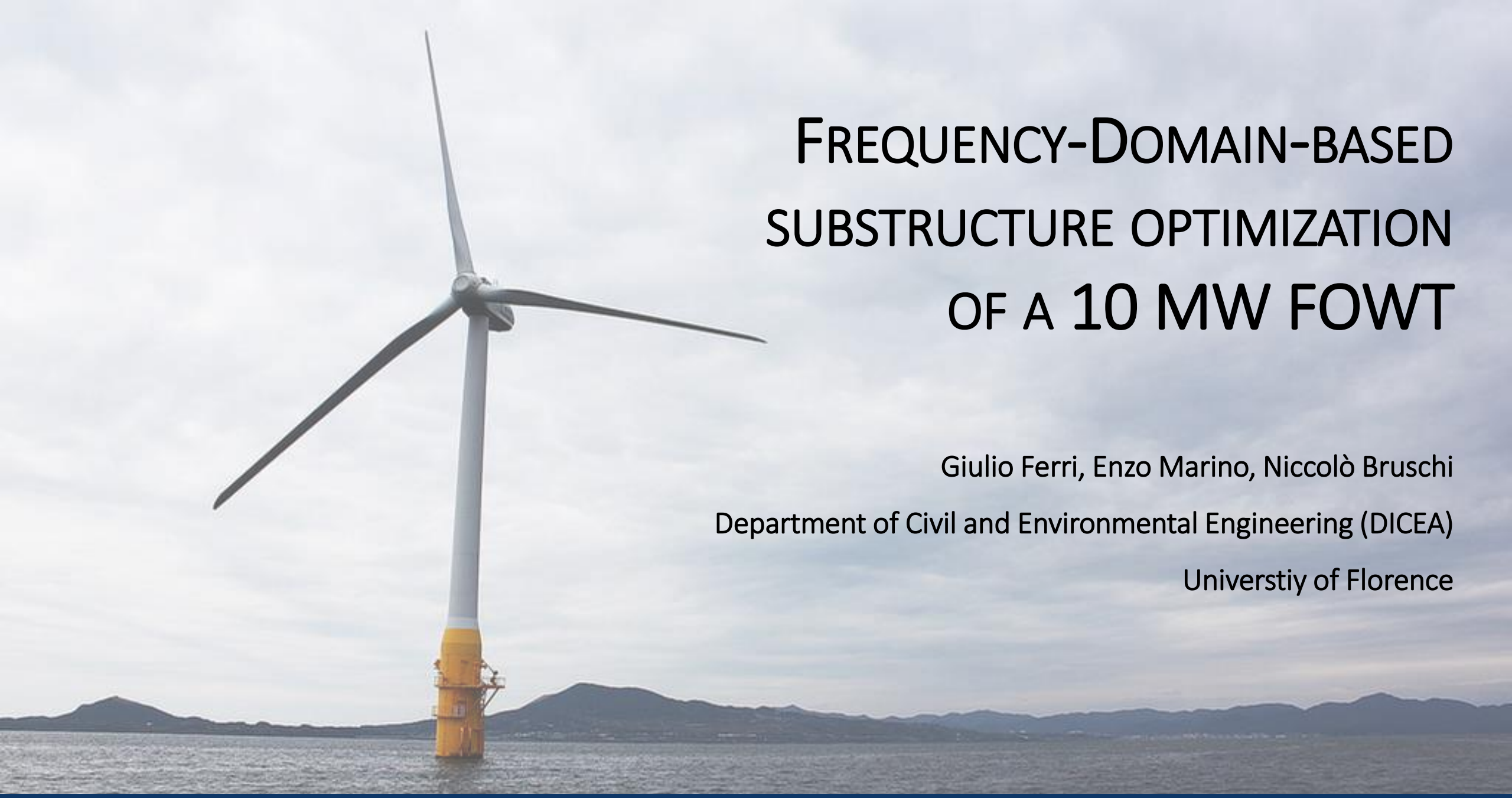


FREQUENCY-DOMAIN-BASED SUBSTRUCTURE OPTIMIZATION OF A 10 MW FOWT

Giulio Ferri, Enzo Marino, Niccolò Bruschi

Department of Civil and Environmental Engineering (DICEA)

Universtiy of Florence

EERA DeepWind conference, 19-21, January 2022

Coupled Frequency Domain Models for FOWT

Equations of motion

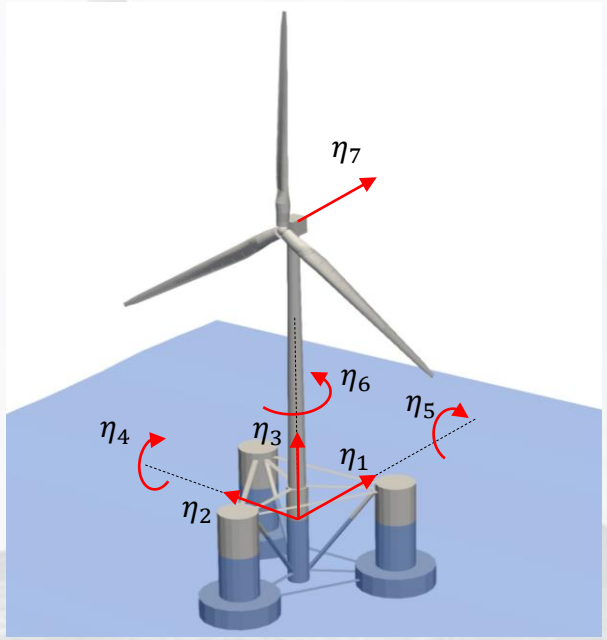
- Steady state condition $\boldsymbol{q}(t) = \hat{\boldsymbol{q}}(\omega)e^{j\omega t}$
- Quasi-static mooring lines model $\boldsymbol{F^{Lines}}(t) = \boldsymbol{F^{Lines,0}} - \boldsymbol{C^{Moor}}\boldsymbol{q}(t)$
- Linearization of the Drag Forces $\boldsymbol{F^{Mor}}(t) \cong -\boldsymbol{B^{Mor}}(\omega, \beta, \sigma)\,\dot{\boldsymbol{q}}(t)$

$$\left[-\omega^2\left(\mathbf{A}(\omega) + \boldsymbol{M^{Float}} + \boldsymbol{M^{Turb}}\right) + \mathrm{i}\omega\left(\mathbf{B}(\omega) + \boldsymbol{B^{Turb}} + \boldsymbol{B^{Mor}}(\omega,\beta,\sigma)\right) + \left(\boldsymbol{C^{Hydro}} + \boldsymbol{C^{Moor}} + \boldsymbol{C^{Turb}}\right)\right]\breve{\boldsymbol{q}}(\omega)$$
$$= \left(\mathbf{X}(\omega,\beta)\sqrt{2S_\eta(\omega)\Delta\omega} + \boldsymbol{F_d}\sqrt{2S_{wind}(\omega)\Delta\omega}\right)$$

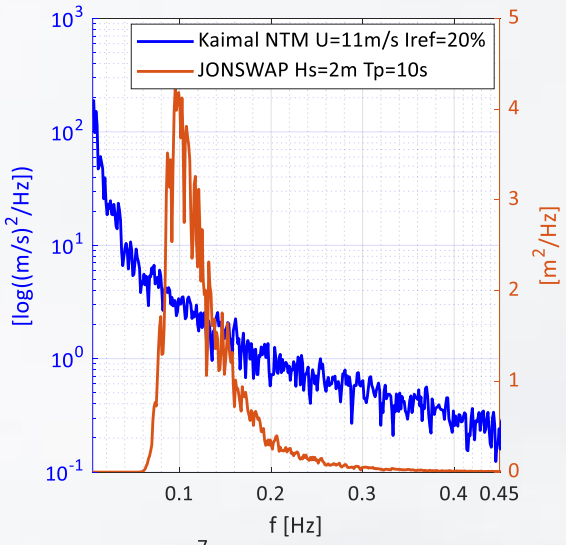
$$\breve{\boldsymbol{q}}(\omega) = \begin{bmatrix}\eta_1\\ \eta_2\\ \eta_3\\ \eta_4\\ \eta_5\\ \eta_6\\ \eta_7\end{bmatrix}$$

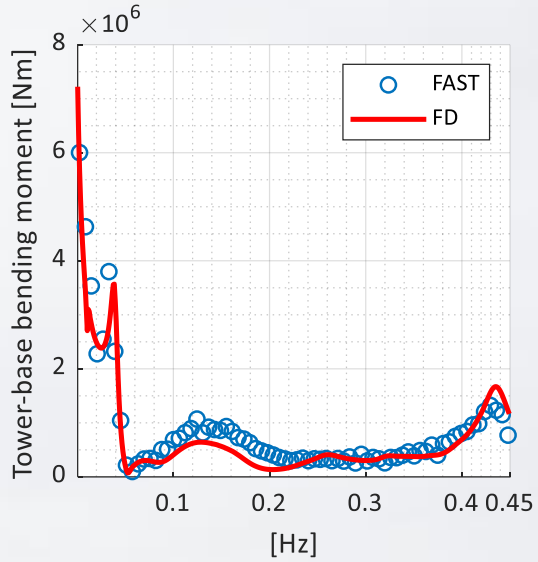
6 rigid platform DoFs

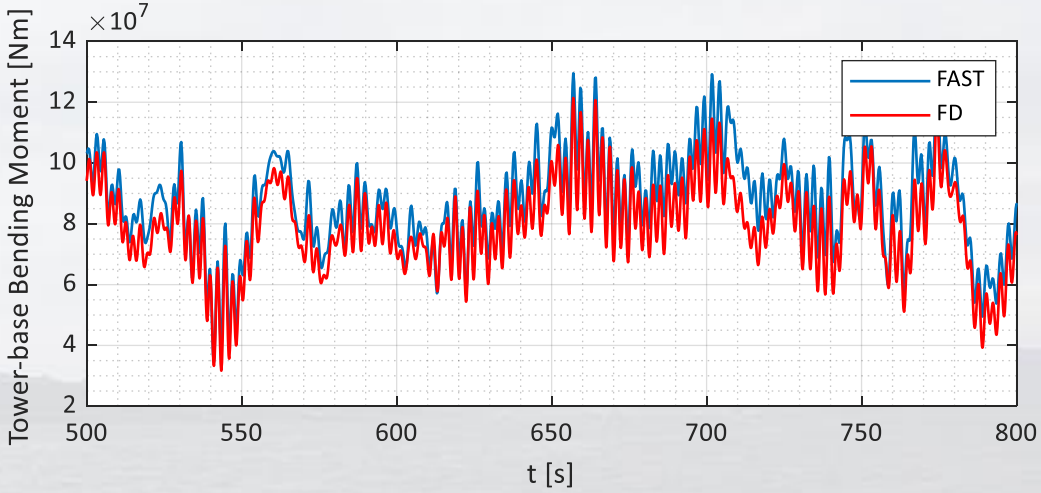
Fore-Aft tower deflection



Response under turbulent wind and irregular wave

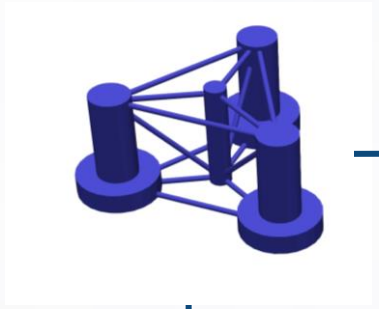






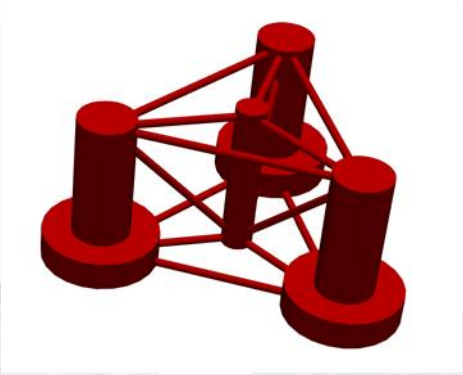
Optimization of a 10 MW semisubmersible FOWT

5MW



Upscaling $S_f = \sqrt{\frac{10\text{MW}}{5\text{MW}}}$

10MW

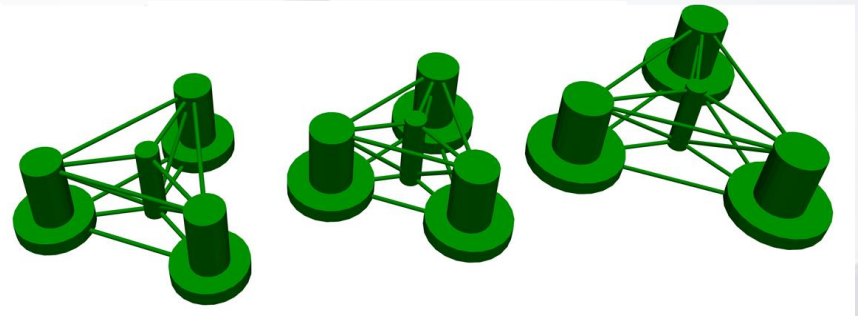


$$\min_{\boldsymbol{x}} f_{obj}(\boldsymbol{x}) \qquad f_{obj}(\boldsymbol{x}) = \begin{cases} cost\ € \\ RAO \\ \dots \end{cases}$$

$$const(\boldsymbol{x}) = 0 \qquad const(\boldsymbol{x}) = \begin{cases} displ. \\ stress \\ cost\ € \\ \dots \end{cases}$$

$$\boldsymbol{x}\ design\ variables \qquad \boldsymbol{x} = \begin{cases} geometry \\ concept \\ \dots \end{cases}$$

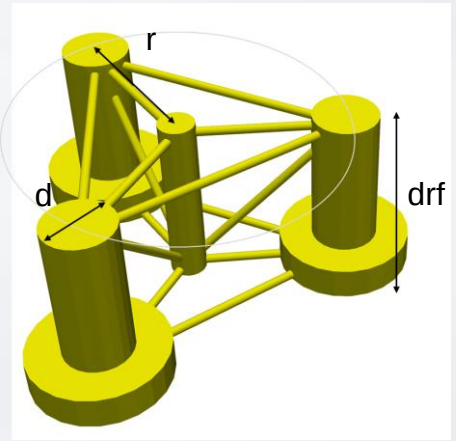
Optimized 10MW



Genetic Algorithm single-objective optimization

Design variables

3-variable Optimization	5-variable Optimization
Column diameter, d	Column diameter, d
Platform radius , r	Platform radius, r
Draft, drf	Draft, drf
-	Anchor radius, x_{anch}
-	Cable lenght, L



Constraints

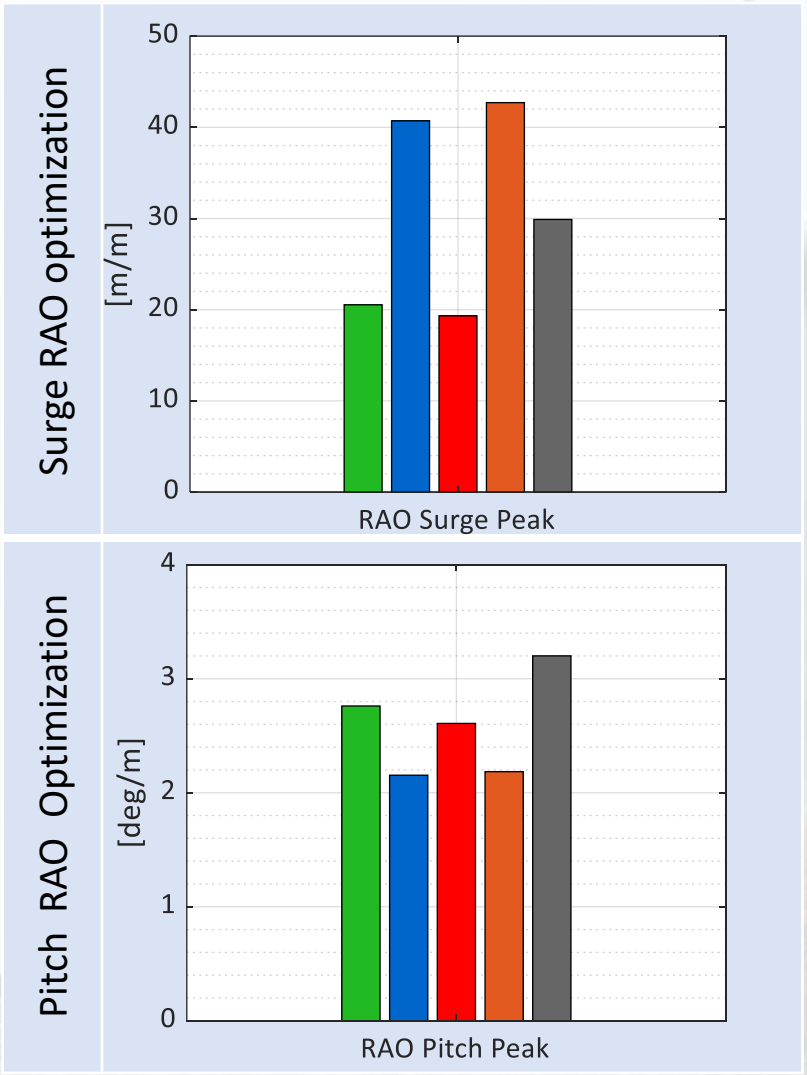
- Steady pitch at rated wind speed: $\eta_5 \leq 5°$ with V_{hub} =11.4 m/s
- Platform admissible offset: $\frac{\Delta x_{offset}}{z_{depth}} \leq 0.15$
- Triangle side length: $L > \sqrt{(x_{anch} - x_{Fair})^2 + (z_{anch} - z_{Fair})^2}$
- Line resting on seabed: $L_B = L - \frac{|V_{Fair}|}{\omega_{moor}} \geq \frac{L}{10}$

Objective functions

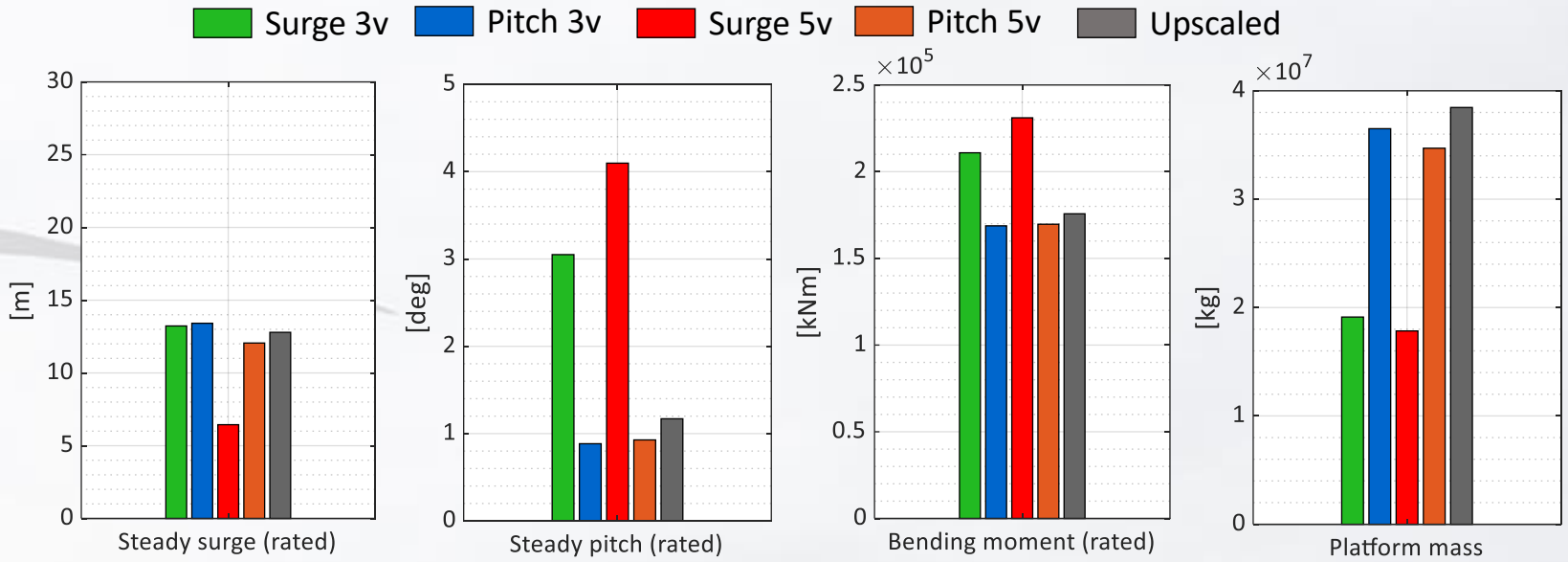
- RAO peaks at platform eigenfrequencies

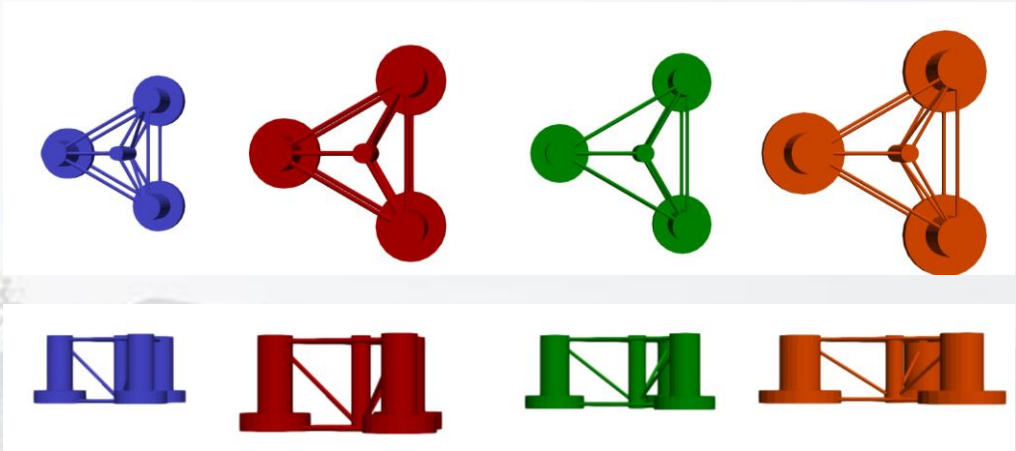
Platform optimization results

Surge and Pitch RAOs optimization



Optimized substructures: Mean values





Conclusions

- ✓ Coupled FD models show a good accuracy, which makes them promising for optimization procedures of FOWTs

- ✓ The optimization of a 10MW semisubmersible FOWT shows that upscaling procedures may lead to overdesigned solutions

Future works

- Site-specific and cost optimization of a 10MW FOWT

Reference
G.Ferri, E. Marino, N. Bruschi, C.Borri – *Platform and moorings optimization of a 10 MW Floating Offshore Wind Turbine,* Renewable Energies January 2022.