Floating Wind Turbine Control Optimization

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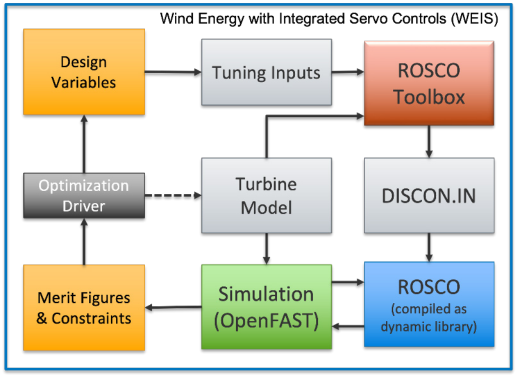
Goals and Motivation

- Use the open-source, Wind Energy with Integrated Servo control (WEIS) framework with the Reference OpenSource Controller (ROSCO) to determine optimal floating offshore wind turbine (FOWT) control parameters
- Demonstrate the framework on several control configurations and FOWTs and ensure the best possible controller in each case and a fair comparison between models



WEIS control optimization workflow: an optimization driver determines design variables, which are used to tune a ROSCO controller used in OpenFAST simulations. The outputs of the simulations are used as merit figures and constraints to iterate toward optimal control parameters. WEIS can also compute FOWT costs and change wind turbine and platform design variables.

WEIS Toolset

A collection of tools for simulating and optimizing FOWTs and their controllers (co-design) including:

- A parameterized turbine and platform
- Geometry, mass, and cost estimates
- OpenFAST input generation
- Controller tuning
- Hydrodynamic preprocessing
- Aero-servo-hydro-elastic modeling
- Loads postprocessing
- Structural postprocessing.

Examples and use cases can be found here: https://github.com/WISDEM/WEIS.

ROSCO for Wind Turbines

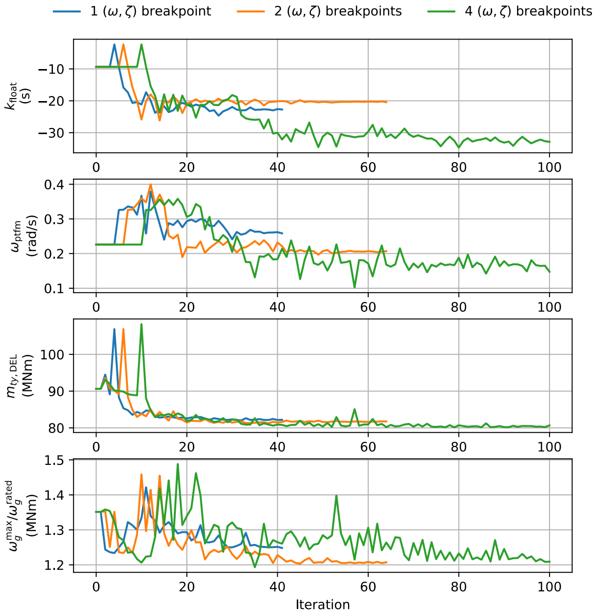
A flexible controller developed to provide common functionalities to those of a modern original equipment manufacturer's controller. Use cases include:

- A baseline controller for advanced controller development
- An automatically tuned controller for use in engineering studies for a variety of turbines (ROSCO has been used on turbine models from 500 kW to 15 MW)
- Control co-design optimization.

Examples and use cases can be found here: https://github.com/NREL/ROSCO

Users can tune and optimize (design variables available and **optimized in this study**) the following:

- Collective and individual pitch control (**natural frequency ω** and **damping ratio ζ,** individual pitch control gains and azimuth offset).
- Tip-speed ratio tracking torque control
- Peak shaving (maximum thrust limit, relative to maximum thrust)
- Floating feedback (**gain k_{float}** and **phase ω_{ptfm}**)
- Filter cutoff frequencies.

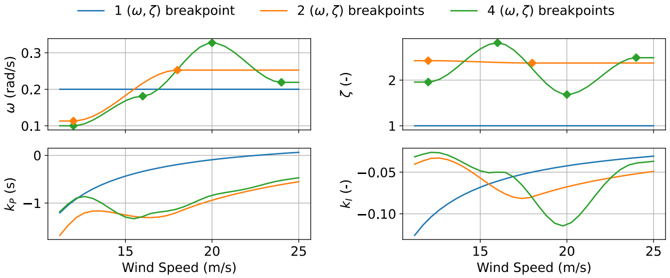


The convergence of design variables, constraints, and merit figures for the International Energy Agency's 15-MW ROSCO optimization with 1, 2, and 4 equally spaced breakpoints to define $\omega(u)$ and $\zeta(u)$.

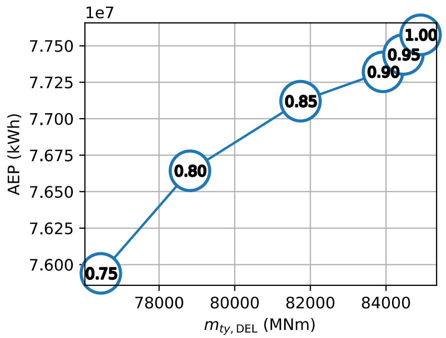
Floating Control Optimizations Performed

In each optimization, we minimize the tower-base damage equivalent loading with a constraint on the maximum generator overspeed using design load cases (DLCs) 1.1, 1.3, and 1.6. We considered three variations:

1. Increasing the number of breakpoints, resulting in a more flexible pitch controller
2. Varying the peak shaving value, which includes re-optimizing the collective pitch controller
3. Various platforms (spar, semisubmersible, barge, and tension leg), where loads can be compared independently of control effects.



Optimal proportional (k_P) and integral (k_I) pitch control gains, which are determined based on the natural frequency $\omega(u)$ and damping ratio $\zeta(u)$, where u is the wind speed. In ROSCO, k_P and k_I are scheduled using a low-pass-filtered blade pitch angle.



The annual energy production (AEP) versus the tower-base damage equivalent loading ($m_{ty,DEL}$) for six different thrust limits from 0.75 to 1.00, as indicated in the figure.

Conclusions and Future Direction

- Optimizations converge in 40–100 iterations, wherein each iteration is a set of DLCs that can be performed in parallel
- Controller tuning parameters can be determined automatically and optimally
- Current and future work investigates optimizing the FOWT platform and wind turbine geometry along with the controller.

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The Science of Making Torque from Wind (TORQUE)
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