - Contour plot of the windward velocities on the horizontal plane (Figure b)
  - Windward velocities analysis at:
    - A. 0.5 D
    - B. 1 D
    - C. 2 D
  - Normalised windward velocities (v/U_∞) were calculated and plotted with respect to the radial position
    - windward velocity profiles
- Percentage Deviation (ε_v)
  - The ratio between the last three operating conditions, independently, to the baseline study with the respective radial position and distance downstream
  - $\varepsilon_v|_{\text{operating condition}} = \left(\frac{v_{\text{operating condition}} - v_{\text{bsl}}}{v_{\text{bsl}}} \times 100\right)_{x\text{D}}$
  - Positive percentage deviation
    - windward velocities at the last three operating conditions are faster than the baseline study





b)

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Results

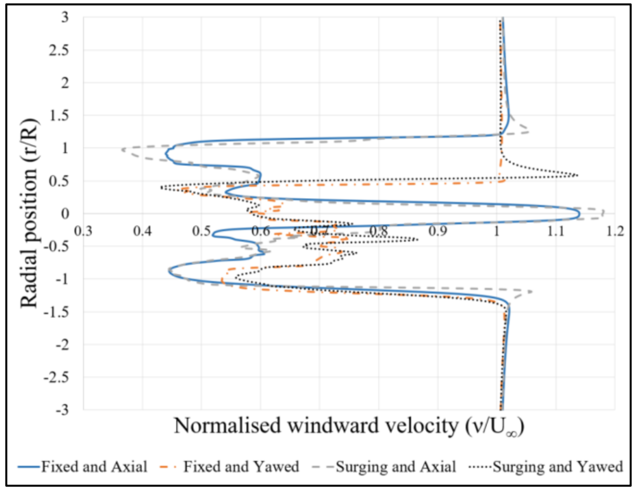
○ Windward Velocity Profiles

- ○ In all the operating conditions the wake centre is at a greater velocity than the free stream velocity in the near wake at 0.5 D downstream. This is partly because the presence of the rotor hub not being modelled.
- ○ For the last three operating conditions the windward velocity profile is effected by the blade azimuthal angle.
- ○ Yawed, surging and combination of both led to asymmetric profiles as one side was slower than the other.
- ○ Yawed conditions tend to lead to disturbed wake centre further downstream in the near wake while shifting the wake away from the wind turbine centre (Figure a).

○ Percentage Deviation

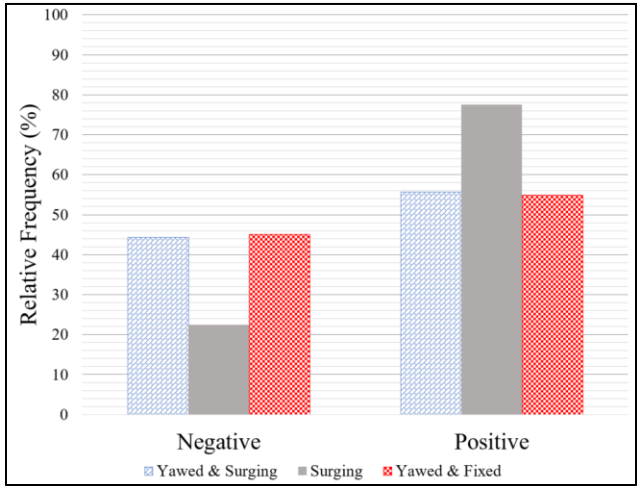
- ○ Greater number of points resulted to have a positive deviation in the near wake at 0.5 D, contrary to what was observed at 1 D and 2 D (Figures b and c). This shows that near wake flow is in general slower for yawed, surging and a combination of both conditions than for fixed and axial condition.

a)



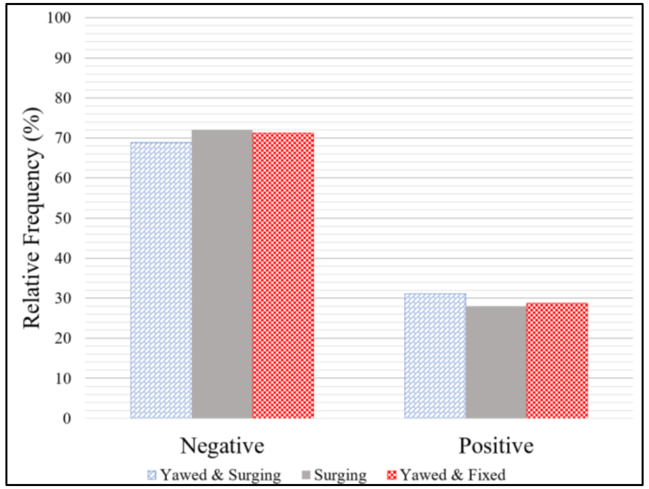
At 2 D downstream and ψ of 0°

b)



At 0.5 D downstream and ψ of 0°

c)



At 2 D downstream and ψ of 0°