Design and Validation of a Hybrid Model Testing Setup for Scaled Energy Converters in the NREL Wave Tank

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Hybrid Model Testing at SWEL

Background

- 14 meters long, 2.5 meters wide, 1.3 meters deep

- Flap-type 2D wave generator

  - 0.2 meter amplitude

  - 0.5-5 second periods

- Qualisys optical tracking

- FRM1Q floating platform[1,2]

Photo by Joe DelNero, NREL 70306

Photo by Gregory Cooper, NREL 98911

[1]Wiley et al. (2023) [2] Neary et al. (2014)
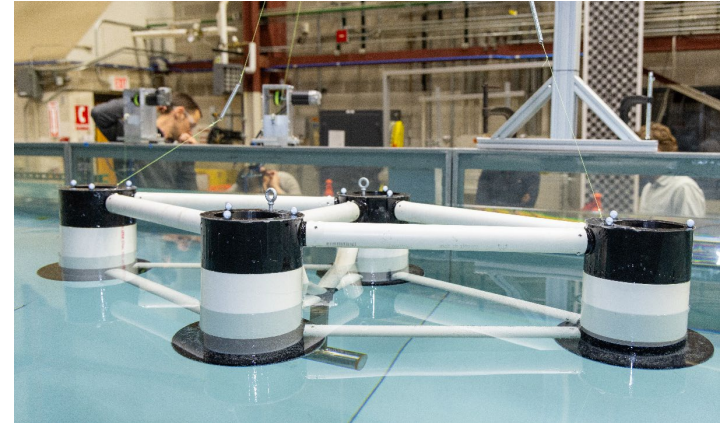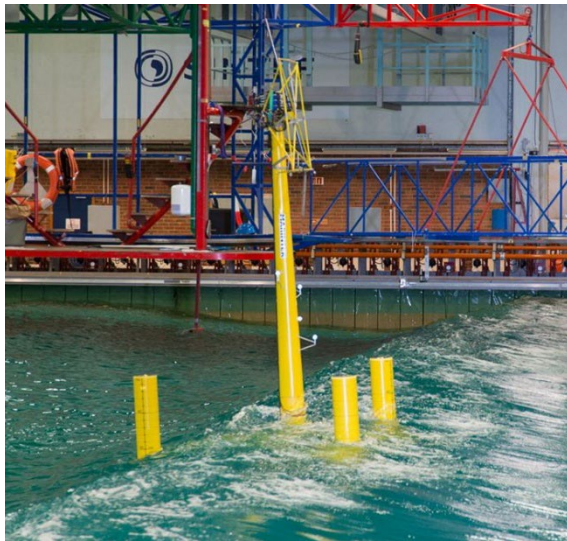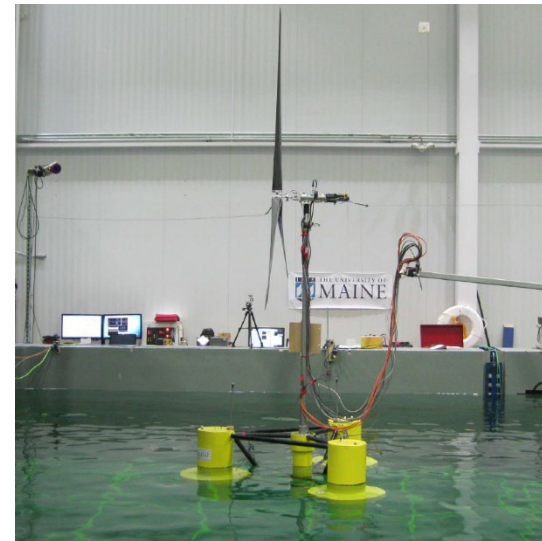
Hybrid Model Testing in Wave Tanks

Real-time hybrid model testing of a floating wind platform for extreme marine environments.

Photo from SINTEF (2016)

Hybrid model test with multi-propeller actuators at UI Hydraulics Wave Basin Facility.
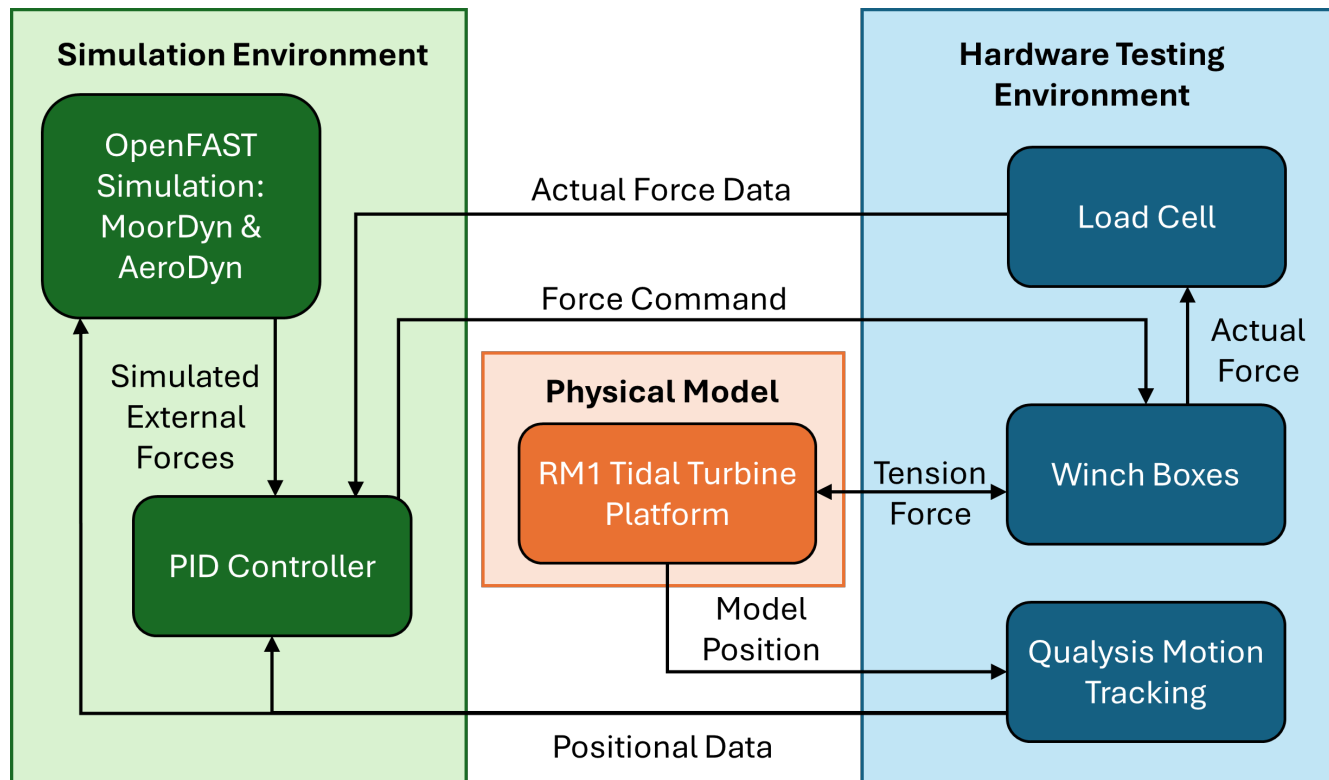
Photo by Senu Sirnivas, NREL

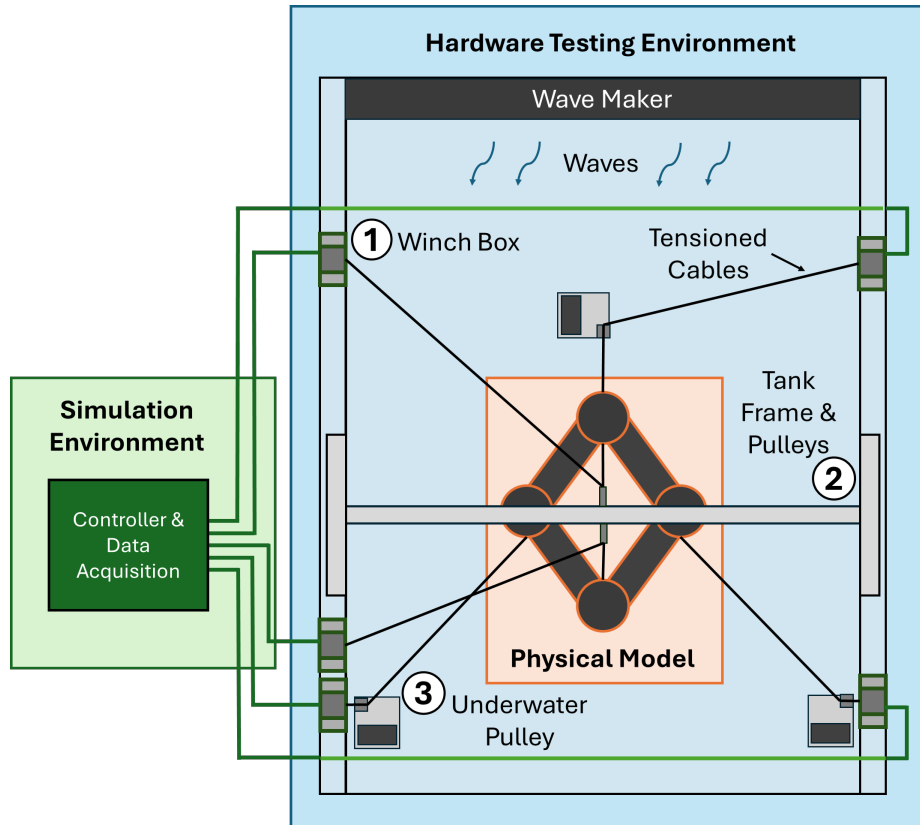DeepCwind semisubmersible in wave basin with cable-based hybrid coupling.
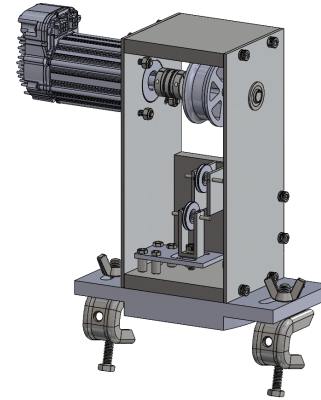
Photo from Hall (2016)

Hybrid Model Test Setup

Physical Hardware
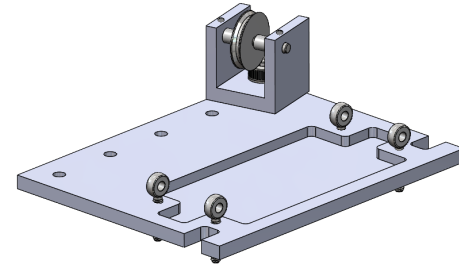
Floating Tidal Turbine

Full Tank Setup

Tank Frame & Pulleys

Scaled Floating Tidal Turbine Platform

Winch Boxes

Controller, Data Acquisition, & Power Supply

Underwater Pulley

Photo by Senu Sirnivas, NREL

Controls Overview

Tension Control	Feedforward Control	Motion Accommodation

- Generates pretension
- Distributes wrench between winches

- Speeds up rise time
- Anticipates the motion required to achieve desired force

- Computes velocity
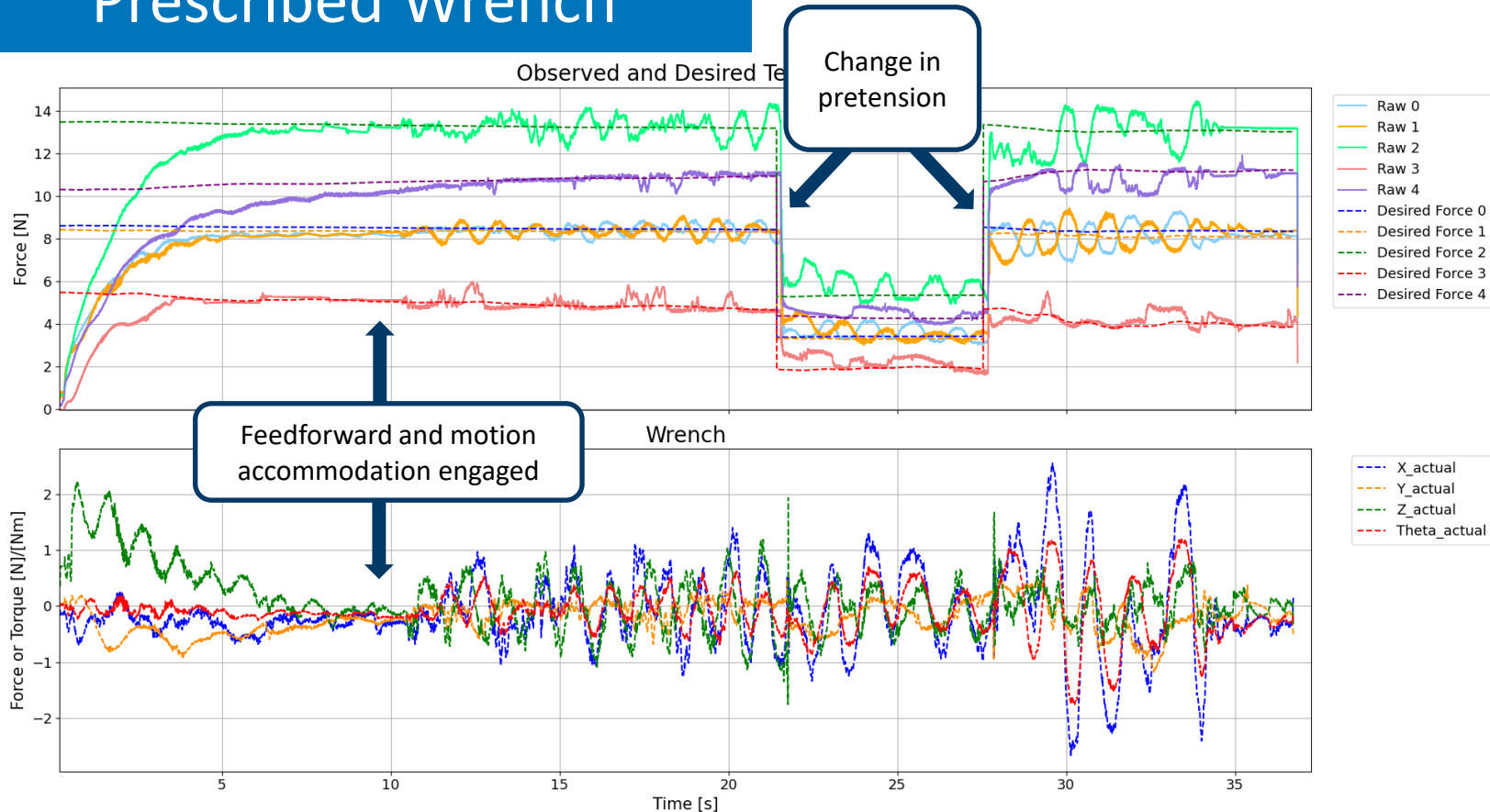- Allows floating body to move freely

Results: Zero Prescribed Wrench
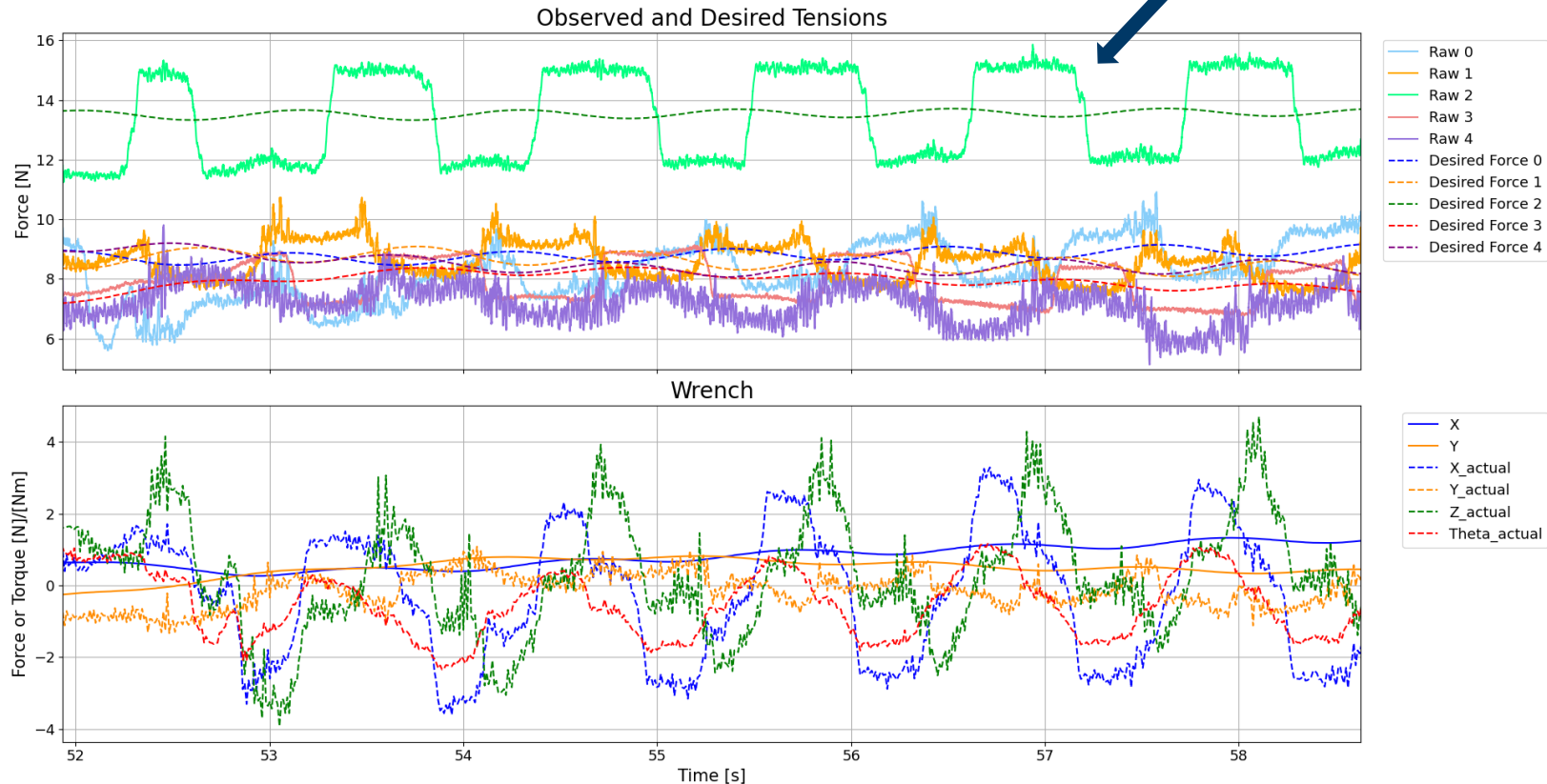

Observed and Desired Te...

Change in pretension

Feedforward and motion accommodation engaged

Wrench

Legend (top plot): Raw 0, Raw 1, Raw 2, Raw 3, Raw 4, Desired Force 0, Desired Force 1, Desired Force 2, Desired Force 3, Desired Force 4

Legend (bottom plot): X_actual, Y_actual, Z_actual, Theta_actual

Force [N]

Force or Torque [N]/[Nm]

Time [s]

Results: Wave Case with Small Prescribed Wrench

Phase shift and deviation from desired force
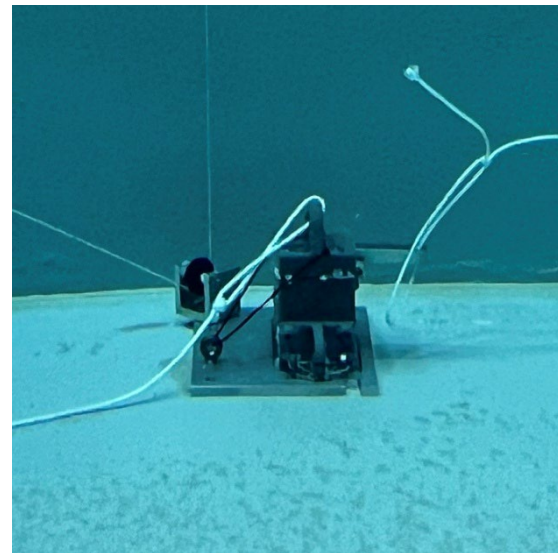
Observed and Desired Tensions

Wrench

Challenges

Addressed:

- Accuracy of underwater pulley placement and measurement

- Access to underwater hardware after installation

Additional:

- Oscillations about tension set point

- Friction in underwater pulleys

- Additional noise from motion accommodation

Conclusions

- System hardware designed, tested, and deployed

- Preliminary full system tests performed

- Errors identified and addressed

- Additional issues outstanding

- Expands the testing capabilities at SWEL

Video by Senu Sirnivas, NREL

Future Work

Improve controller to achieve wrench within 5% RMS of desired values

Integrate control system with OpenFAST

Install 2 additional winches for control in 6 DOFs

Test other scaled marine energy converters and floating platforms

References

M. Hall, "Hybrid Modeling of Floating Wind Turbines," Ph.D. dissertation, Dept. Mech. Eng., Univ. of Maine, Orono, ME, 2016. [Online] Available: https://digitalcommons.library.umaine.edu/etd/2477

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W. Wiley, H. Ross, A.K. Sundarrajan, and T.T. Tran, "Design and Modeling of an Open-Source Baseline Floating Marine Turbine" in *University Marine Energy Research Community Conference*, Durham, New Hampshire, United States, 2023.

Thank You!

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