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CYBERLAB KPN

Comparison of quasi-static and dynamic mooring line models for shared mooring floating wind farms

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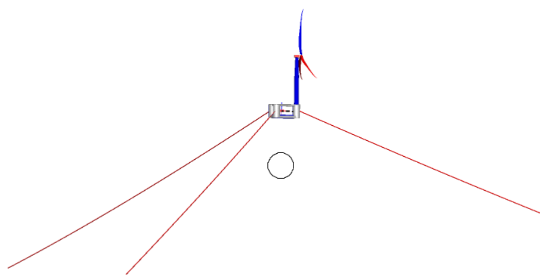
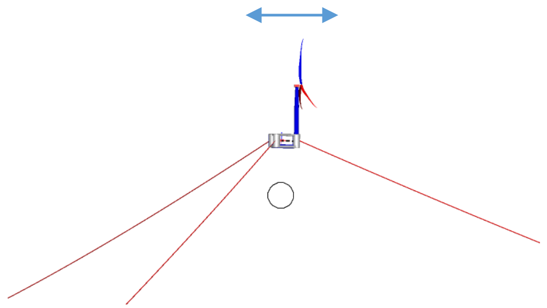
Motivation



Damping sources for floater motion :

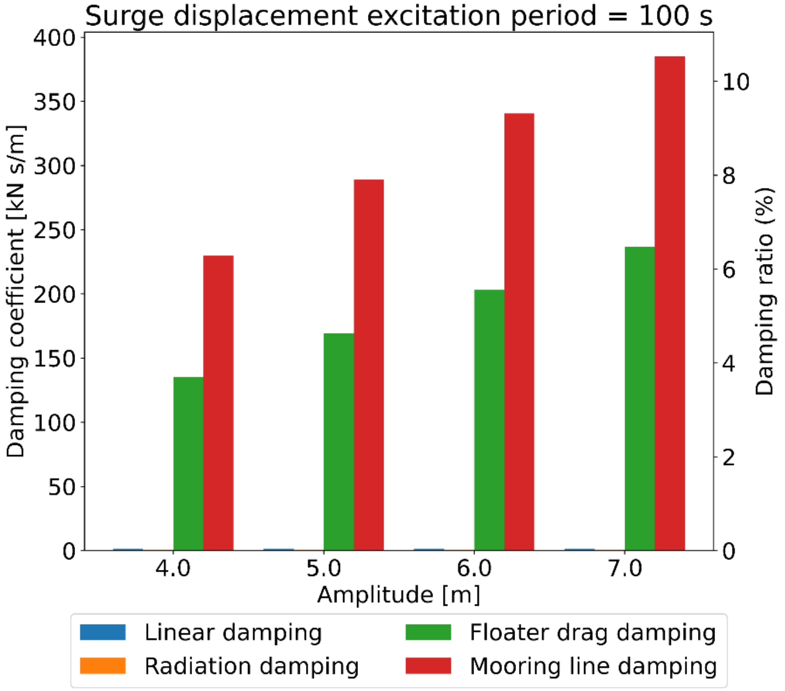
- Radiation damping
- Aerodynamic damping
- Damping from drag loads on the floater
- Damping from inertial and drag loads acting on the mooring lines

Motivation



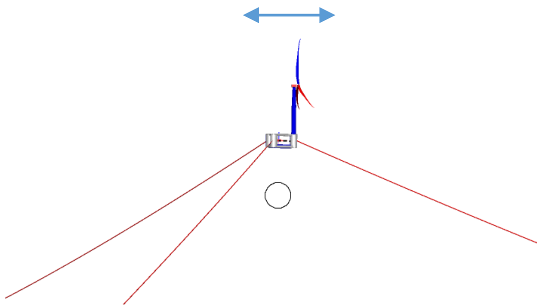
A prescribed motion test on an individually moored turbine produces the following damping coefficients at low frequencies.

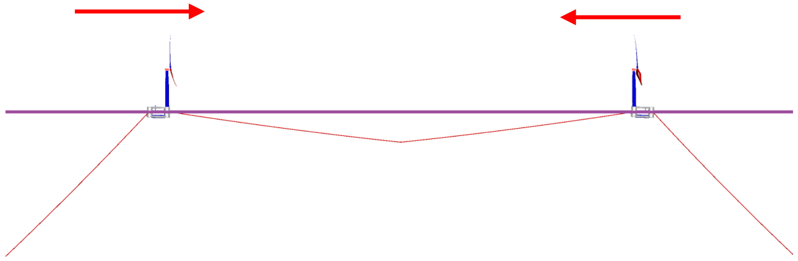
-> At lower frequencies the damping from the floater and mooring line becomes comparable.

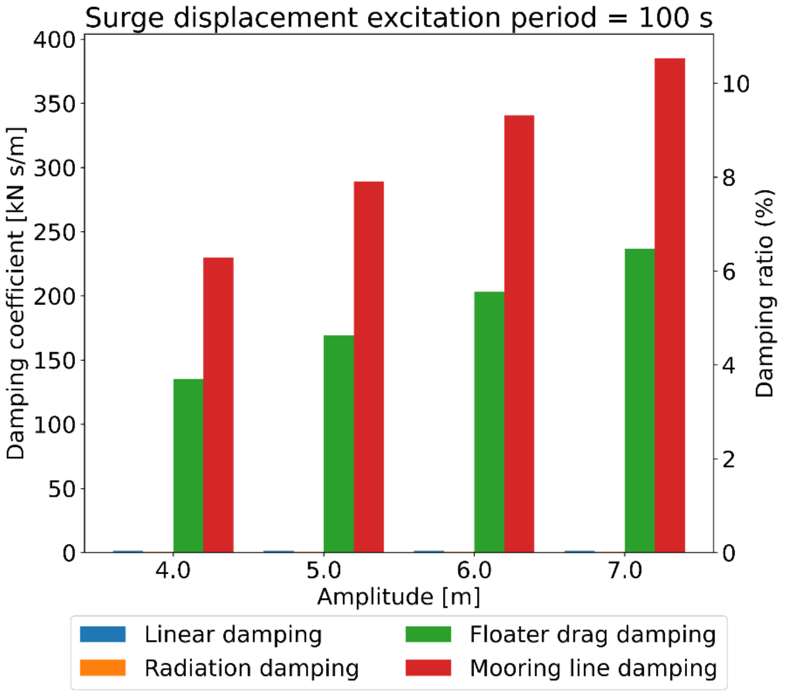


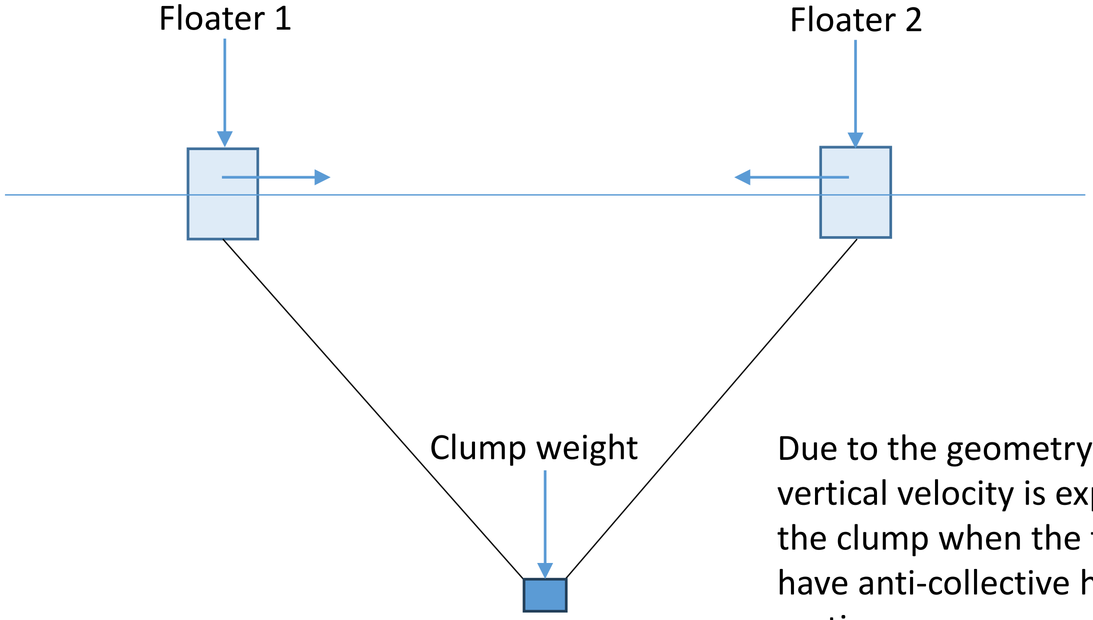
Anchor line		
Line material	Polyester	
Line diameter	264	mm
Minimum breaking load	18.64	MN
Line stiffness (EA)	466	MN
Dry mass coefficient	44.7	kg/m
Wet mass coefficient	9.5	kg/m
Horizontal footprint	1300	m
Line pretension	1.8	MN
Water depth	500	m

Motivation



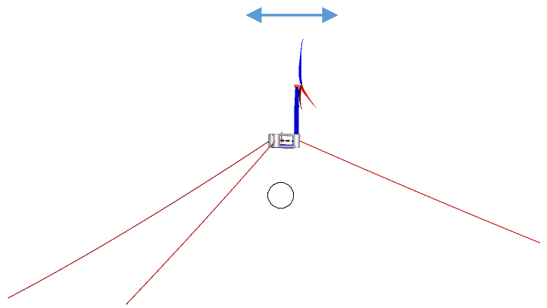




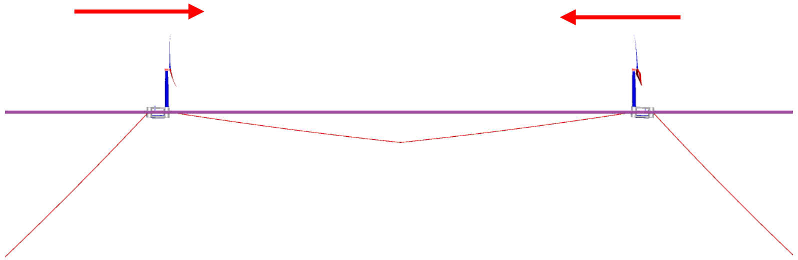


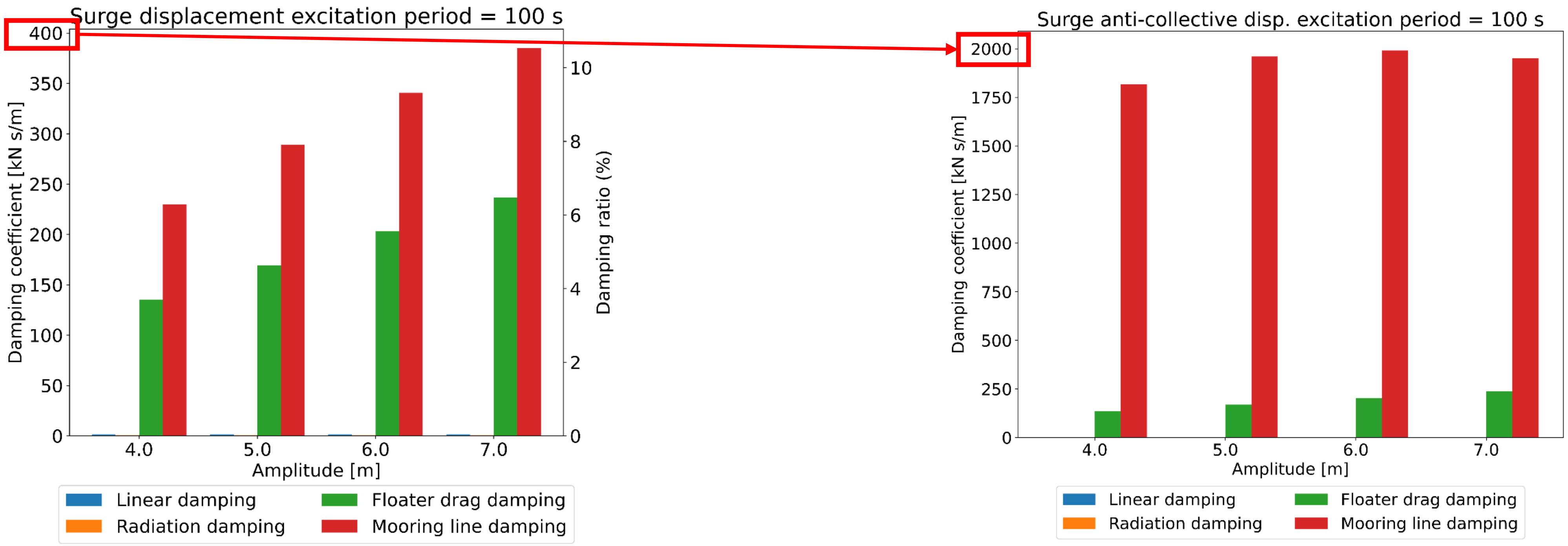
Due to the geometry – large vertical velocity is expected at the clump when the floaters have anti-collective horizontal motions.

Motivation



Ascertain how this affects the platform motions by comparing simulations using quasi-static and dynamic line models.

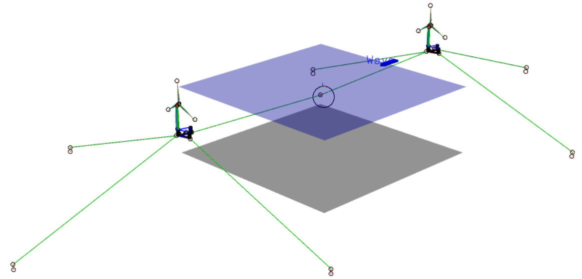




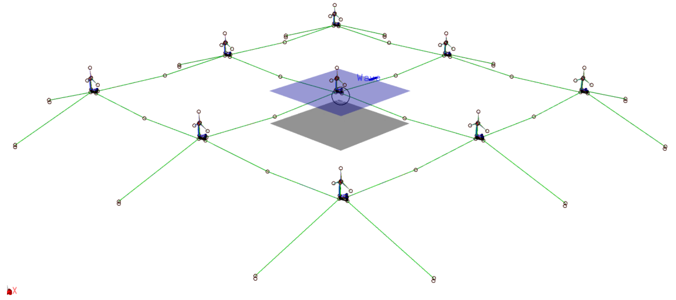
Test cases

Lattice variants

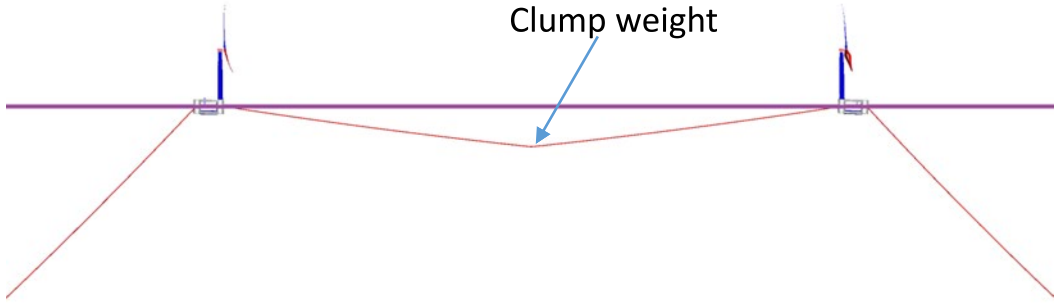
Grid21



Grid33



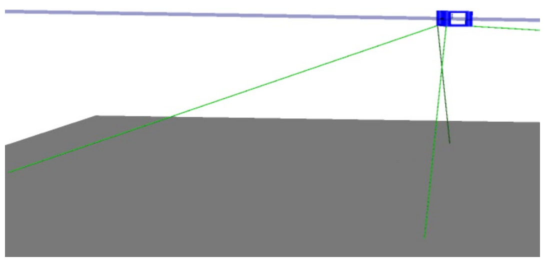
Shared line design



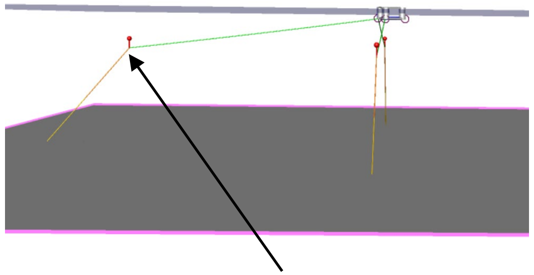
Line/clump property variants

Variant	Polyester line dia [mm]	Clump weight [t]	MBL (MN)	Pretension (MN)
D264_clmp50	264	50	18.640	3.754
D264_clmp30	264	30	18.640	3.201
D241_clmp30	241	30	15.696	2.860
D213_clmp30	213	30	12.263	2.414

Anchor line design



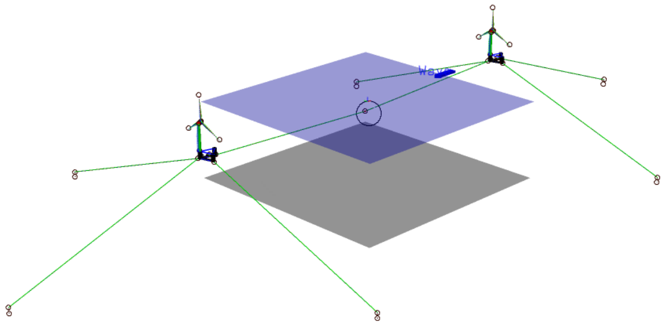
Taut anchor lines

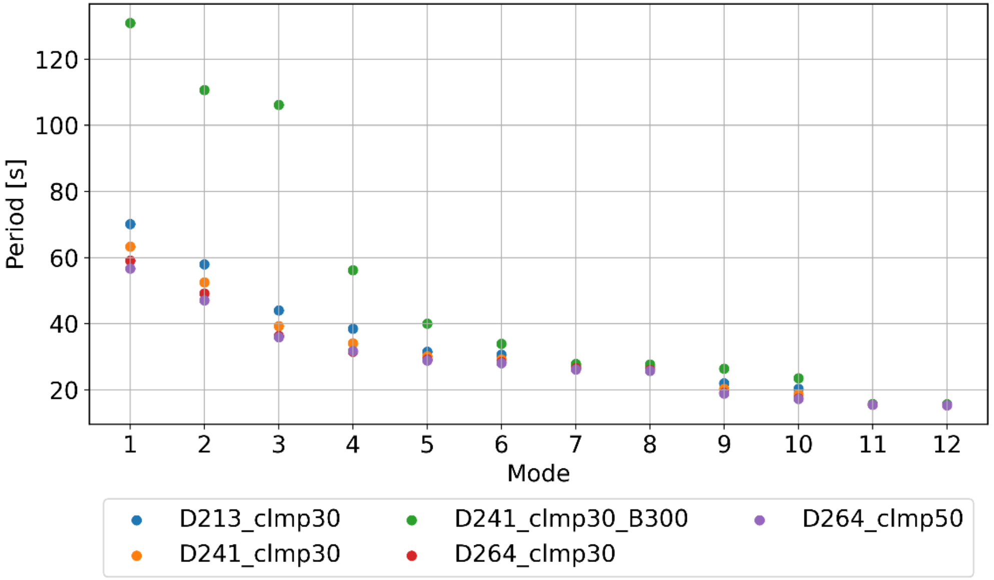


Buoyancy module on anchor lines

Eigen value analysis – Grid21

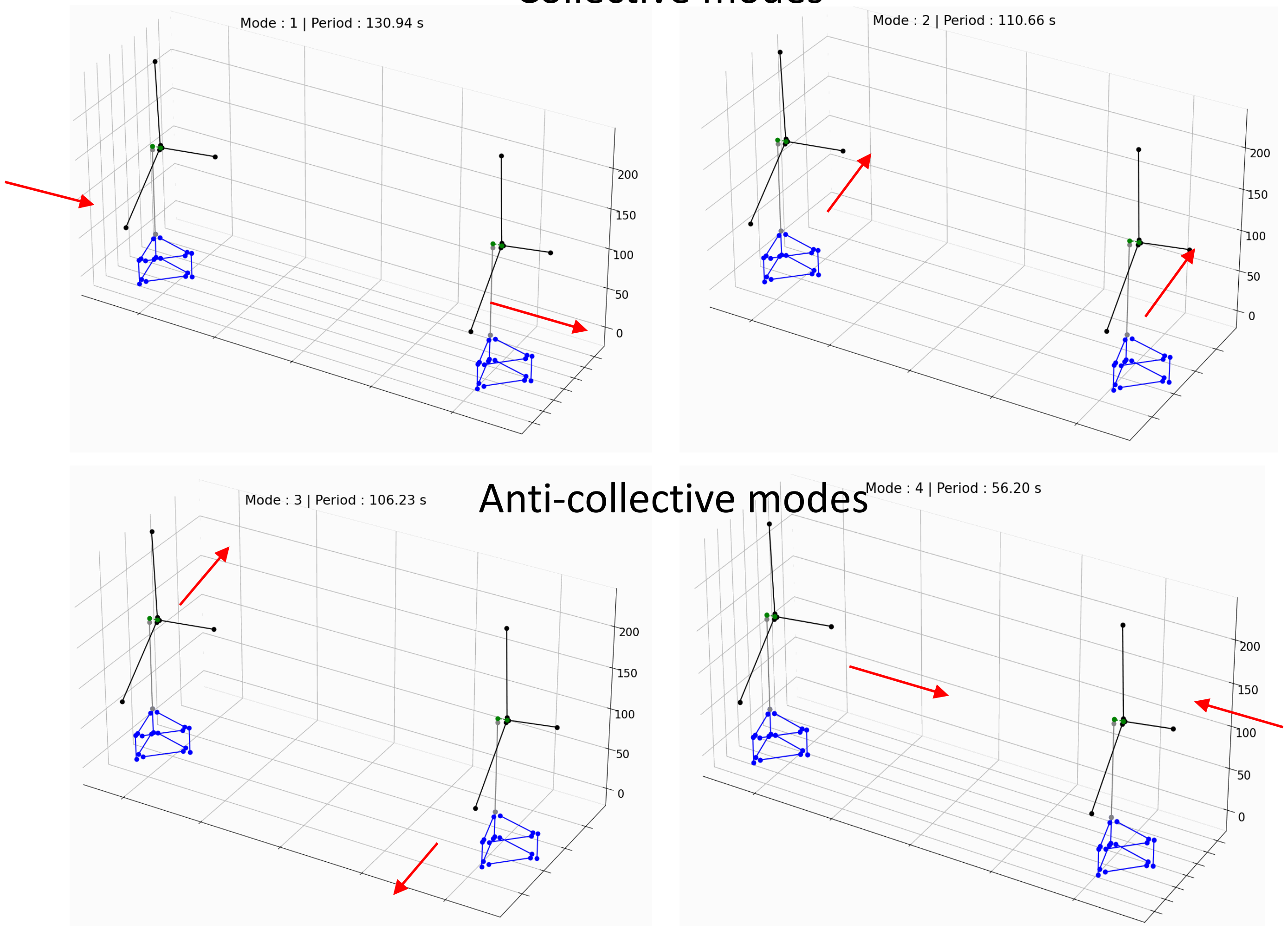
Grid21





First 4 modes for D241_clmp30_B300

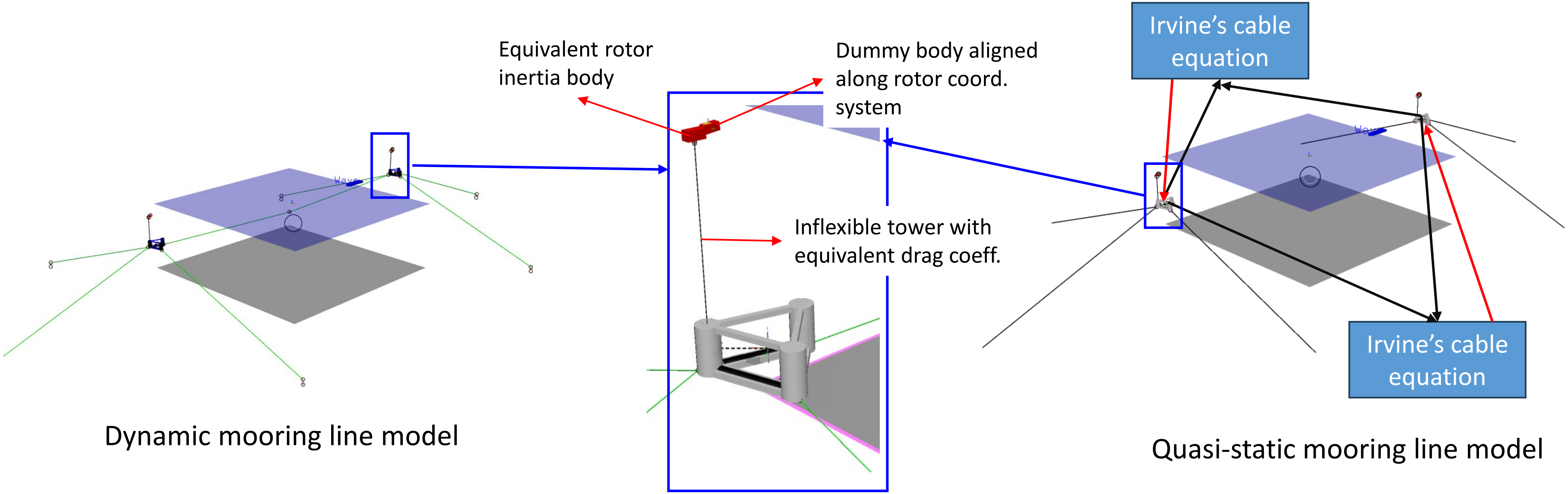
Collective modes



Methodology

- Environment condition : **Hs – 2m , Tp – 7s**, **Wind speed = 12 m/s**, Turbulent wind

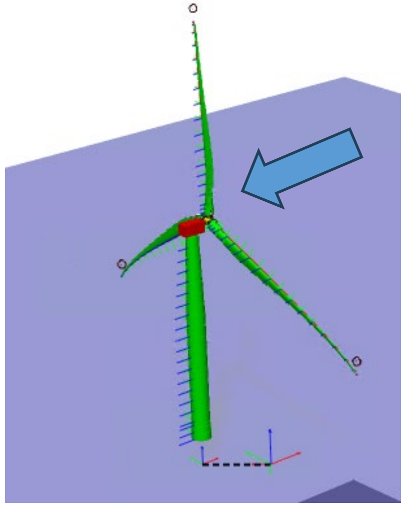
- Focus is to conclude on the importance of damping -> two statically equivalent models are built :
  - Quasi-static mooring line model -> Catenary/Irvine’s cable equations
  - Dynamic mooring line model -> RIFLEX FEM model

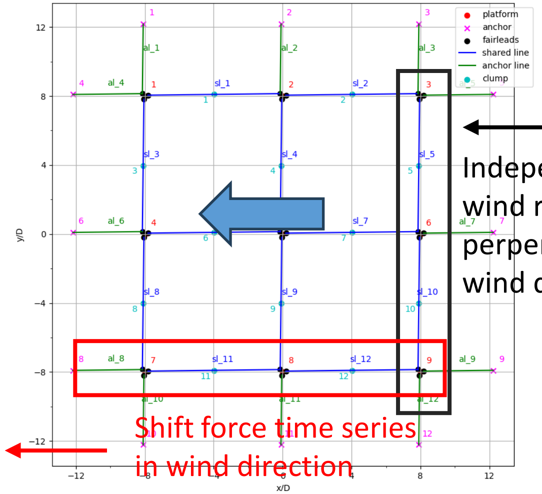


Methodology

- 2 step simplified simulation approach

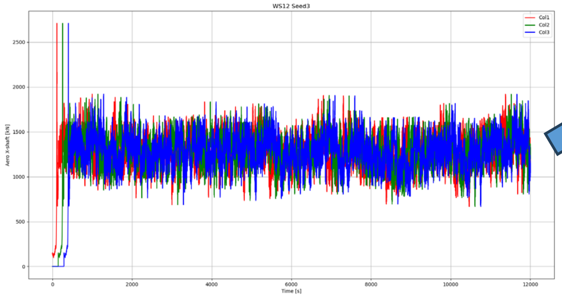
Step 1 - Turbulent wind fixed tower + rotor test -> obtain time series of 6 dof aero force



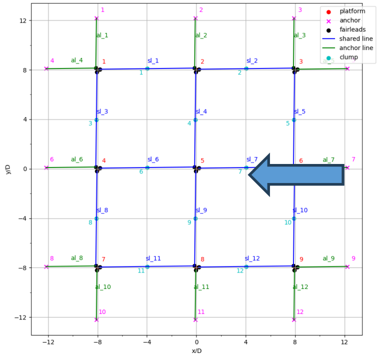


Independent wind realizations perpendicular to wind direction

Shift force time series in wind direction

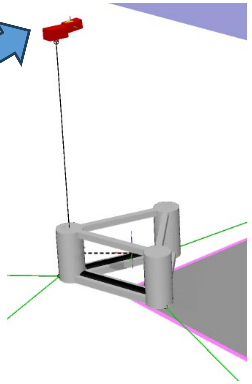


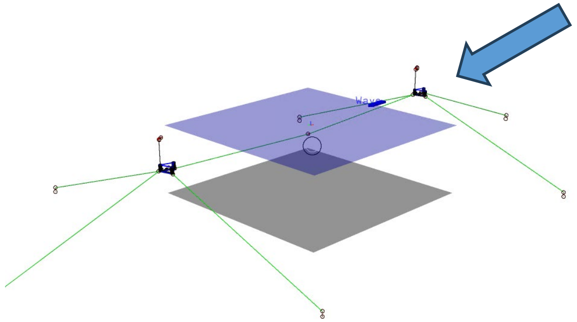
Step 2 – Prescribed 6 dof aero force + constant wind (to get the tower drag) + wave simulation



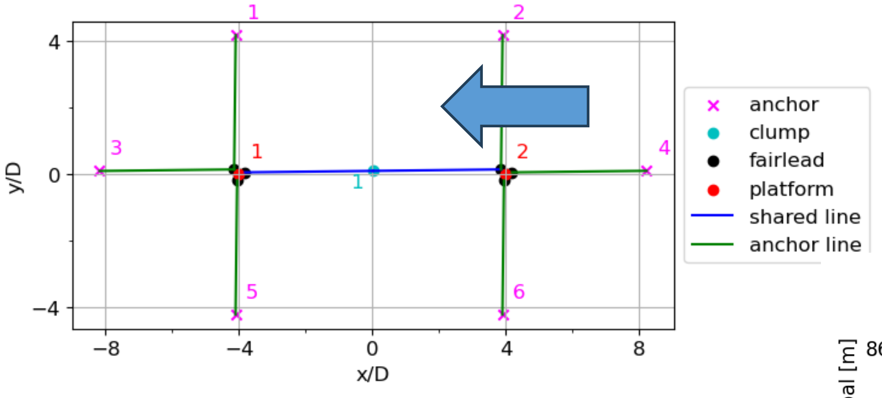
☺ Computationally efficient approach (10x faster)

☹ No effect of platform motions on aerodynamics

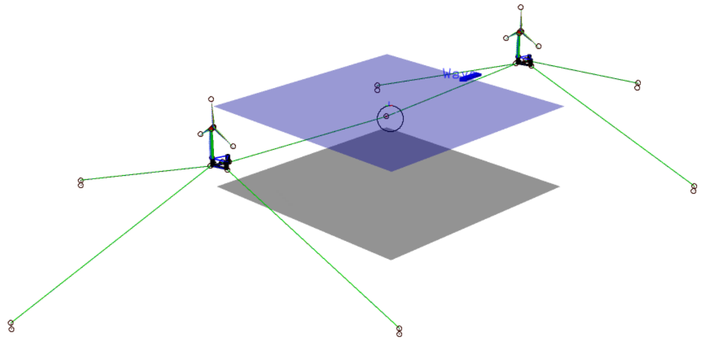


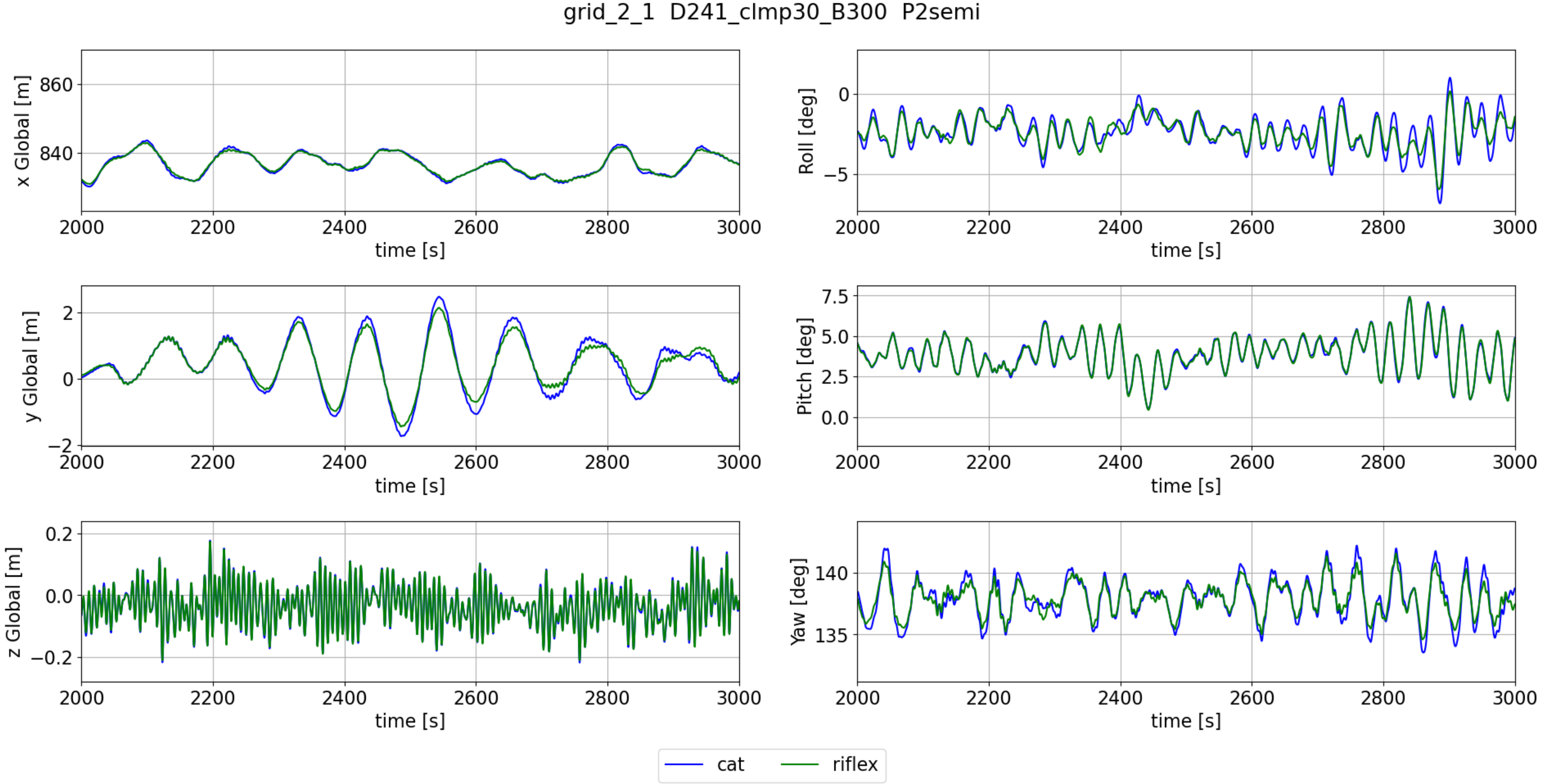


Results – Grid21 Platform motions

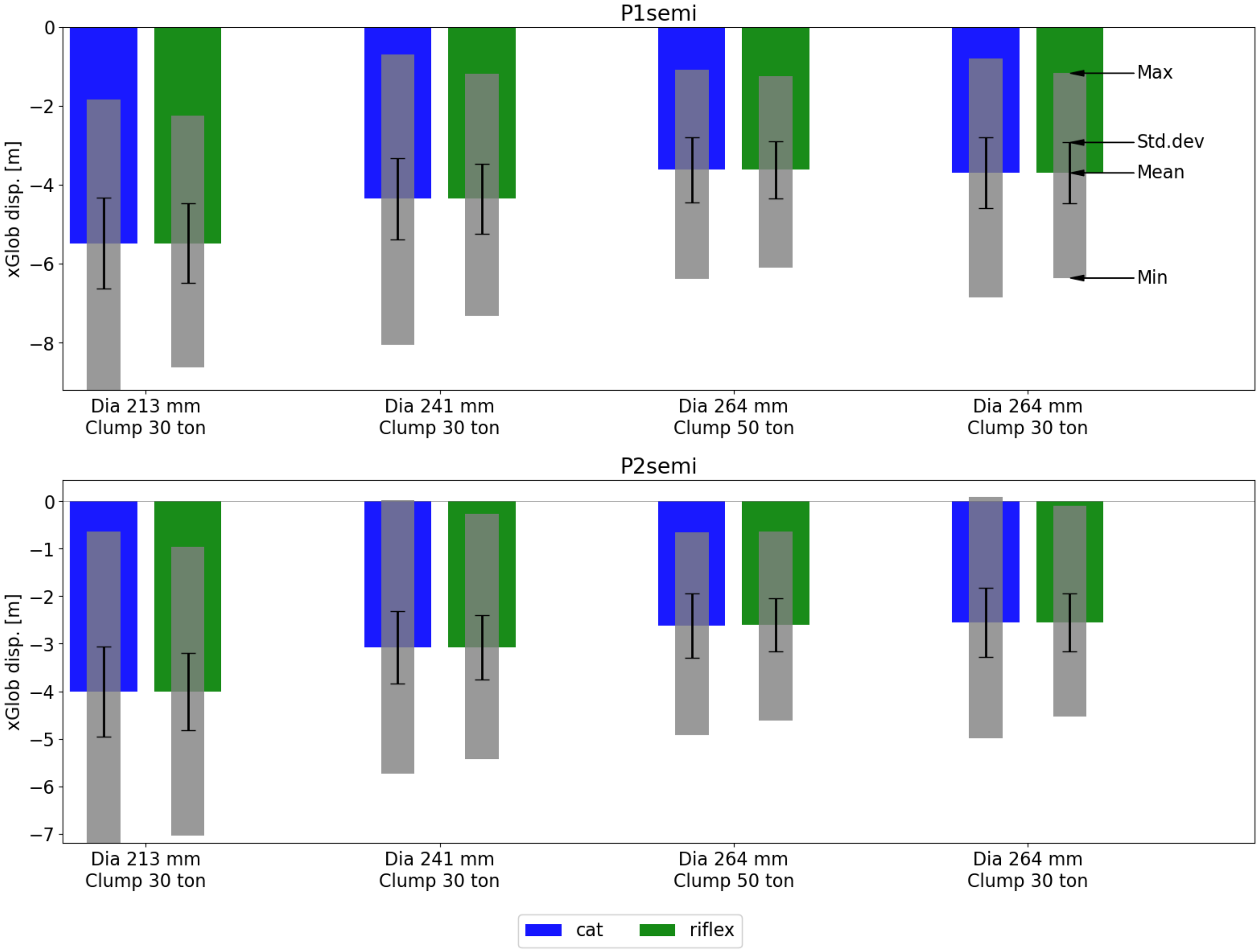


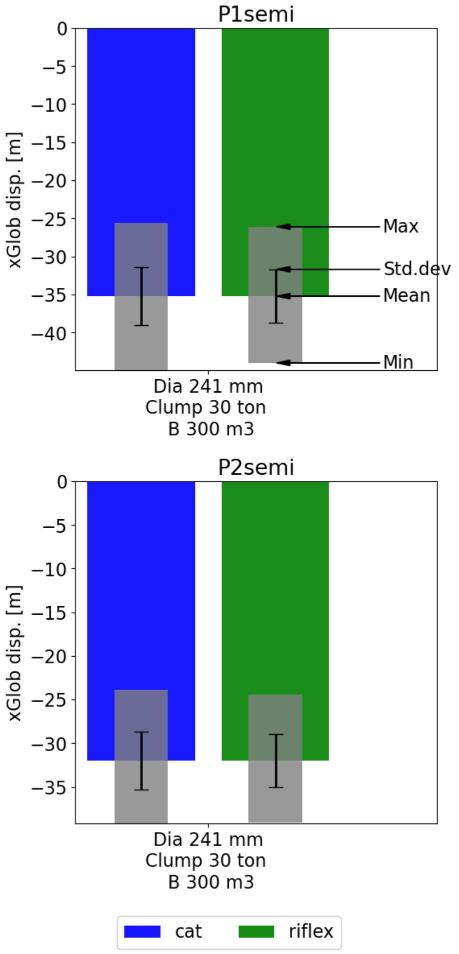
General observation over all tested cases -> A portion of motion time series of the least stiff system is shown below -> **The dynamic and quasi-static line models lead to nearly same motion responses for all the cases (small low frequency variations observed)**

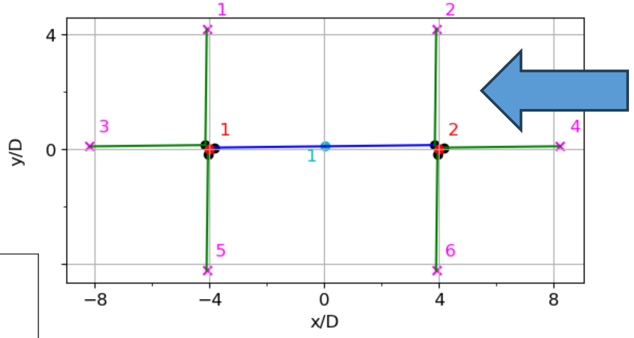




Results – Grid21 Platform motion statistics



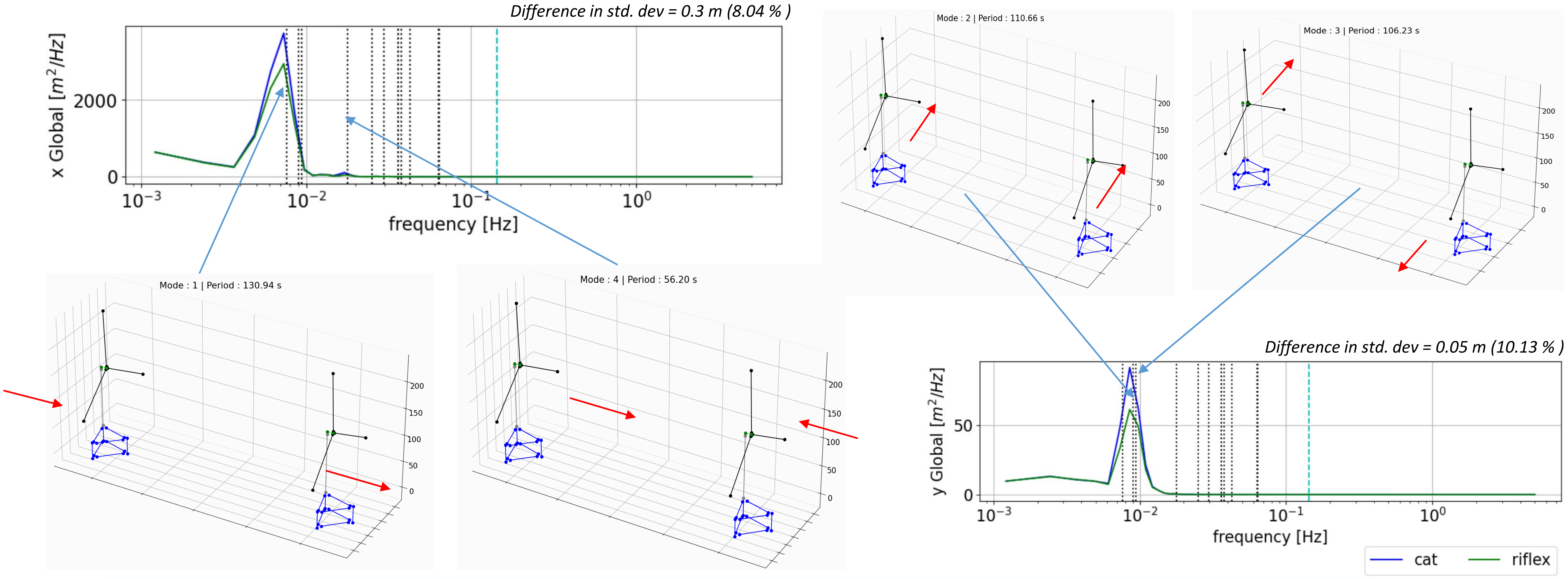




- Statistically the motions are similar between catenary and RIFLEX models.
- For all the cases std. dev are comparable between RIFLEX and catenary -> slightly smaller in case of RIFLEX due to damping.
- The max. difference in std. deviation is 0.3 m (Buoy case)

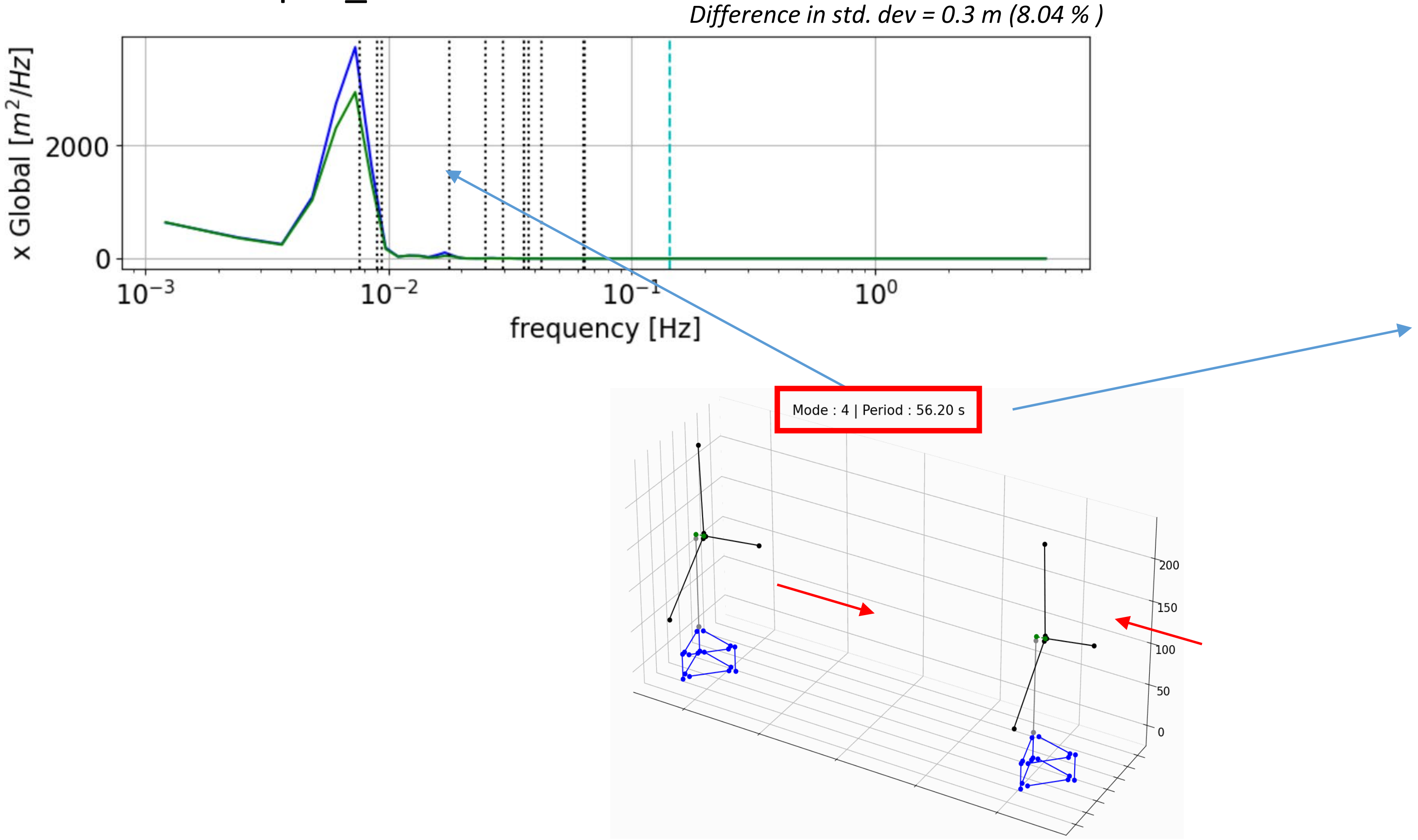
Results – Grid21 Platform motion spectrum

The differences in motions of the platform are seen at specific eigen frequencies – motion spectrum for D241Clmp30_B300 P2semi is shown as an example.



Results – Grid21 Platform motion spectrum

D241Clmp30_B300 P2semi



Eigen period of the anti-collective mode not low enough for the line damping to be dominant.

Similar observations were made for Grid33 variant of the lattice.

Conclusion

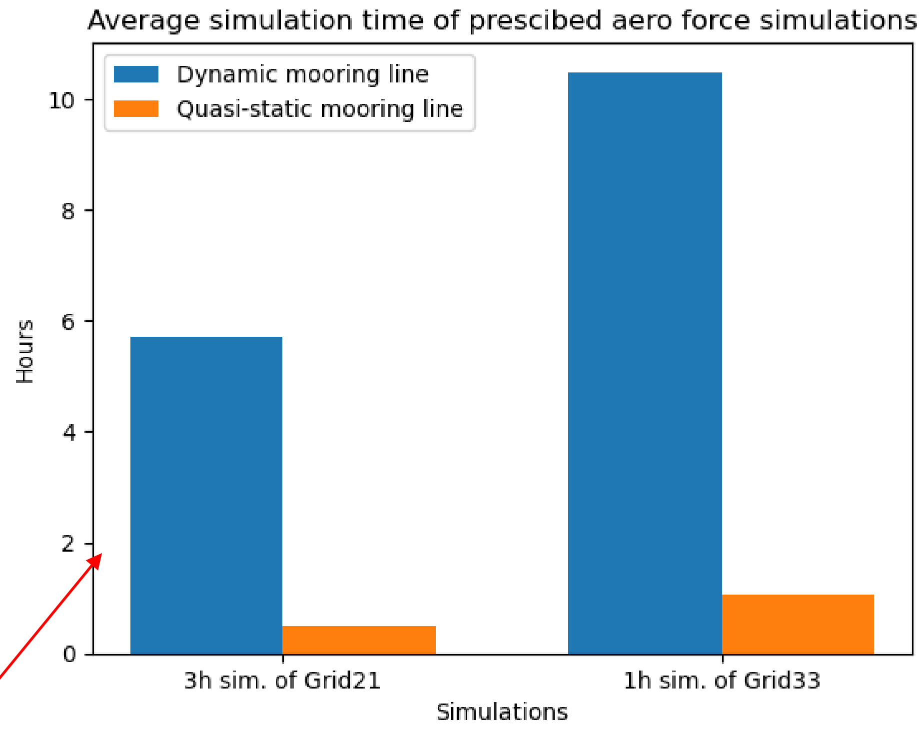
- Compared the motions of platforms the in 2 shared mooring lattice configurations with 5 different variants of the mooring system design with dynamic and quasi-static mooring line models.

- For near rated condition (and extreme wave condition (Hs = 11 m, Tp = 12 s – not shown in the presentation) no significant difference in platform motions is seen between using a dynamic mooring line model and quasi-static mooring line model.

- The small differences occur at specific eigen frequencies of the lattice.

- Comparing the dynamic and quasi-static mooring line models (Grid21) :
    - Max. difference in std. dev in displacement in x global direction – 0.3 m (Deviation of approx. 8.04%)

- Significant time saving in simulation can be obtained by using a quasi-static mooring line model for lattice simulations.



Thank you

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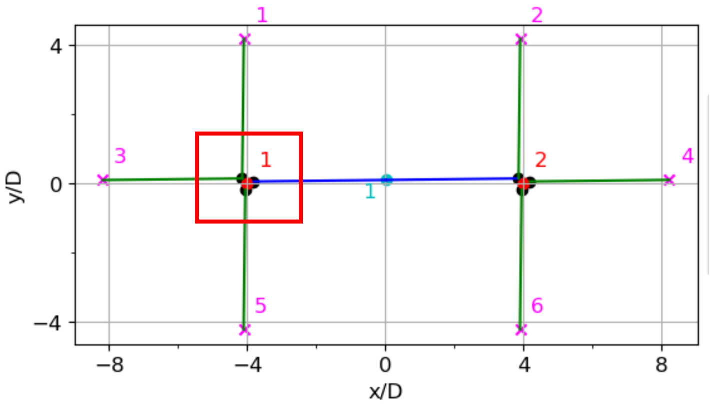
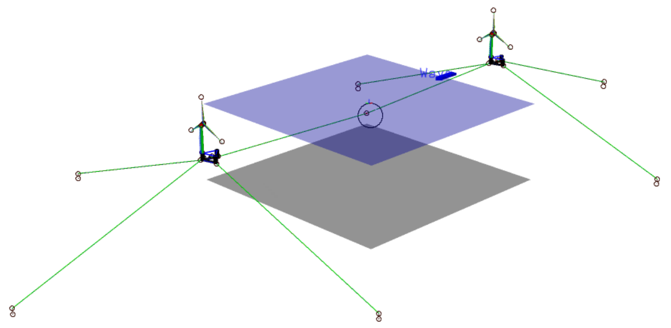
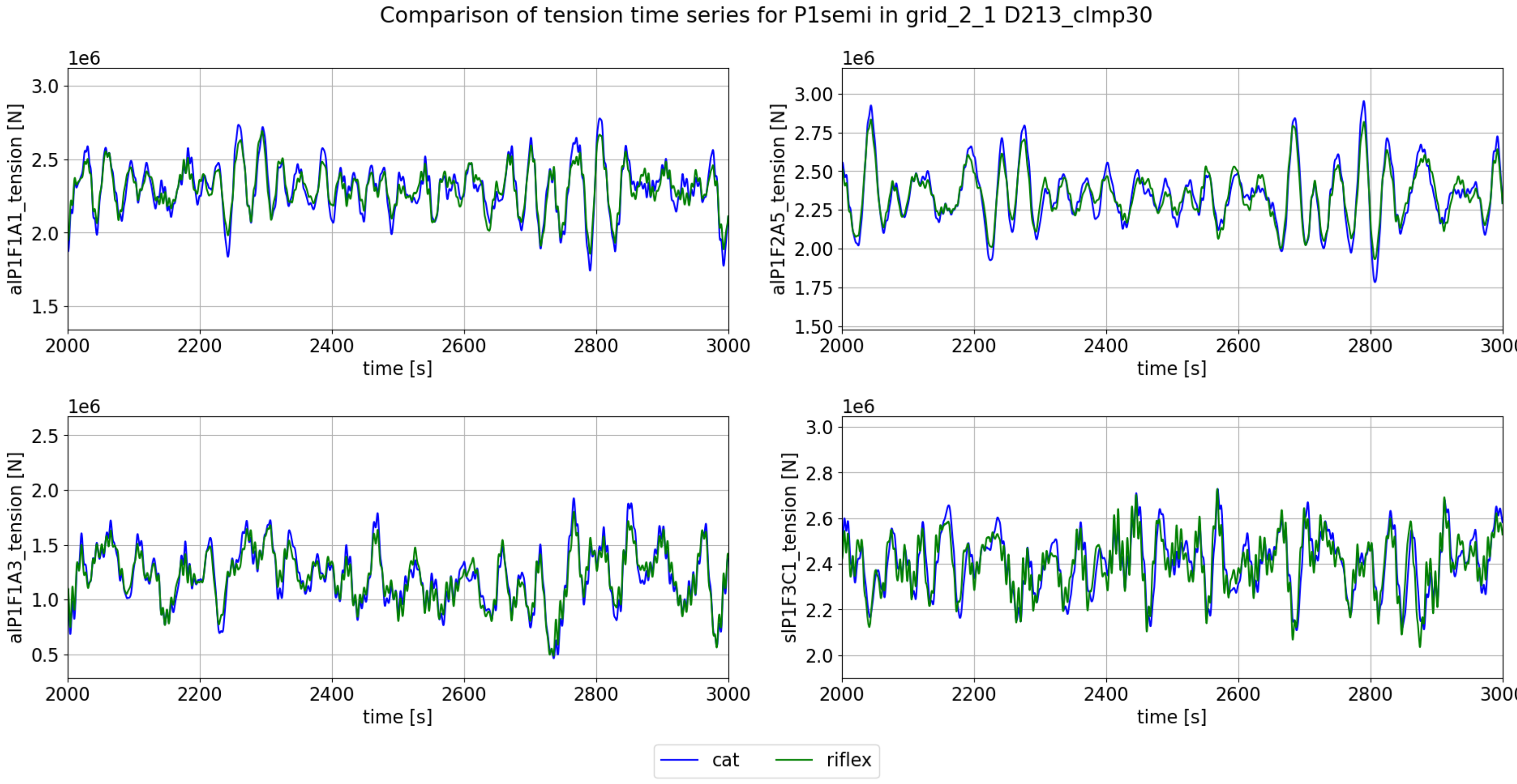
Grid21 – Tension time series

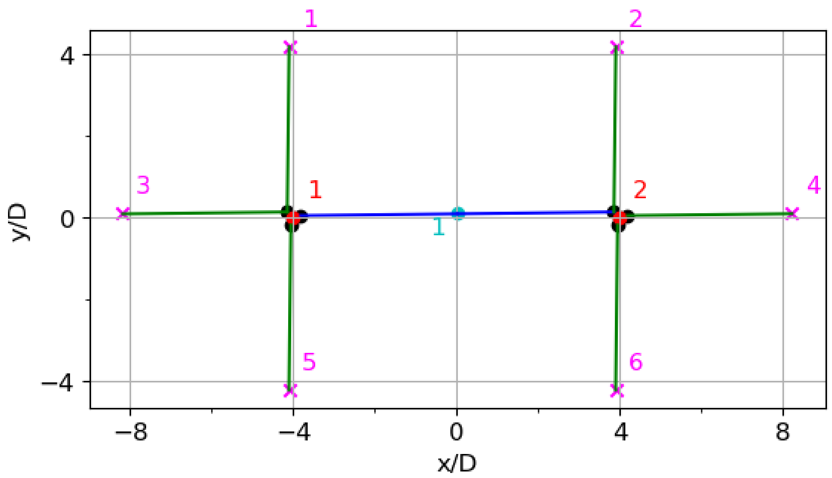
Small motions of the platform ⇒ good agreement between dynamic and quasi-static tensions

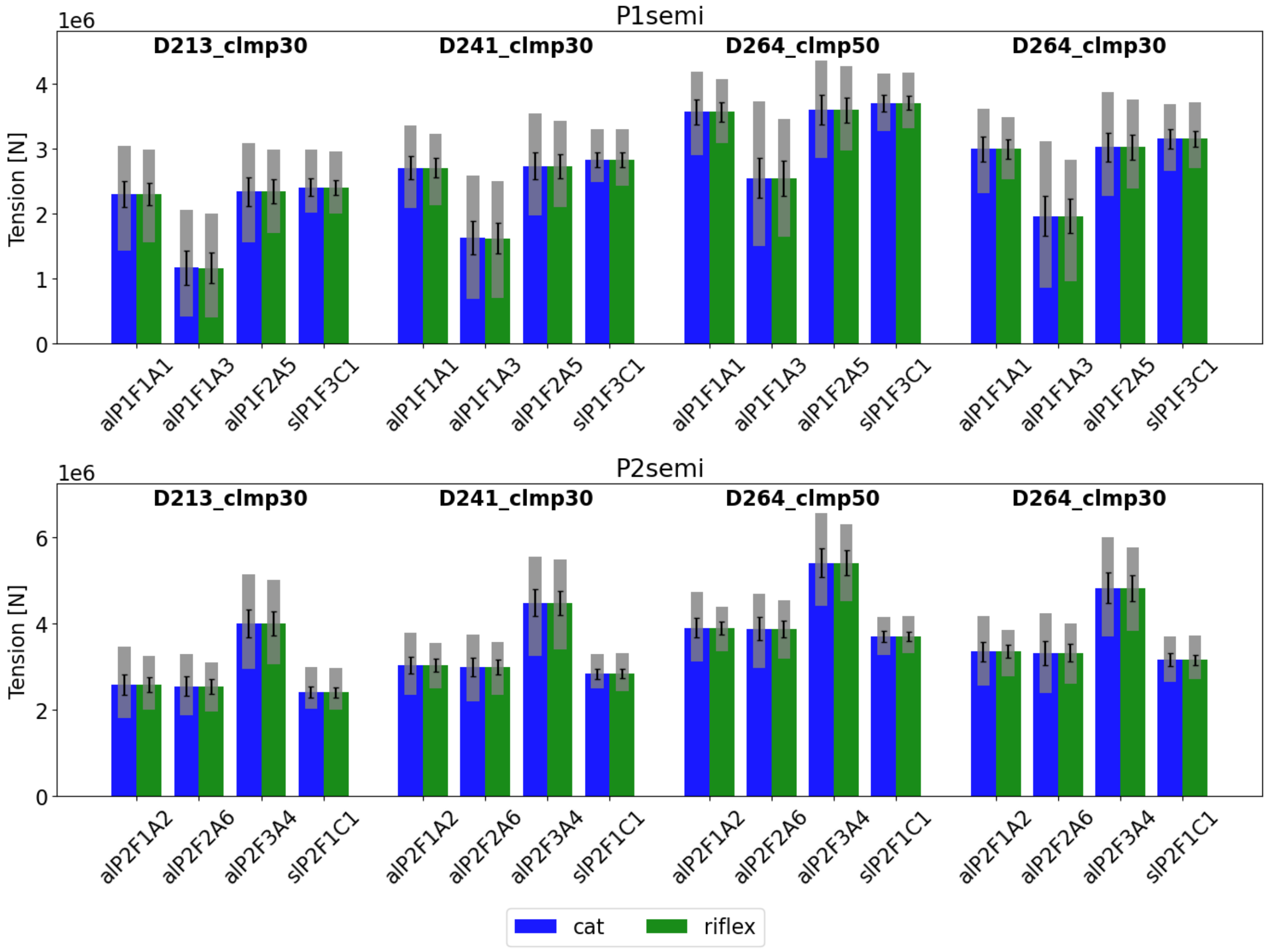






Grid21 – Tension statistics





- Max tension occurs in P2 al_4 as expected due to thrust accumulation.
- Similar tensions from both dynamic as well as quasi-static approaches.
- No slacking of the lines in any of the designs for this sea state.
- Max tensions much less than MBL –> this may not be the driving condition.