On the preliminary integrated design of a 10MW floating wind turbine

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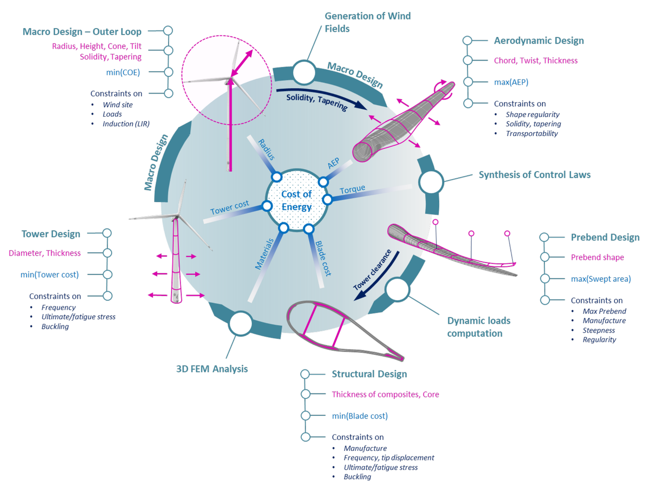
Introduction and Motivation

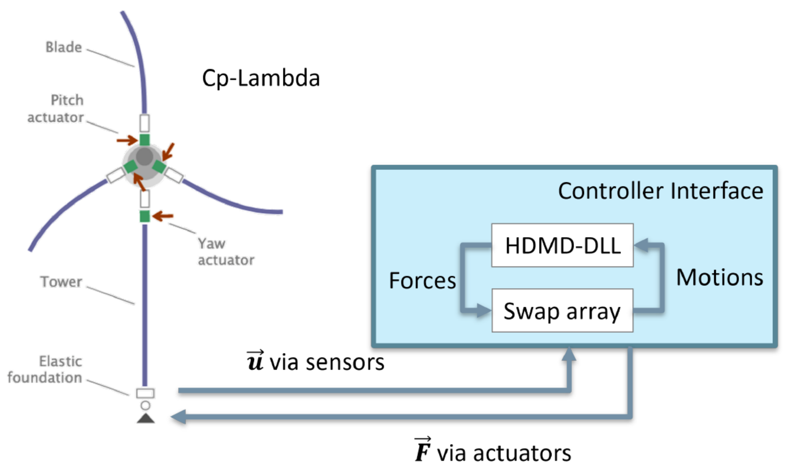
- Floating Wind Turbine (FWTs) development is crucial to achieving 2050 goals
- Design of FWT is challenging and the LCoE still high compared to other electrical energy sources
- Current design approach is to size rotor and floating foundation separately (suboptimal)
- Need to develop an **integrated design approach** with the aim of minimizing LCoE

Methodology

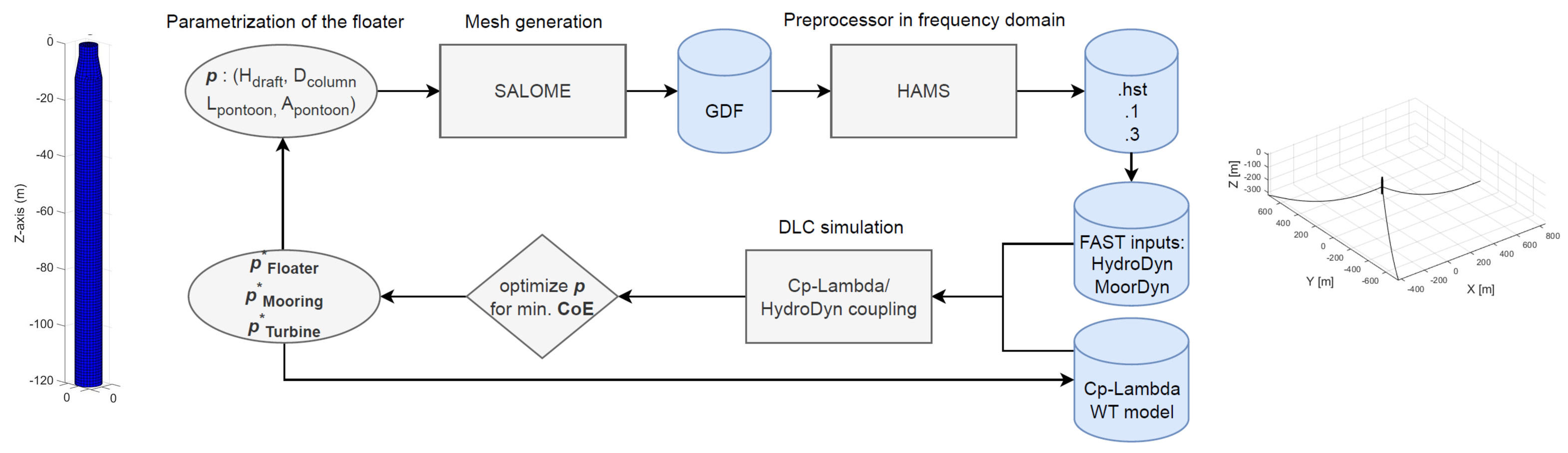
Land-based holistic design: Cp-Max [1], [2]



FWT modeling [2], [3]



Floating substructure and hydrodynamic modeling



Floating substructure design constraints

- Mean platform pitch ≤ $\theta_{plf\,AVR}$ during power production
- Max platform pitch ≤ $\theta_{plf\,MAX}$
- Mean platform heave ≤ $z_{plf\,AVR}$
- Max platform heave ≤ $z_{plf\,MAX}$
- Platform offset on horizontal plane ≤ $\delta_{plf\,MAX}$
- Max anchor uplifting angle < $\theta_{anc\,MAX}$

Global limit states

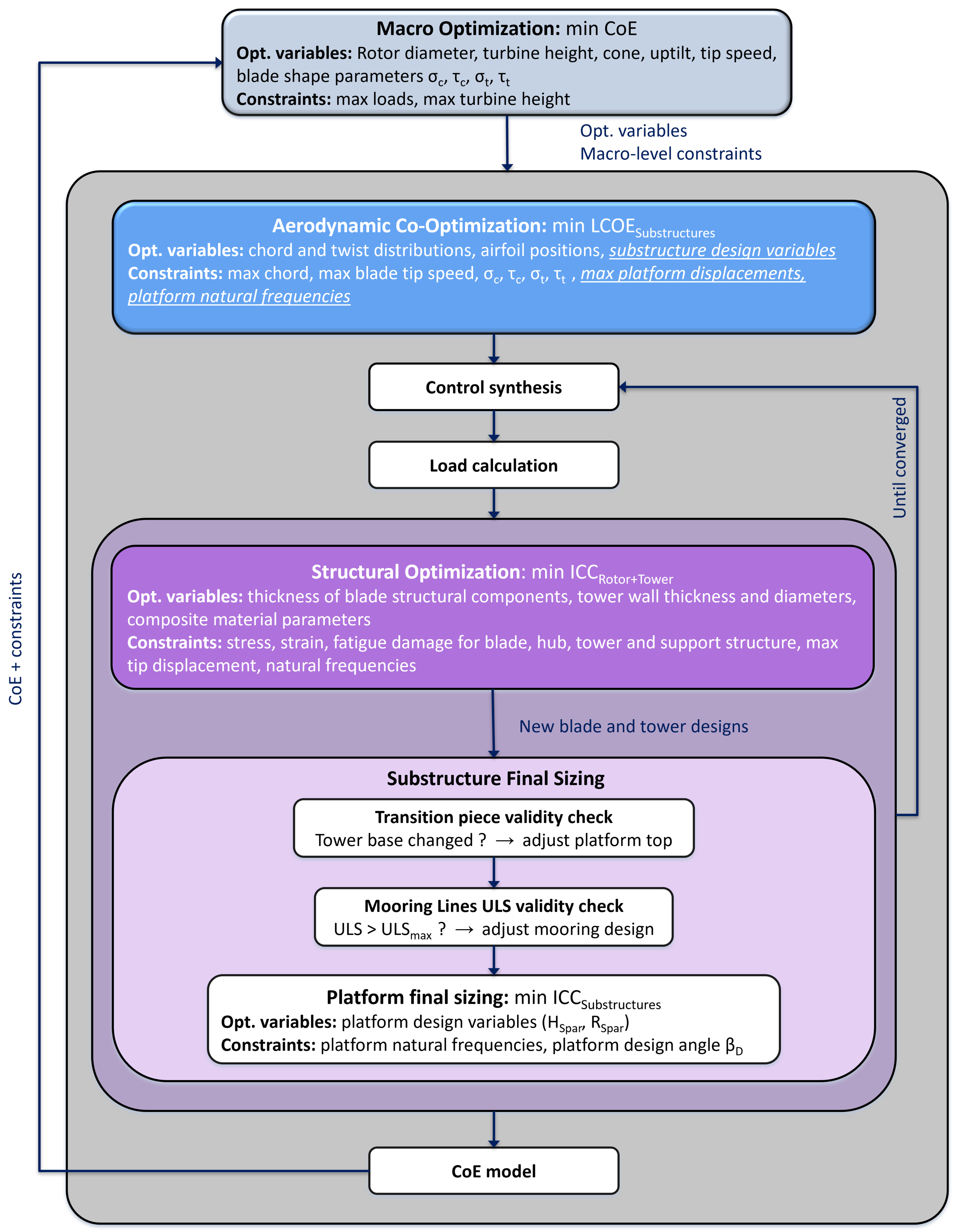
- Lowest platform T_N > 25s
- 0.7 < ω_{Pitch} / ω_{Heave} < 0.9 (Mathieu stability)

Dynamics

- Max characteristic mooring tension < min mooring line breaking load
- Constraints according to DNV standards for shell and column buckling
- Max nacelle acceleration < 0.3 g

Ultimate loads

Integrated design of FWTs in Cp-Max



Results

Baseline: 10MW (bottom-fixed) PoliMI Wind Turbine [1]

Baseline PoliMI 10 MW

Rated power	10 MW
Rotor orientation	Upwind
IEC class	1A
Blade length	86.35 m
Rotor diameter	178.3 m
Hub height	119 m
Rotor overhang	7.07 m
Prebend	5.94 m
Nacelle up-tilt	5°
Rotor cone	2.5°
Maximum tip speed	84 m/s
Hub mass	105520 kg
Nacelle mass	446036 kg

Design Variables (DVs)

Blade Aerodynamic DVs

$p_a = [p_{chord}, p_{twist}]$

Blade Structural DVs

$p_b = [t_{shell}, t_{spars}, t_{webs}, t_{reinf}]$

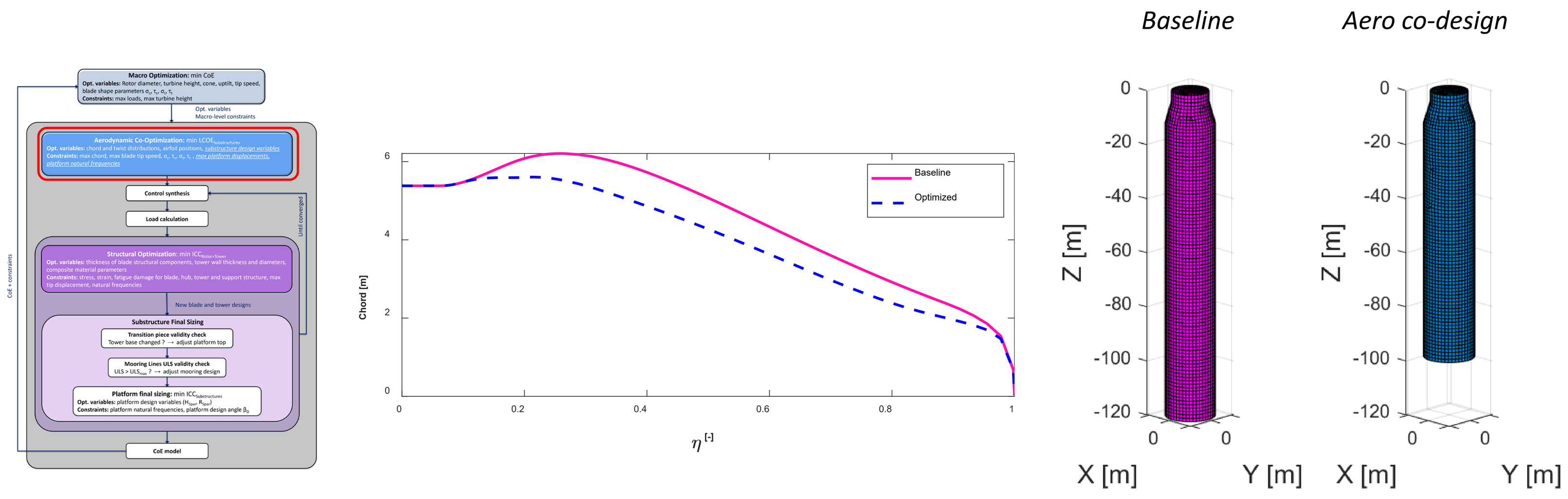
Tower structural DVs:

$p_t = [D_{tower}, t_{tower}]$

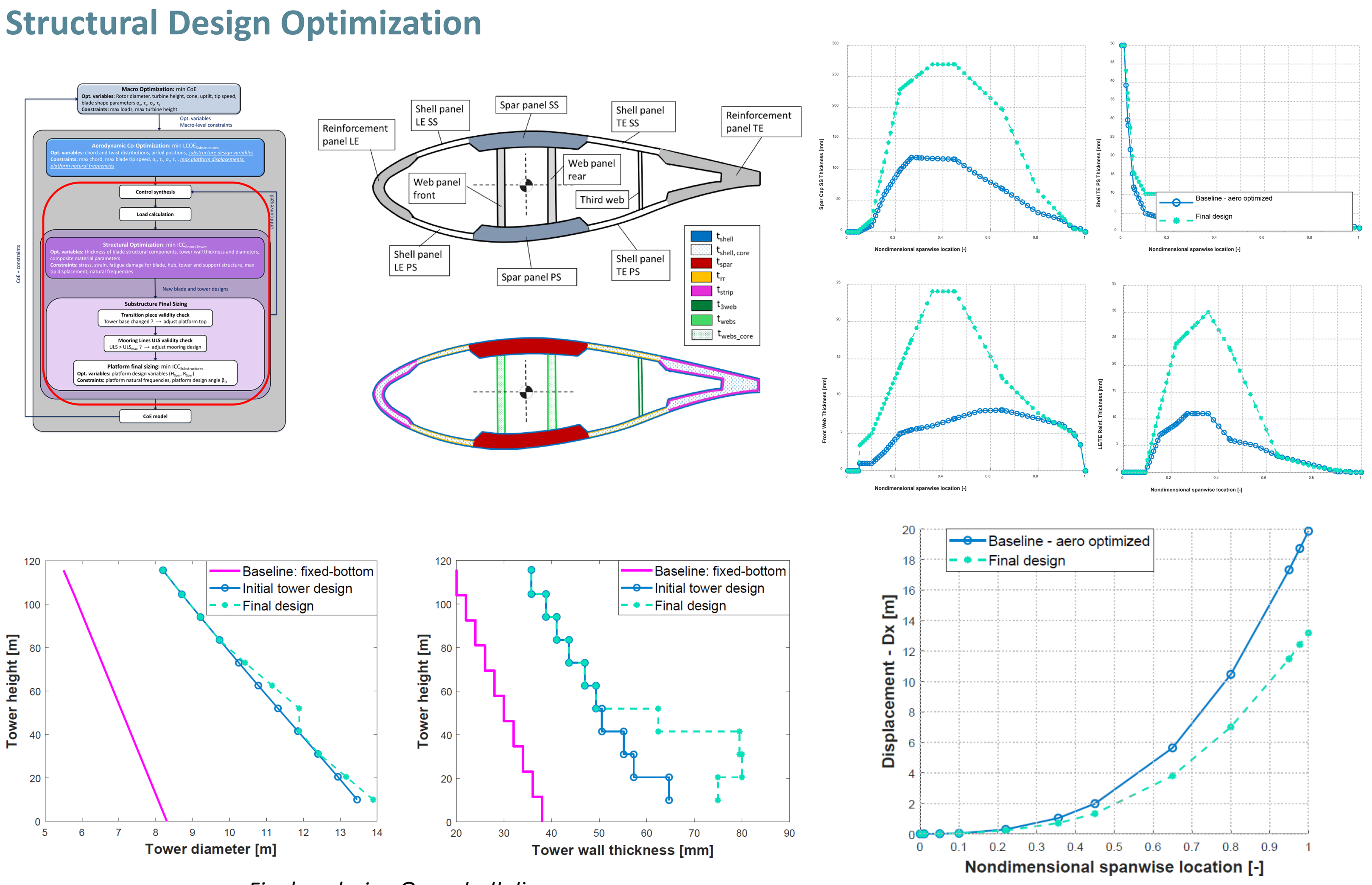
Floating Substructure DVs:

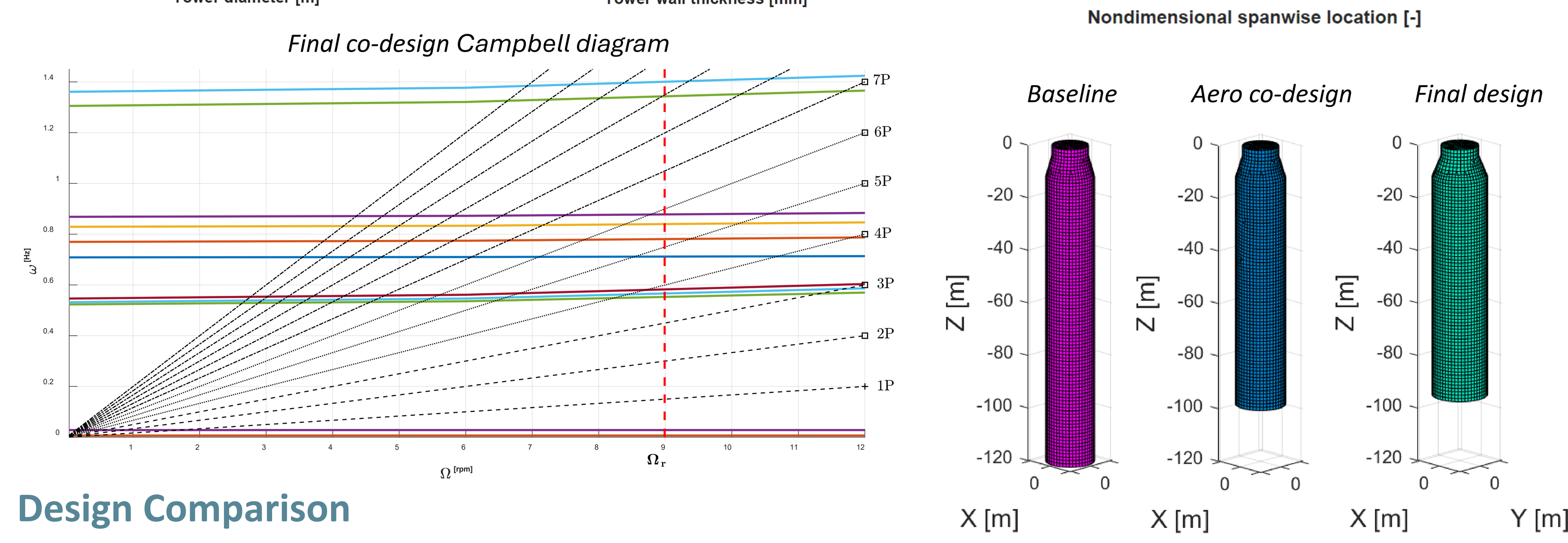
$p_{sub} = [H_{spar}, R_{spar}, d_{mooring}, R_{mooring}, s_{mooring}, z_{fairlead}]$

Aerodynamic Co-Optimization



Structural Design Optimization





Design Comparison

	H_{Spar}	R_{Spar}	$d_{Mooring}$	$R_{Mooring}$	$s_{Mooring}$	$z_{Fairlead}$	AEP_{Static}	$C_{Substructures}$	β_D	z_{CoG}
Baseline	120 m	9 m	0.177 m	855.2 m	0.177	-77.2 m	50.906 GWh	29.79 M€	4.05°	-94.97 m
Aero co-design	98.09 m	9.24 m	0.136 m	769.71 m	0.173	-66.44 m	50.665 GWh	24.37 M€	6.54°	-77.77 m
Final co-design	94.75 m	10.23 m	0.170 m	769.71 m	0.173	-66.44 m	50.708 GWh	28.29 M€	6.50°	-75.65 m

	LCOE	Blade mass	Blade cost	Tower mass	Tower cost
Aero co-design	112.46 €/MWh	39832 kg	269.15 k€	$1.498\ 10^6$ kg	4.936 M€
Final co-design	121.10 €/MWh	70639 kg	358.53 k€	$1.762\ 10^6$ kg	5.807 M€
Difference	+7.68%	+77.34%	+33.21%	+17.64%	+17.64%

Conclusions and future works

- A preliminary **integrated design approach** with the aim of minimizing LCoE has been developed
- **Strong coupling** between floating substructure and rotor aerodynamic design
- Increased blade tip deflection in floating conditions
- Increased fatigue loads on tower bade

- Extending the tool to other platform types (semi-sub, TLP, barge, etc.)
- Exploring the 2-bladed FWT and alternative rotor configurations (i.e. downwind)
- Exploring bigger size (10+MW)

References

[1] Sartori, L. (2019) – System Design of Lightweight Wind Turbine Rotors

[2] L. Sartori, S. Cacciola, A. Croce, and C. E. D. Riboldi, "A research framework for the multidisciplinary design and optimization of wind turbines," Design Optimization of Wind Energy Conversion Systems with Applications, p. 25, 2020.

[3] Yilmazlar K, (2024) – Integrated Desing and LCoE Minimization of Floating Wind Turbines

Acknowledgment

This work has been conducted within the FLOAWER (FLOAting Wind Energy network) project. This project has received funding from the European Union's Horizon H2020 research and innovation programme under the Marie Słodowska-Curie grant agreement N°860579.