Dynamically positioned floating offshore wind turbines

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Velosco Energy — Commercial focus technically delivered

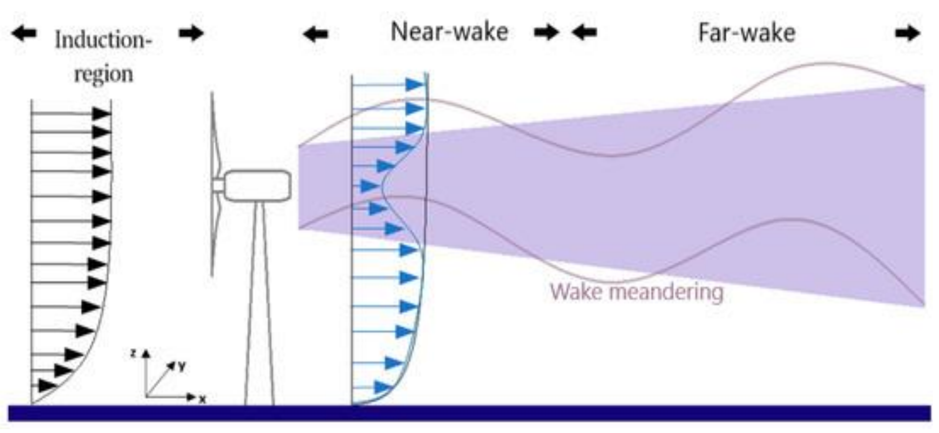
THE UNIVERSITY OF EDINBURGH

Sustainable Energy Systems

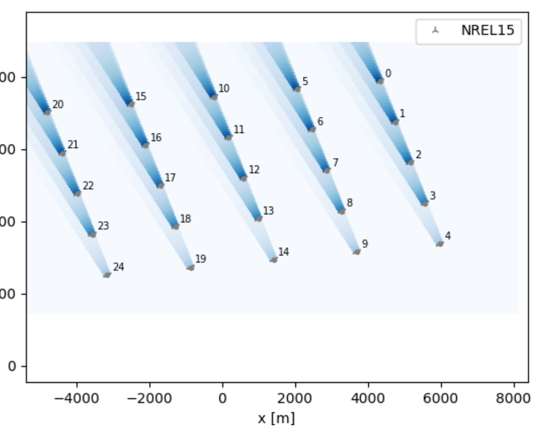
Wake Management

Reducing the effects of wakes to reduce turbulent loads and increase lifespan and energy yield

Turbines disturb air & extract energy, forming wakes that flow downstream.



Alaoui-Sosse et al., 2022



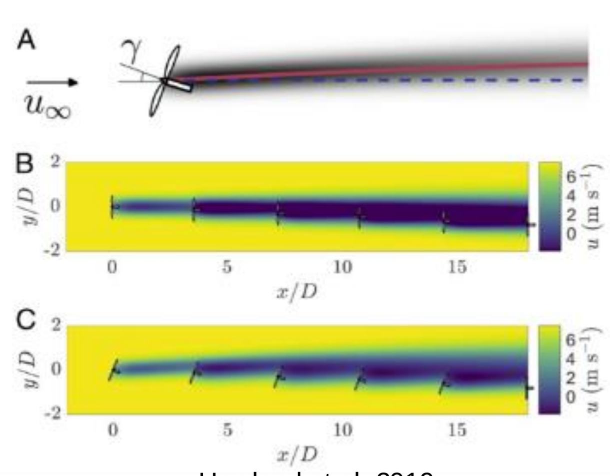
Generated with PyWake

Wakes can
- Increase fatigue loads by 15%[1]
- Reduce turbine lifespans[1]
- Reduce yield by 40%[2]
- Reduce financial viability

Avoiding wakes can be
- Accomplished by siting, array design
- Actively managed by turbines
- 850M USD/year across every 500GW with 1% gain improvement[3]

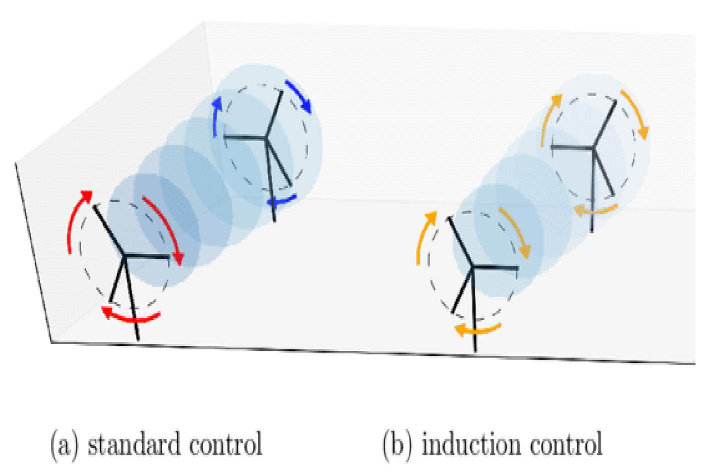
Existing Wake Management Strategies

Wake Steering



Howland et al. 2019

Active Induction Control



Vollmer, 2019

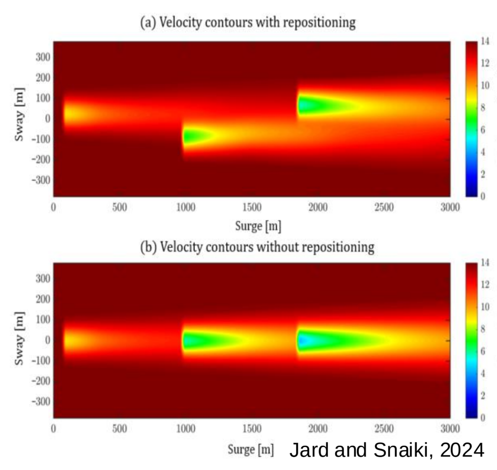
Novel Wake Strategy: Dynamic Positioning

Photo: Ocean Winds

Floating Offshore Wind

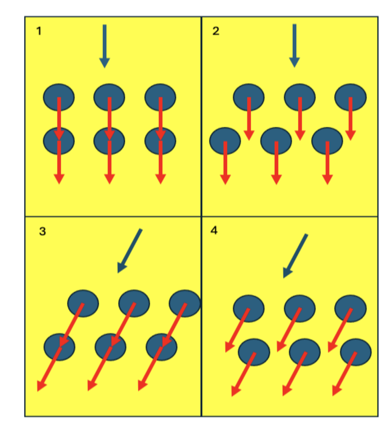
Floating offshore wind platforms represent an unexploited design opportunity, as these turbines can move around on the surface of the ocean. This motion, if controlled, could be used to move turbines out of incoming wakes.

Arrays are initially designed to allow wakes to slip between turbines for the most powerful wind directions – when the wind shifts, a dynamic farm can be repositioned and reoptimized.
(Scan Citation QR for animated example)

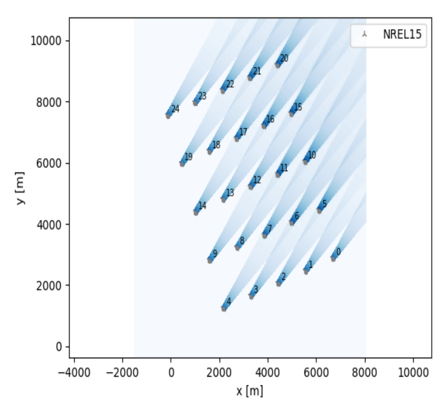


Jard and Snaiki, 2024

CFD proof-of-concept on three-turbine, unoptimized farm[4]



Sequence of dynamic positioning to react to changing wind conditions



Generated with PyWake

Methodology

Dynamic farms are simulated on PyWake, a farm-level wake-deficit modelling Python tool with a simple wind-direction based control algorithm. The annual energy yield of dynamic farms is compared to that of an optimized static farm under the same wind time series data[5]. Dynamic farms are modelled for a variety of wind conditions, motion frequencies, and motion constraints. The CapEx required to create dynamic farms is estimated for each scenario, to determine if dynamic farms are financially viable.

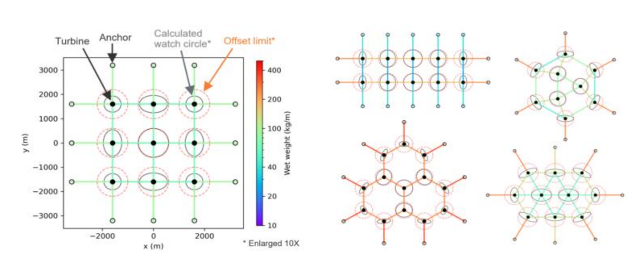
Support Technologies

These technologies are considered when analyzing system CapEx, though not as part of dynamic farm simulation. Accomplishing a dynamically positioned farm would require these or other novel/speculative controls, moorings, and mechanics.

Control Algorithms

- Must be able to move turbines independently
- Must not crash or tangle moorings
- Frequency dependent solutions
- May not be turbine-level optimal
  - Game Theoretic Farm-Level Alg.[6]
  - Forecasts will improve performance

Shared Moorings

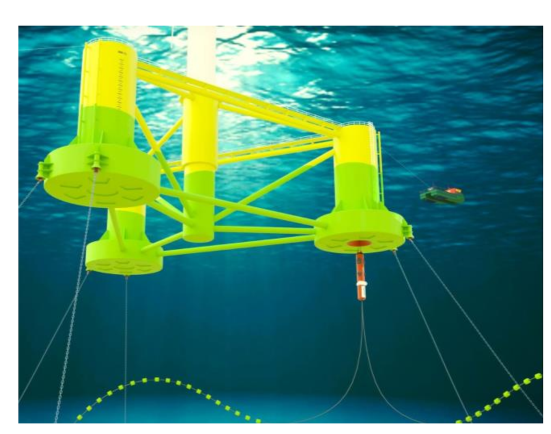


Hall et al. 2022

Winch Systems

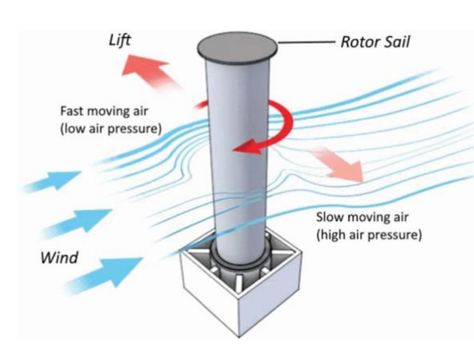
Keppel Limited

Quick Disconnect Moorings



Apollo Engineering

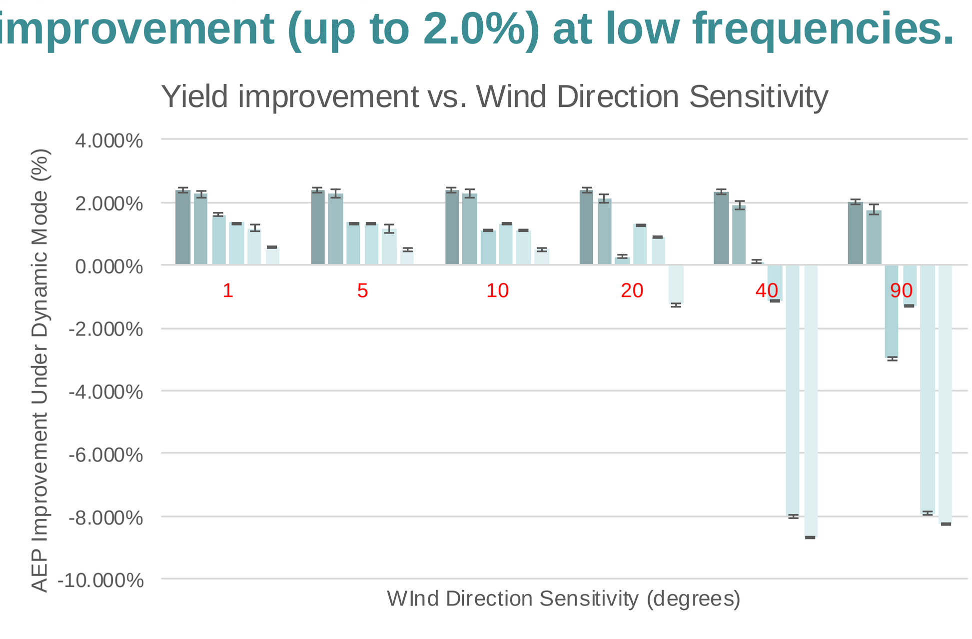
Aerodynamic Locomotion

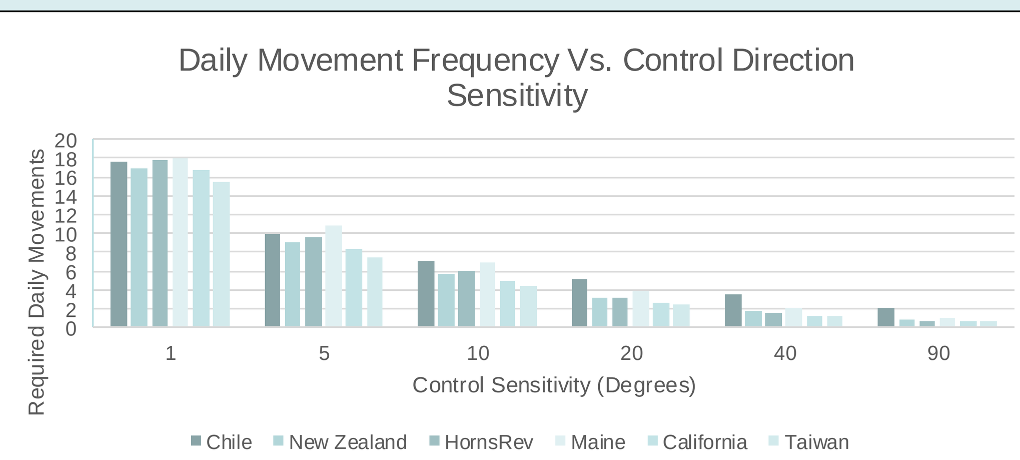


Tay and Konovessis, 2023

Results

Simulations of an abstracted dynamic farms at various sites for a variety of sensitivities to shifting winds show yield gain (up to 2.4%) at high sensitivity. Some sites retain improvement (up to 2.0%) at low frequencies.





Wind direction sensitivity correlates strongly with frequency of turbine motion. Achieving a particular frequency of movement requires certain design and control choices which likely makes dynamic repositioning cost prohibitive, for some or all sites. Very low sensitivity, but high yield sites may exist.

Conclusions

Dynamic repositioning is similarly or more effective than other wake management strategies, but significantly less cost-effective. A cheaper design, better controls, and combining a variety of wake management strategies could increase the viability of a limited version of dynamic positioning.

EYA & CapEx Results

For a 25-turbine farm, in the best cases, the annual yield of dynamic farms is worth about $8M per year, or an NPV of $80M for a 20-year lifespan. CapEx analysis of a simple winched rope design for a dynamic turbine reveals the materials and components cost to upgrade to a winch-based dynamic farm is likely more than $110M, significantly more than the system value.

References & Animations