Gradient-based design optimization of floating wind turbines using surrogate models for hydrodynamic coefficients

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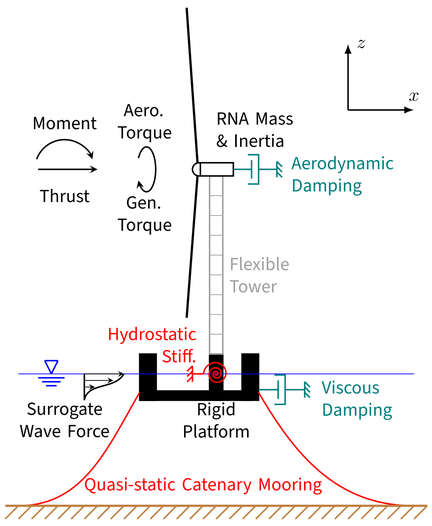
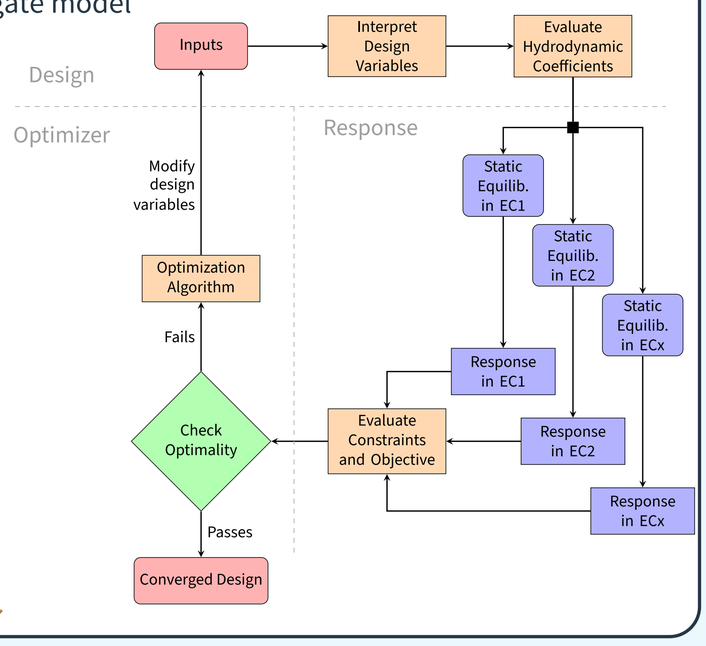
Linearized Frequency-domain Semisubmersible FWT Model (SemiOpt)

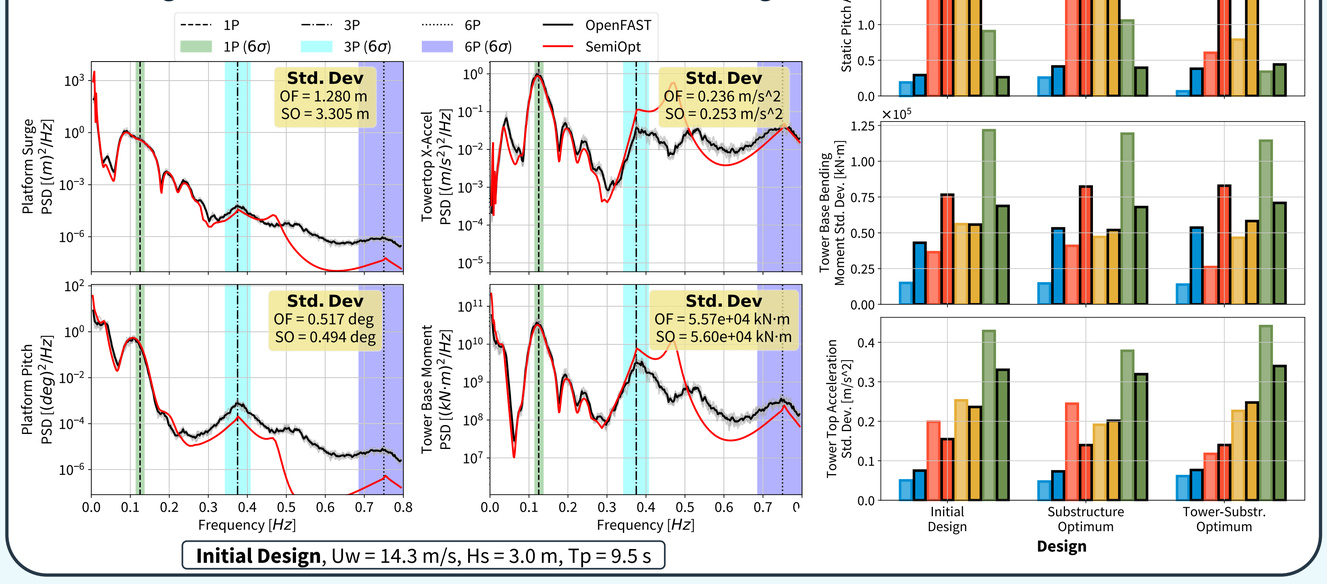
- Rigid platform and flexible tower
- Wave excitation, added mass, and radiation damping computed with surrogate model
- Analytical derivatives defined
- Parallel response calculation





Analysis Model Verification

- Verification against nonlinear time-domain OpenFAST
- Differences with OpenFAST simulations are largely consistent across the design space considered
- Poor agreement between 3P and 6P for reference design

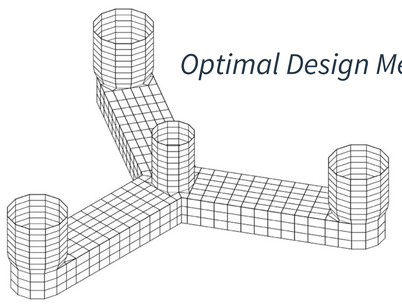


Initial Design, Uw = 14.3 m/s, Hs = 3.0 m, Tp = 9.5 s

Substructure Optimization

Vary pontoon length and outer column radius

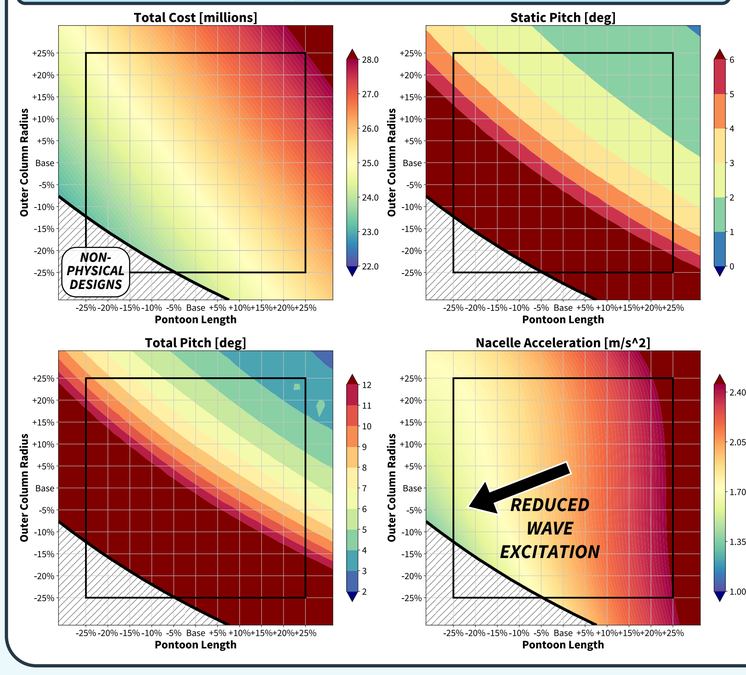
Subject to static pitch, total pitch, and nacelle acceleration constraints in 12 conditions



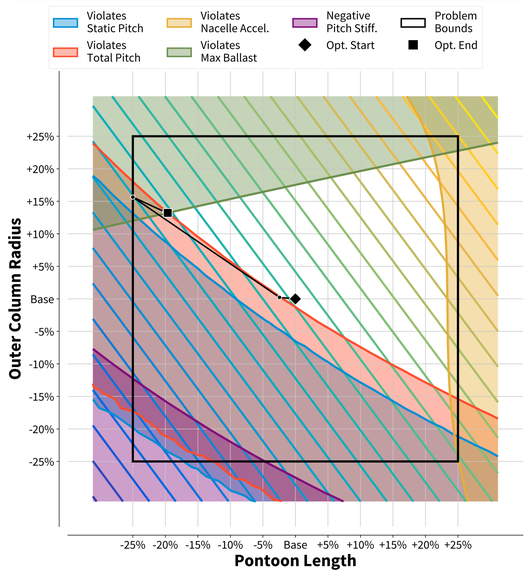
Optimal Design Mesh

- No impact of surrogate variations on optimal design
- Minimal impact of surrogate variations on convergence
- Variable bounds and constraints worth further investigation
- Intuitive optimal design to minimize mass in absence of additional constraints

Design Space Sweep



Optimizer Path

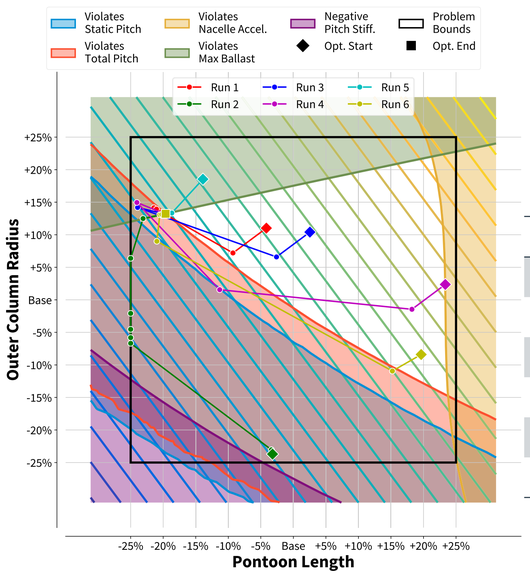


All surrogate variations tested converge to the same optimum

'Worse' surrogates converge faster and in fewer iterations

Samp.	Freqs.	Range	Iter.	Time [s]
30	120	±25%	7	541.3
240	120	±25%	9	705.3
960	120	±25%	9	717.3
3840	120	±25%	12	1003.5
960	30	±25%	13	598.0
960	480	±25%	9	2126.5
960	120	±50%	9	728.6
960	120	±75%	7	577.8

Randomized Start Points



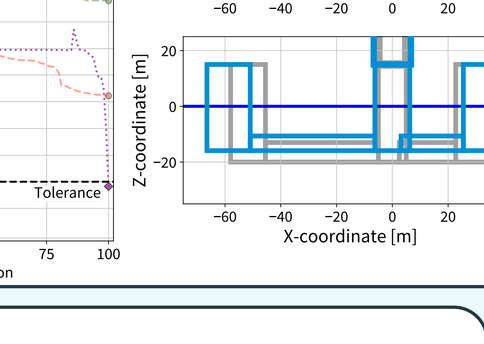
Repeated runs with random start converge to the same optimum

Run	Iter.	Time [s]
1	8	666.5
2	16	1350.1
3	7	573.6
4	8	644.5
5	5	407.5
6	9	727.4

Tower-Substructure Optimization

Vary outer column radius, central column radius, tower radius and wall thickness along the length of the tower, and pontoon length, width, height

Subject to static pitch, total pitch, nacelle acceleration, tower fatigue, tower buckling, and tower natural frequency constraints in 12 conditions



Optimal Design Mesh

- Optimizer decreases cost of initial, infeasible design
- Tower structural constraints dominate optimal design
- Little impact of surrogate variations on optimal tower design
- No substructure structural constraints applied to impact design
- Significant impact of surrogate and start point variations on convergence

Not All Surrogate or Start Point Variations Converge

Optimal Substructure and Tower Design

Equivalent Tower Design for All Converged Variations

0 of 1000 DOE Cases are Feasible, Most are Costlier

Conclusions

- Training data only matters as much as starting point for simpler problems
- Noise from surrogates strongly impacts convergence, little impact on optima
- Further investigations including substructure structural design are needed

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SFI BLUES

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