Mitigation of Loads on Floating Offshore Wind Turbines through Advanced Control Strategies

Research Student: Dawn Ward Main Supervisor: Maurizio Collu Co Supervisor: Ali Mehmanparast

Main Issues for FOWTs

Motion: 'negative damping' which causes increased fatigue loads, especially on the tower, due to combined wave and wind loading which therefore reduced lifespan

Environment: complexity of installation, inspection and maintenance depending upon type

Cost: new technology with a requirement to be competitive long-term for both initial CAPEX and for LCOE

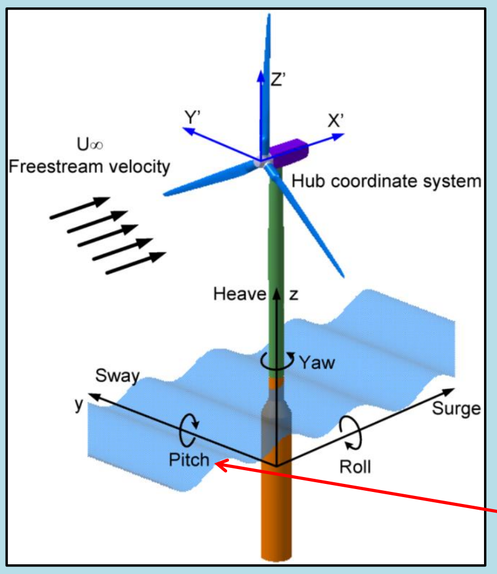
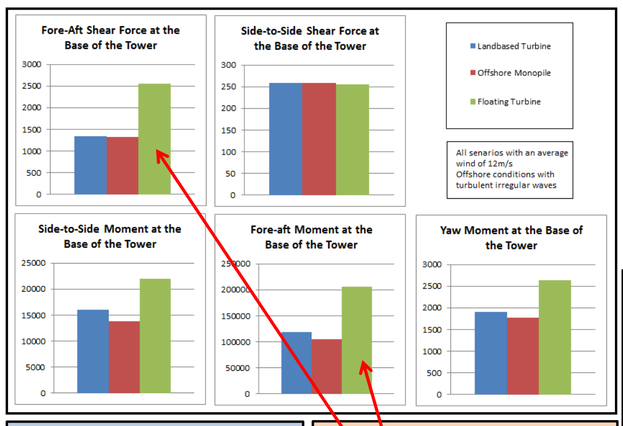


Figure 1. Support Platform Modes of Motion [1]



Reducing the platform pitch motion will reduce the tower fore-aft force and moments at the tower base.

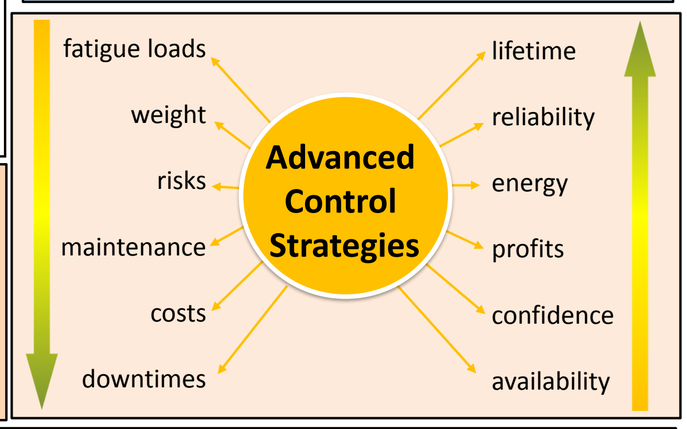
Increased tower fore-aft force and moment causes largest increase in fatigue loads on the tower of a FOWT

Why FOWTs

Sites with unsuitable sea bed conditions

Greater water depths

Shoreline assembly and maintenance



Main Approach

- Analyse and verify a model of a floating semisubmersible platform in FAST
- Validate against open source simulation results for National Renewable Energy Laboratory (NREL), Instituto Superior Tecnico (IST) and Goldwind. from the Offshore Code Comparison (OC4) Phase II
- Turbine based on the NREL 5MW offshore baseline turbine within FAST code
- Semisubmersible floating platform based on platform used for DeepCWind scaled experimental tests.
- Modify model of turbine blades to make active stall simulation possible
- Define and design control regimes and simulation systems.
- Run tests under different control and environmental conditions and compare and analysis changes in loads due to varying strategies.

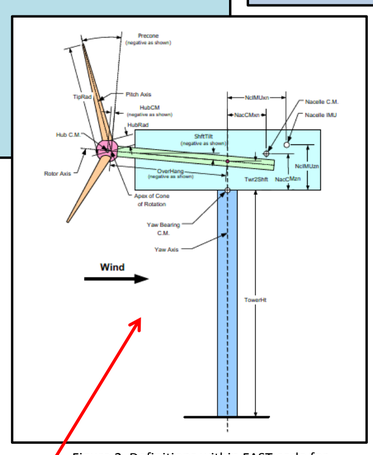


Figure 2. Definitions within FAST code for typical 3 bladed upwind HAWT [2]

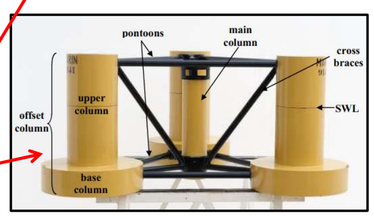


Figure 3. Scaled DeepCWind Semisubmersible as used for OC4 [3]

Project Aim & Objectives

Identify and select a novel advanced control strategy to prevent undesirable loads for chosen FOWT platform type due to platform pitching.

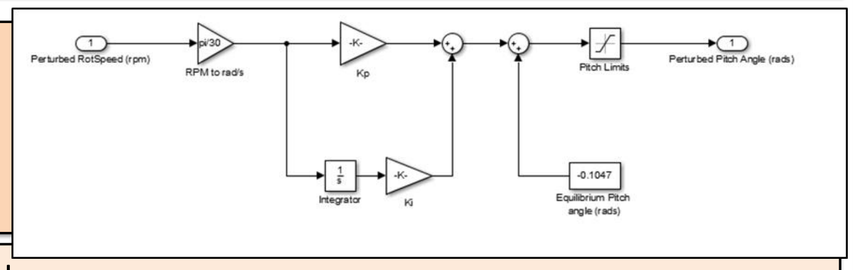
Validate ability to programme chosen simulation packages for fatigue load analysis of the FOWT.

Define and build simulation and control models.

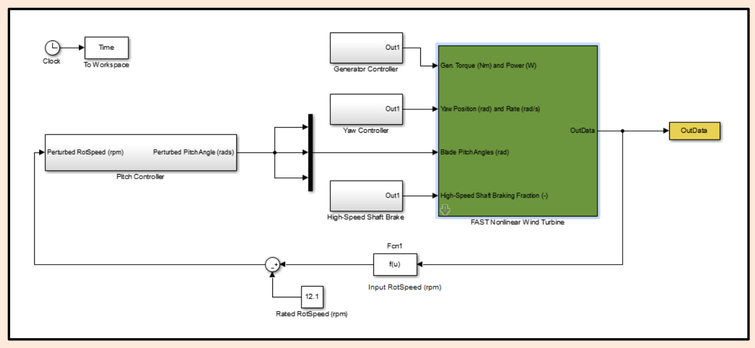
Run simulations under different environmental conditions

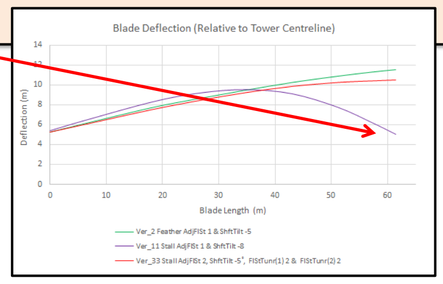
Identify fatigue reduction benefits available from different control strategies.

Pitch to Stall Controller In Simulink



- Blade pitch controller built in Simulink and ran in Matlab utilizing FAST simulation package and specifications
- Blade flapwise stiffness and modal stiffness tuner increased to produce similar deflection seen when operating in Pitch to Feather
- Excessive deflection due to unrealistic stall operating blade profile, prevents simulation runs





Periodic Steady State Curves

- Pitch to stall control provides reduced actuation requirements due to decreased blade angles
- Rotor thrust also is seen to increase at wind speeds above rated.
- The positive slope of the thrust curve could help to avoid negative damping.

Initial Observations of Stall Controller

- Smoother power generation and reduce blade pitch actuation
- Tower fore-aft moment experiences higher loading but cyclical variance is not greatly increased
- A realistic stall designed blade would be preferable but is not an essential element for analysing system changes from control implementation

Next Steps

- Tune pitch to stall controller constant gains. Gain scheduling will then also be implemented.
- Gain understanding of fatigue effects with increased loads but not cyclical variance
- Design, run and analyse other favourable control strategies

References and Literature

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6. B. Skaare et al, *Importance of Control Strategies on Fatigue Life of Floating Wind Turbines*, OMAE 2007-29277.

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