Enhanced Wake-Mixing with Floating Offshore Wind Turbines.

- Controls Co-Design of Offshore Floating Turbines for Wake-Mixing.

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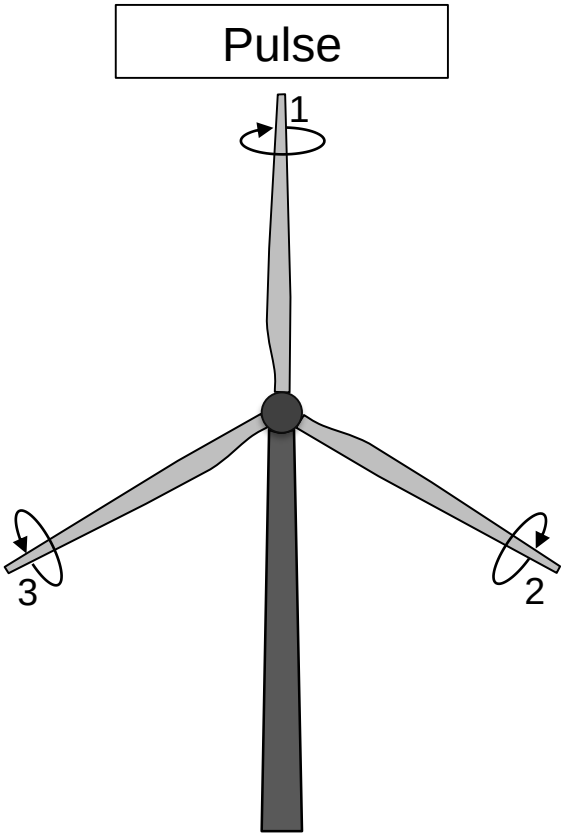

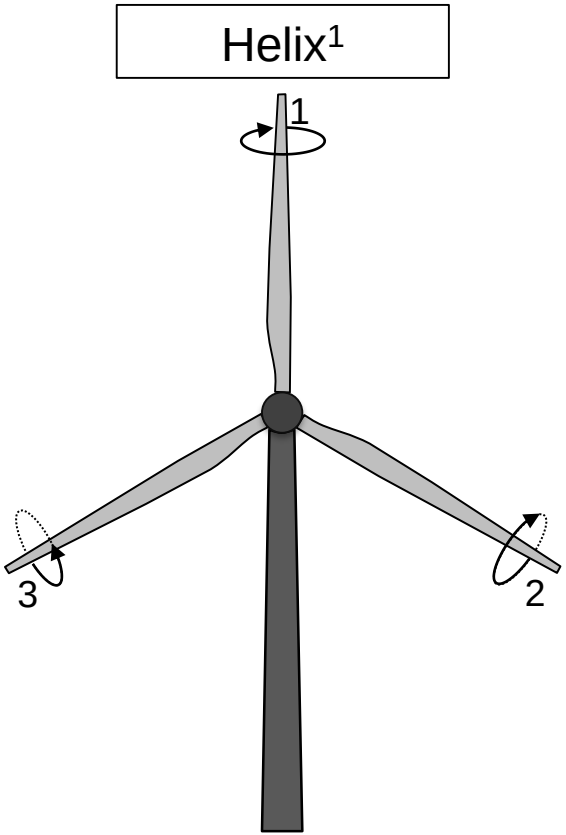

[1]Frederik, Joeri A., et al. "The helix approach: Using dynamic individual pitch control to enhance wake mixing in wind farms." *Wind Energy* 23.8 (2020): 1739-1751.

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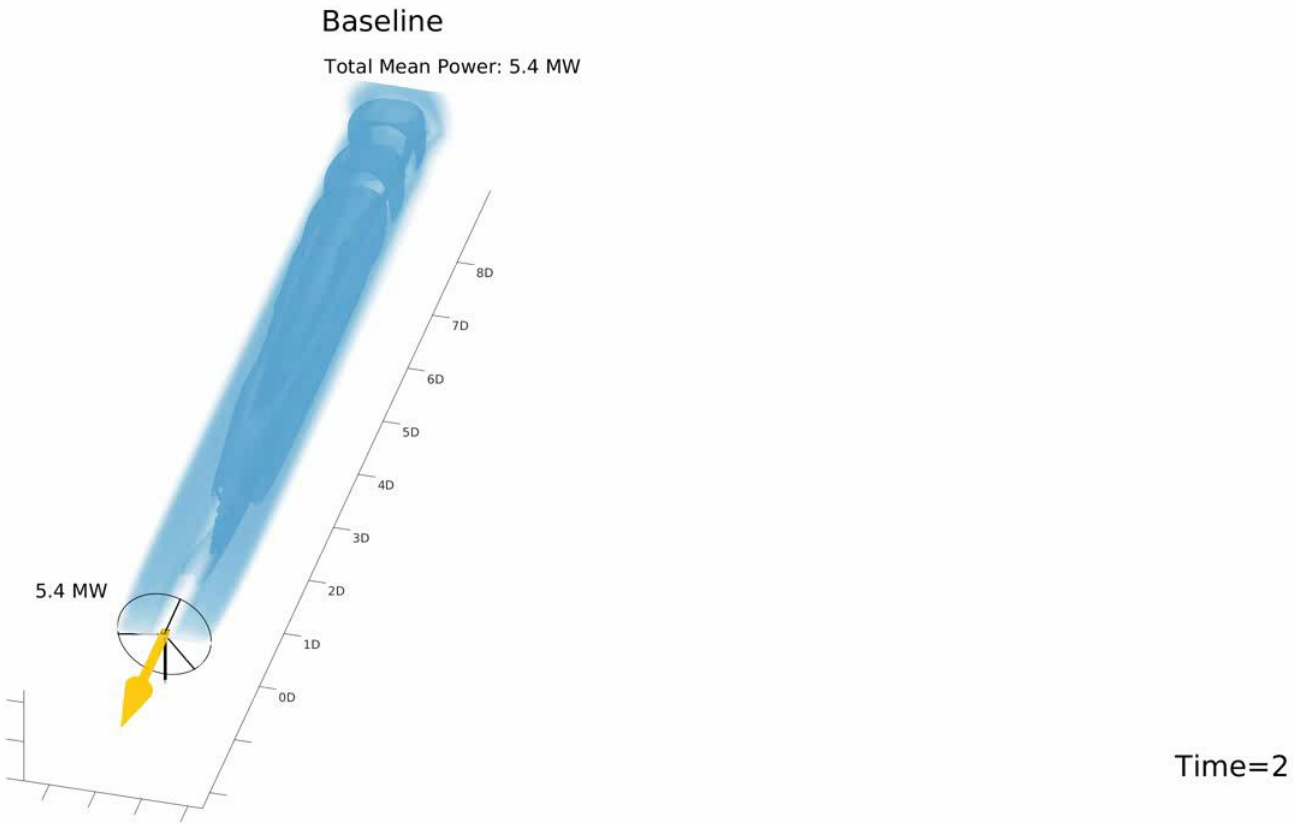

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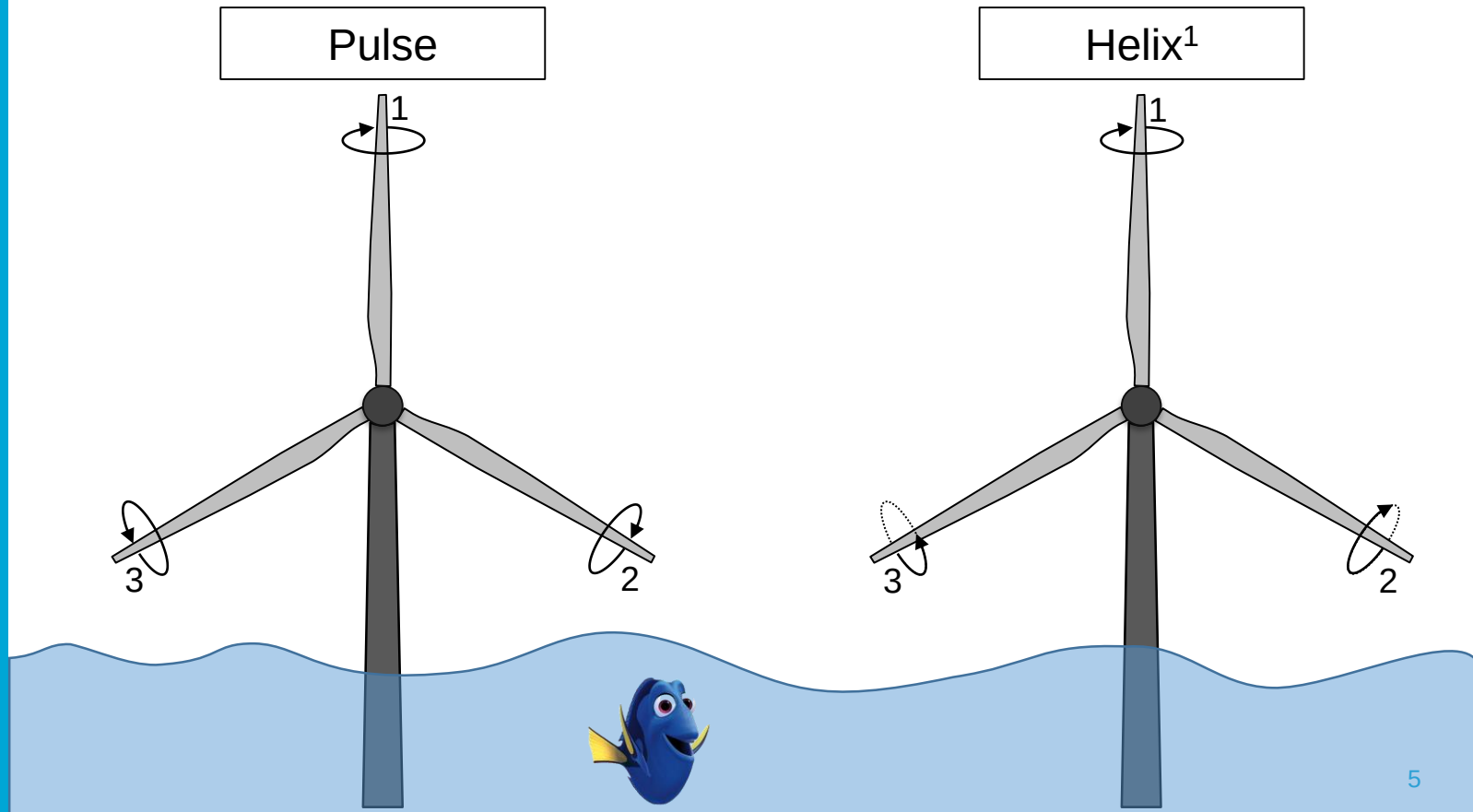

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FOWT Motions – Bode Plots

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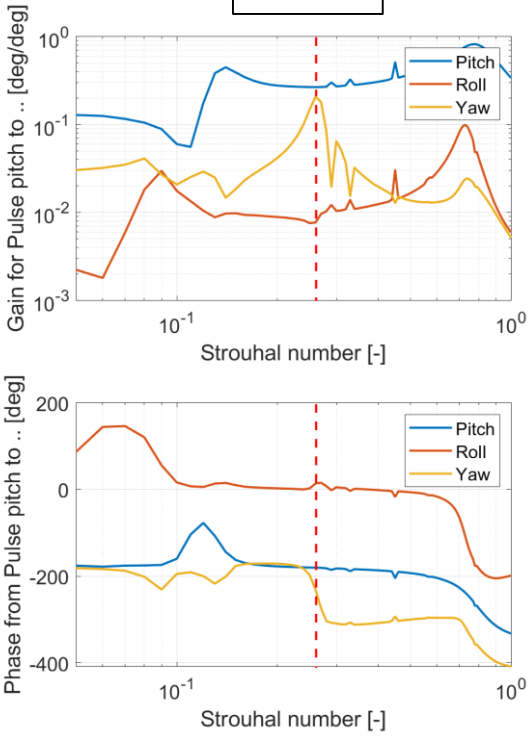
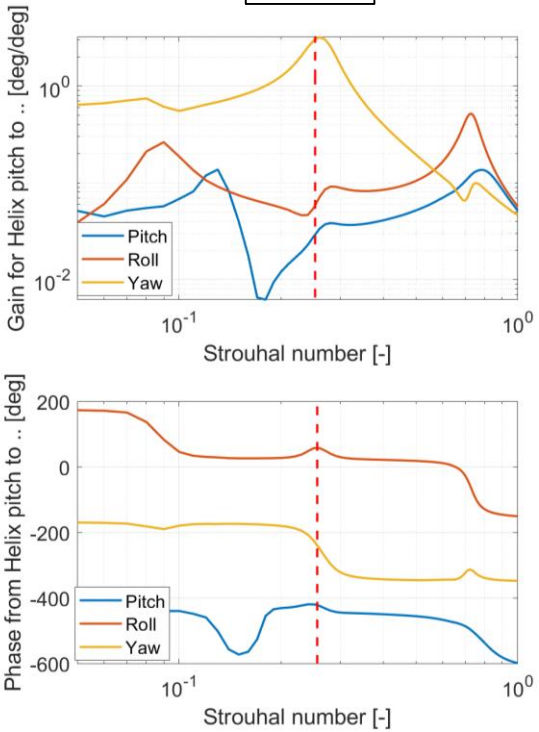
Pulse



Helix



The red dotted line indicates $St = 0.25$, experimentally found to be the ideal mixing frequency for DIC[2].

[2]Wim Munters and Johan Meyers. "Effect of wind turbine response time on optimal dynamic induction control of wind farms". In:Journal of Physics: Conference Series753 (Oct. 2016).doi:10.1088/1742-6596/753/5/052007

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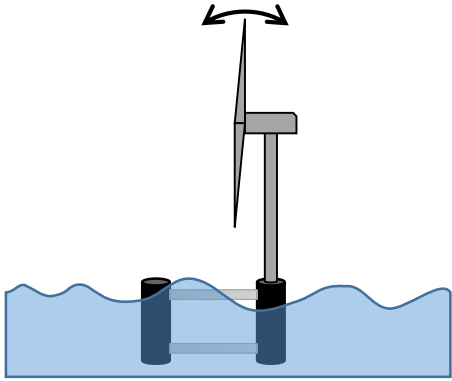
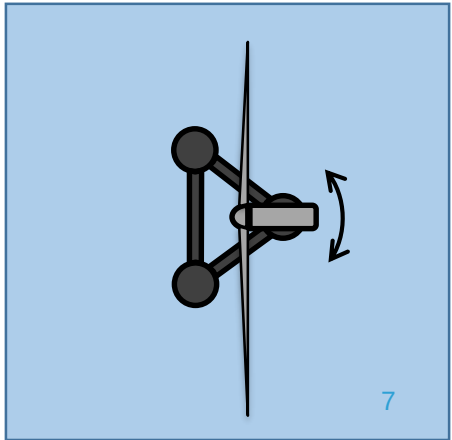
Case Study:

- Several Different scenarios compared based on Bode plot findings.
- DTU 10MW on the Triplespar[3] platform with subscribed motion.
  - Pulse with Qblade:
    - 2 Degree blade pitch, no platform movement.
    - 4 Degree blade pitch, no platform movement.
    - 2 Degree blade pitch, 1 degree platform movement.



  - Helix with SOWFA:
    - 4 Degree blade pitch, no platform movement.
    - 2 Degree blade pitch, 6 degree platform movement.



[3]Lemmer, Frank. "Low-order modeling, controller design and optimization of floating offshore wind turbines." (2018).

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Case Study – Pulse Results – 5D

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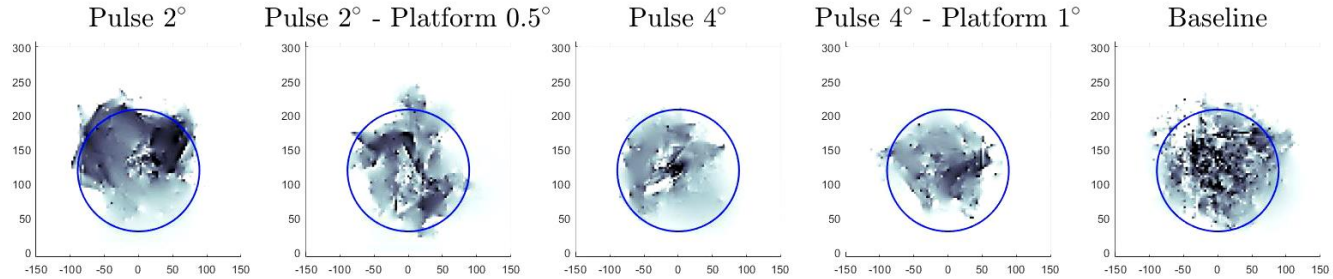

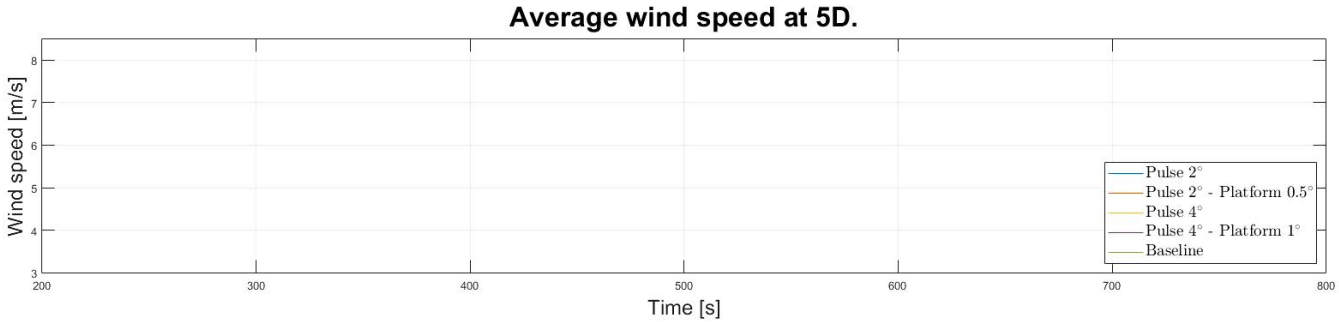

	Baseline	- 2 Degree Pitch - No Platform	- 2 Degree Pitch - 0,5 Degree Platform	- 4 Degree Pitch - No Platform	- 4 Degree Pitch - 1 Degree Platform
Avg Wind [m/s]	5.49 (-)	5.94 (+8.2%)	6.29 (+14.5%)	6.24 (+13.5%)	6.67 (+21.5%)

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Case Study – Helix Results

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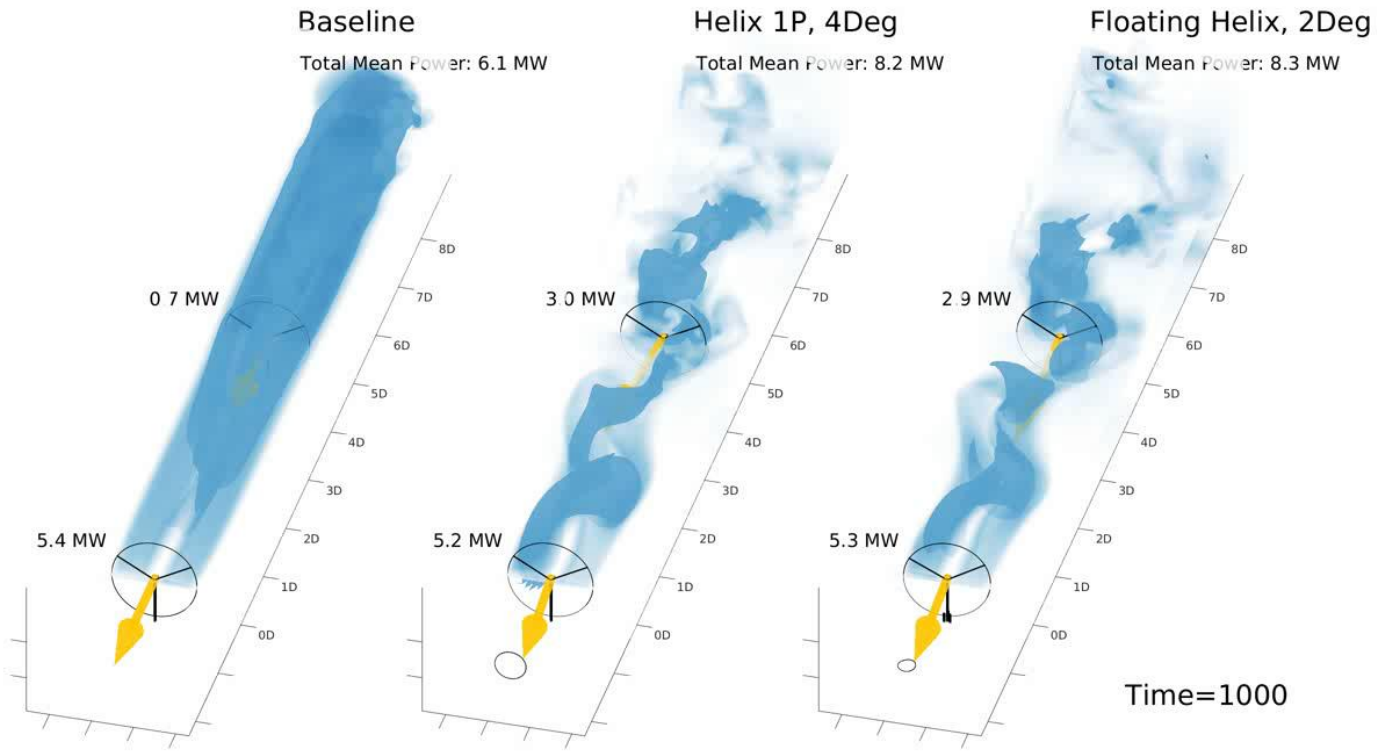

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Conclusion

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- Both Pulse and Helix looks promising.
- Amplification of motion mainly dependent on platform parameters.
- Ideal mixing frequency unknown.
- Implication on FOWT loads?

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Scientific Prospects – Co Design

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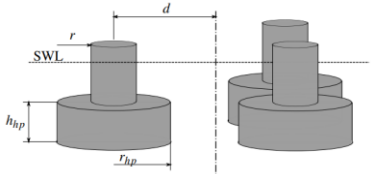
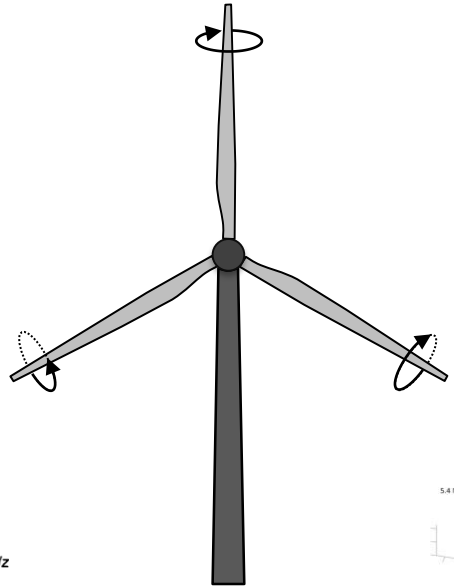
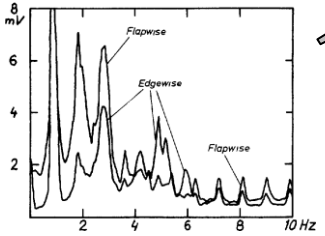
Platform Design[4]

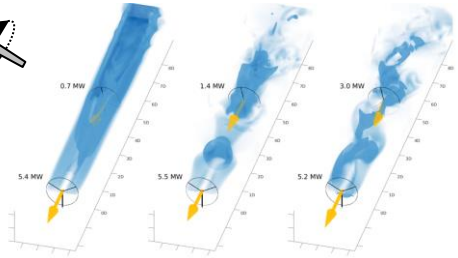




Load Minimization[5]



Wake Mixing



[4]Lemmer, Frank, et al. "Optimization of floating offshore wind turbine platforms with a self-tuning controller." *International Conference on Offshore Mechanics and Arctic Engineering*. Vol. 57786. American Society of Mechanical Engineers, 2017.

[5]Pedersent, T.F., 1986. Wind Turbine Test wind Matic WM15S. *Work*, *20130325*(892), p.20130325T171011.

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FOWT Motions – Pulse

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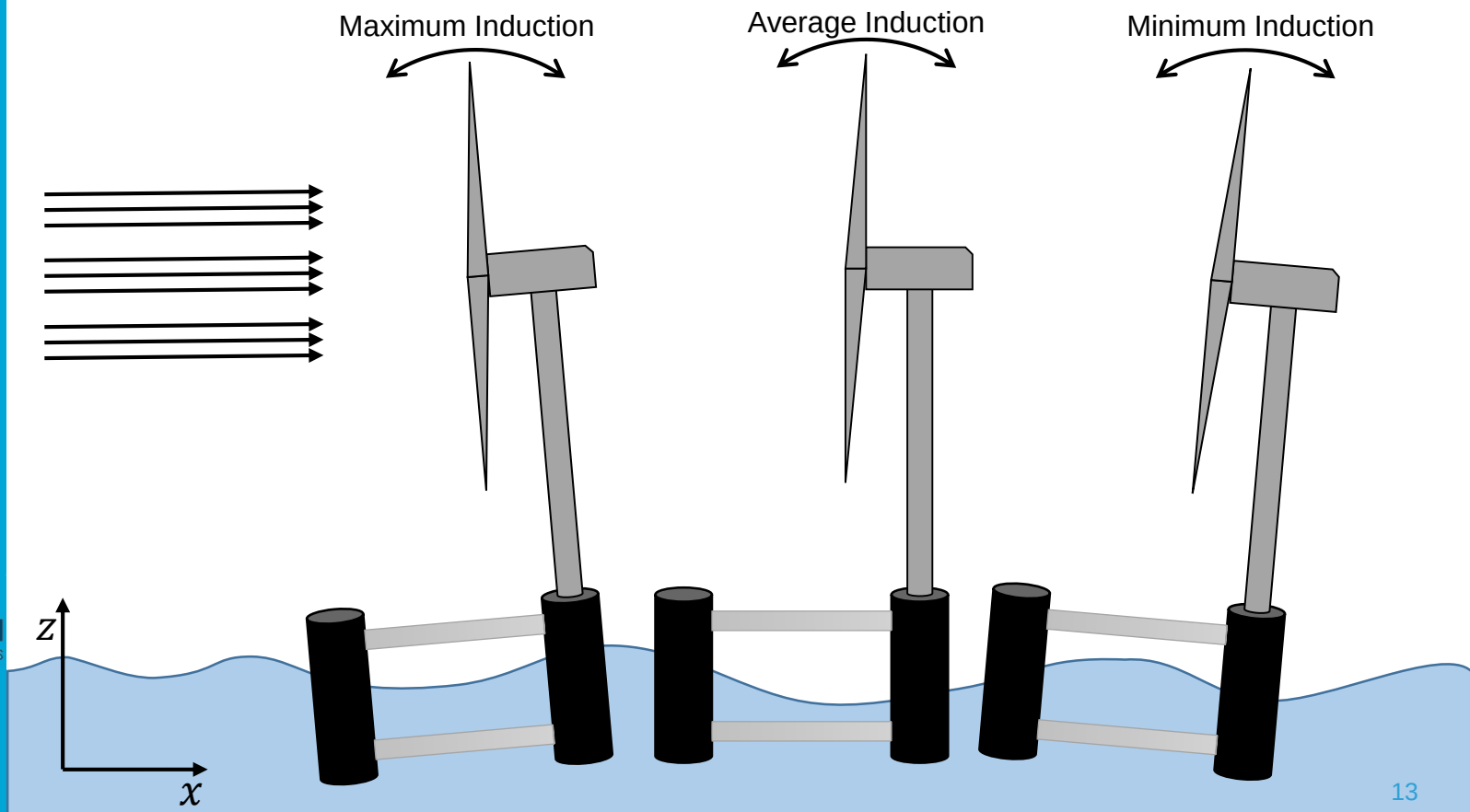

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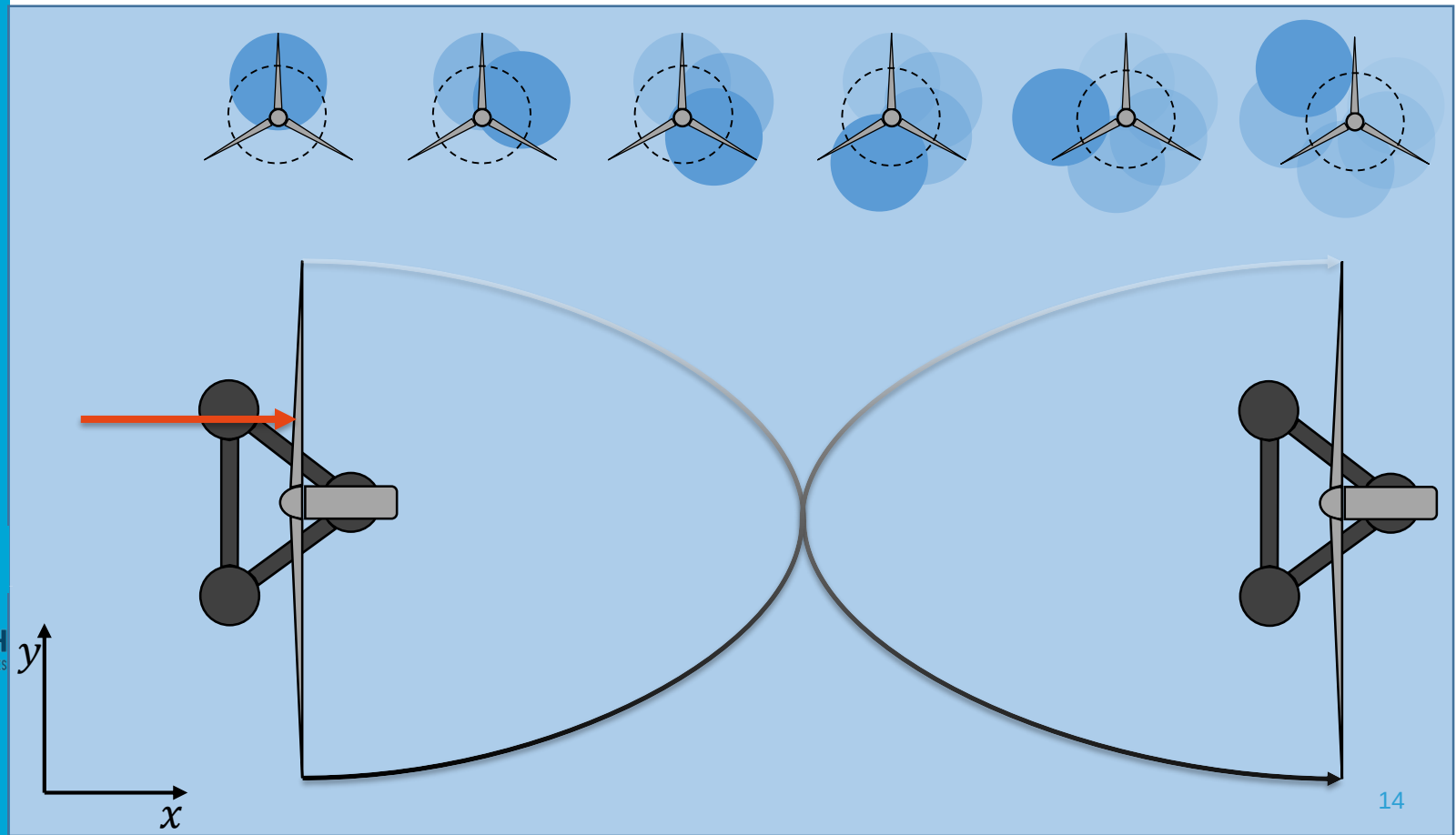

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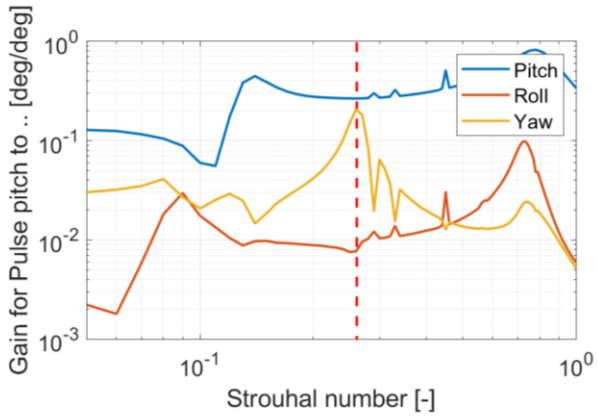
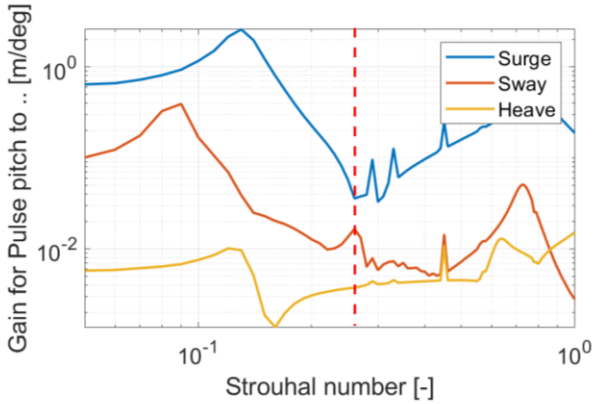
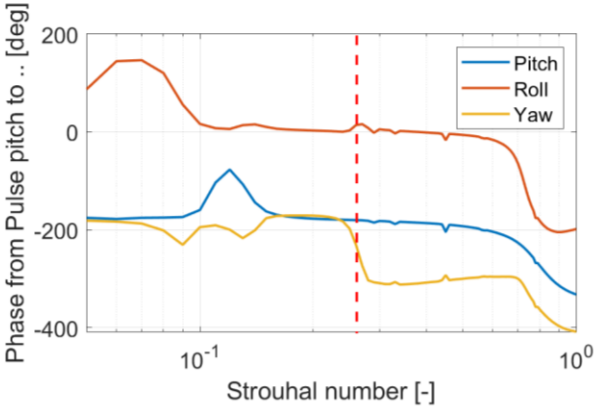
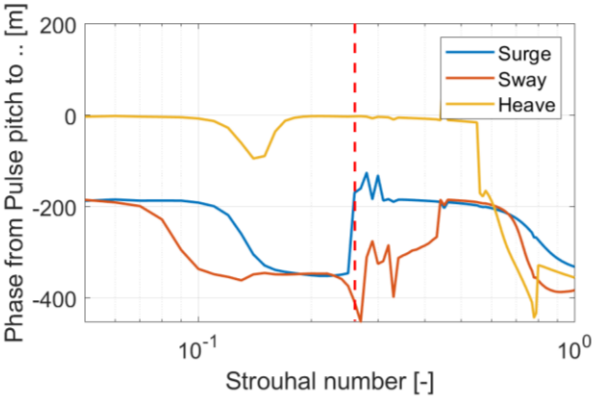
FOWT Motions – Pulse Bode Plots

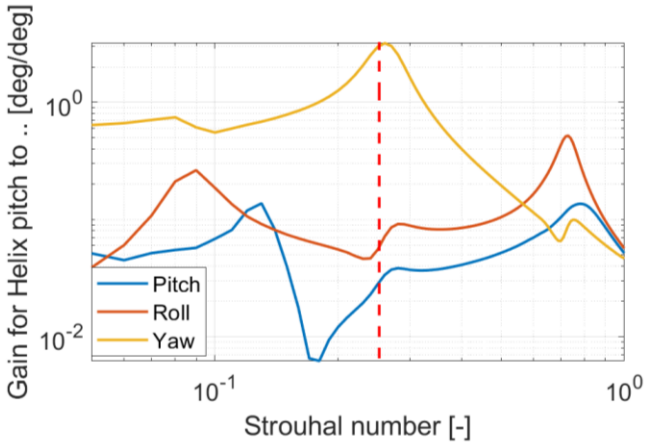


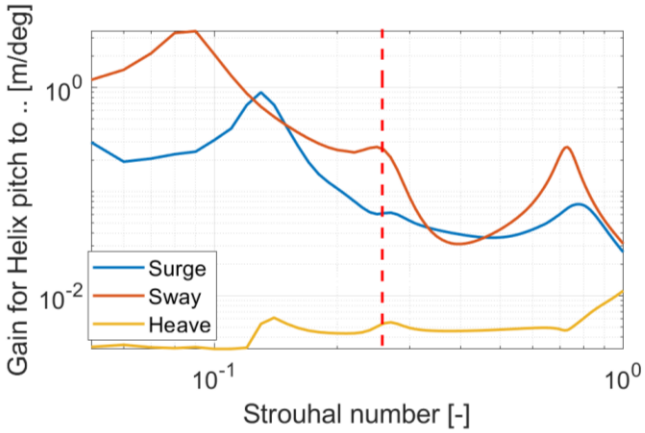


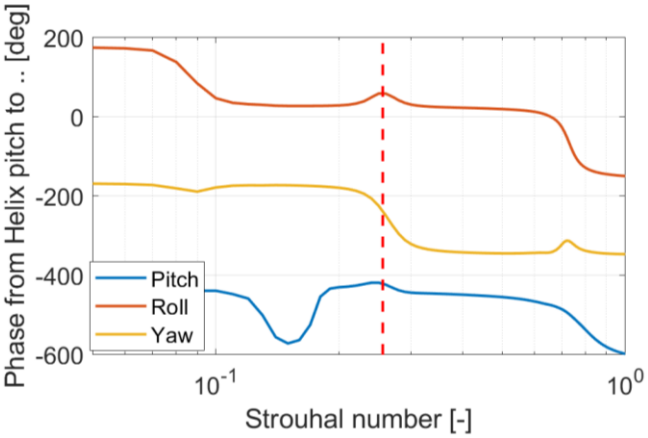


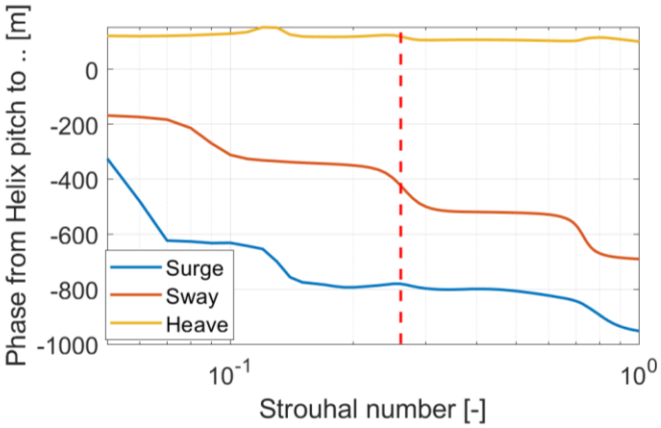


FOWT Motions – Helix Bode Plots









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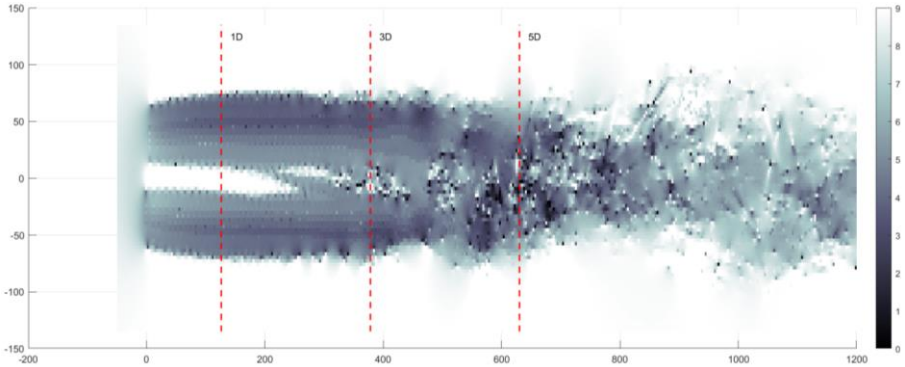
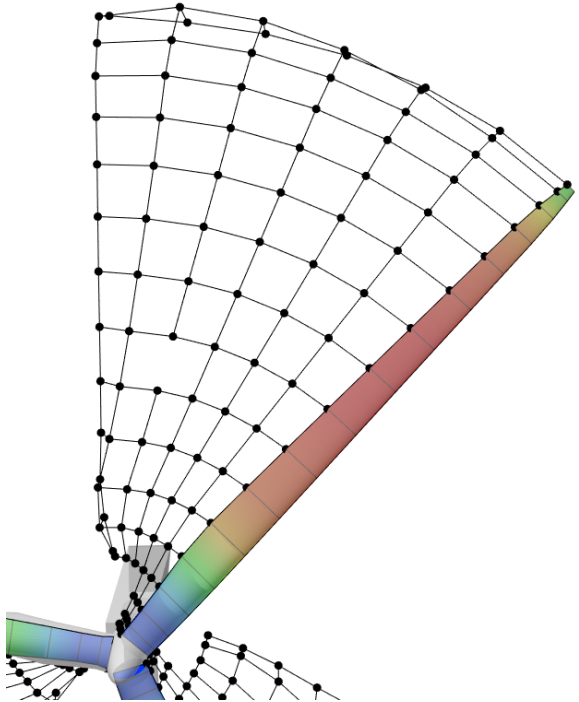
Case Study - Qblade

- Free Vortex Wake Method.
- Solve Lagrangian Marker movement.
  - $\frac{d\boldsymbol{r}}{dt} = V_\infty + V_{ind} + V_{rmb}$
  - V_∞ is freestream velocity
  - V_{ind} is Vortex interaction by Biot-Savart law.
  - V_{rmb} is Velocity changes due to rigid body motion.
- Computationally more efficient method [1].
- Prone to numerical instability for longer wakes [2].





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[1] Shaler, Kelsey, et al. "Preliminary Introduction of a Free Vortex Wake Method Into OpenFAST." *Journal of Physics: Conference Series*. Vol. 1452. No. 1. IOP Publishing, 2020.
[2] S. Gupta and J. G. Leishman. Free-vortex filament methods for the analysis of helicopter rotor wakes. Journal of Aircraft, 39(5):759–775, 2002.