Correlation between Acceleration and Drivetrain Load Effects for Monopile Offshore Wind Turbines

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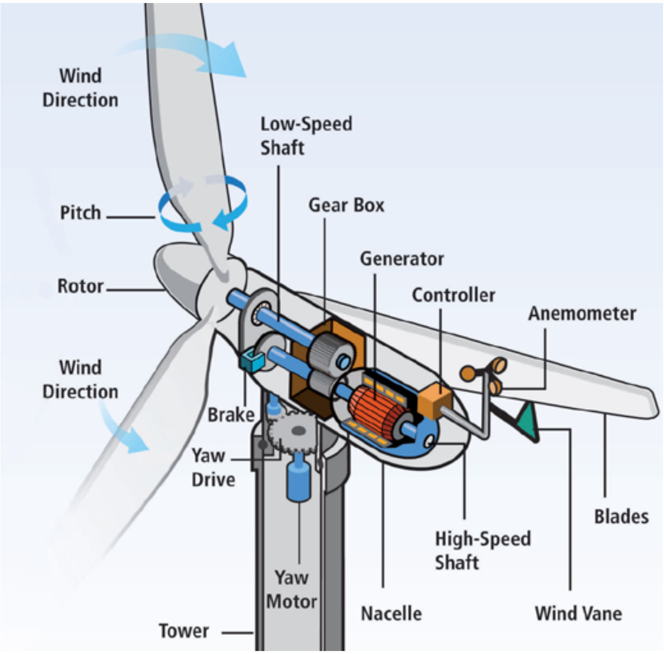
Objectives

- There is a common practice in the wind industry to set a limit for the maximum axial acceleration on the tower-top in the range of 0.2g-0.3g (in particular for the floating wind turbines)

- Is this limit rational?
- What is the correlation between axial acceleration and responses in drivetrain?



Method & Model

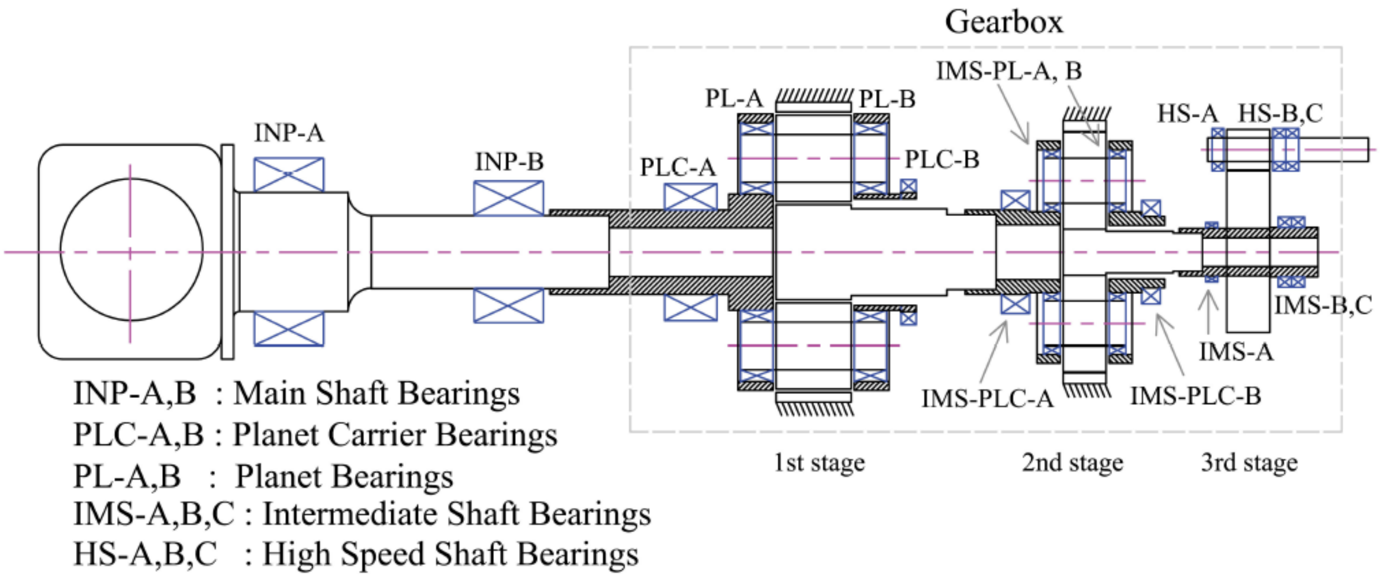
- Effect of tower-top maximum axial acceleration on the drivetrain installed on a monopile offshore wind turbine was investigated.

- Wind/ wave data from an actual shallow water site “North Sea Centre” site from the MARINA platform project with water depth of 29 m is selected. This is similar to the Dogger Bank wind farm.

Method & Model

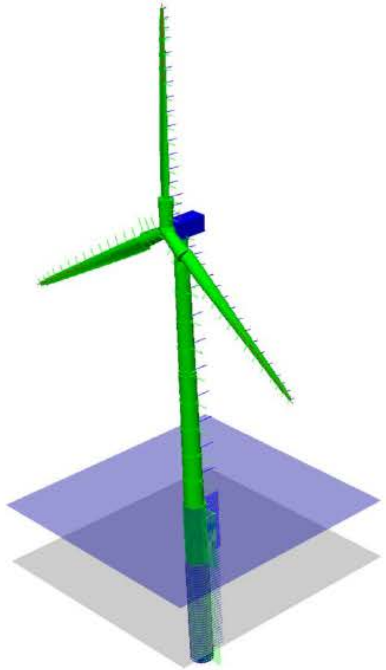
Models:

- NREL 5 MW reference turbine, supported by the monopile foundation from the OC3 study.
- Nowitech/NREL 5 MW reference gearbox.

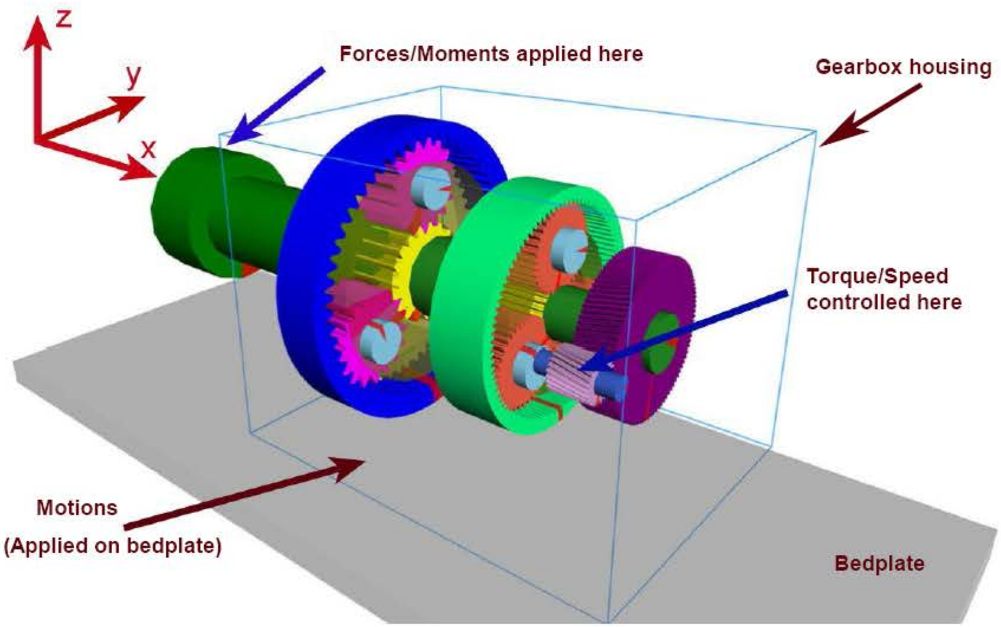


Method & Model

- De-coupled modelling approach:



(a) 5MW wind turbine model in SIMO-RIFLEX-AeroDyn



(b) MBS model of 5 MW reference drivetrain [11]

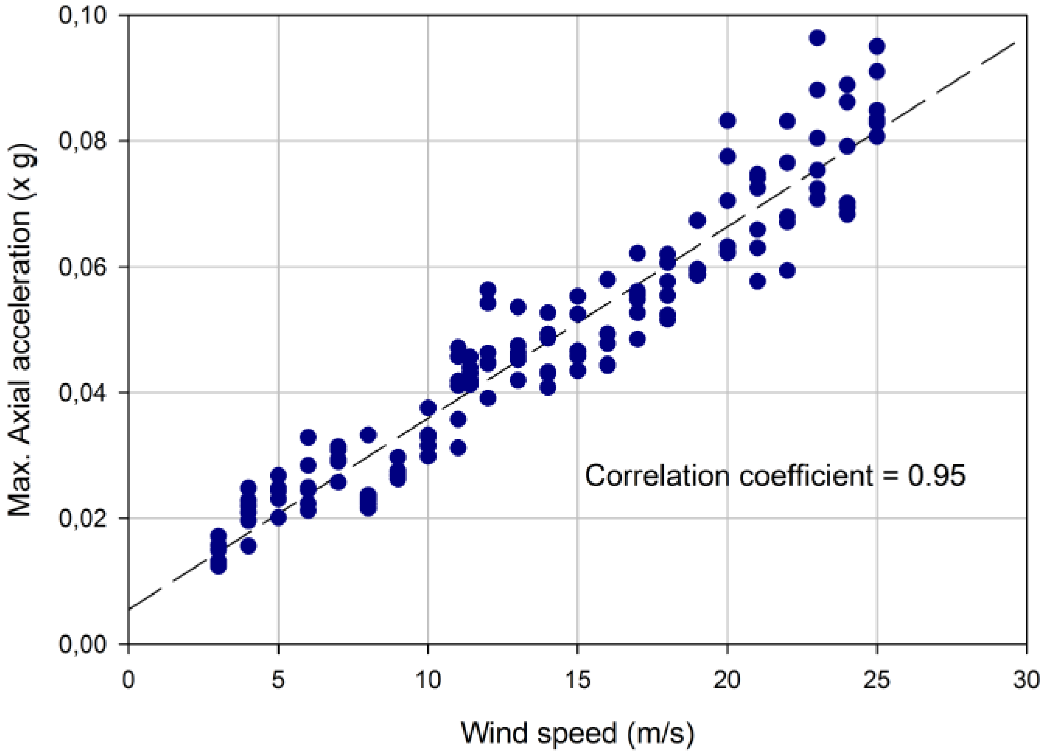
Method & Model

- 24 EC were considered, from cut-in to cut-out:

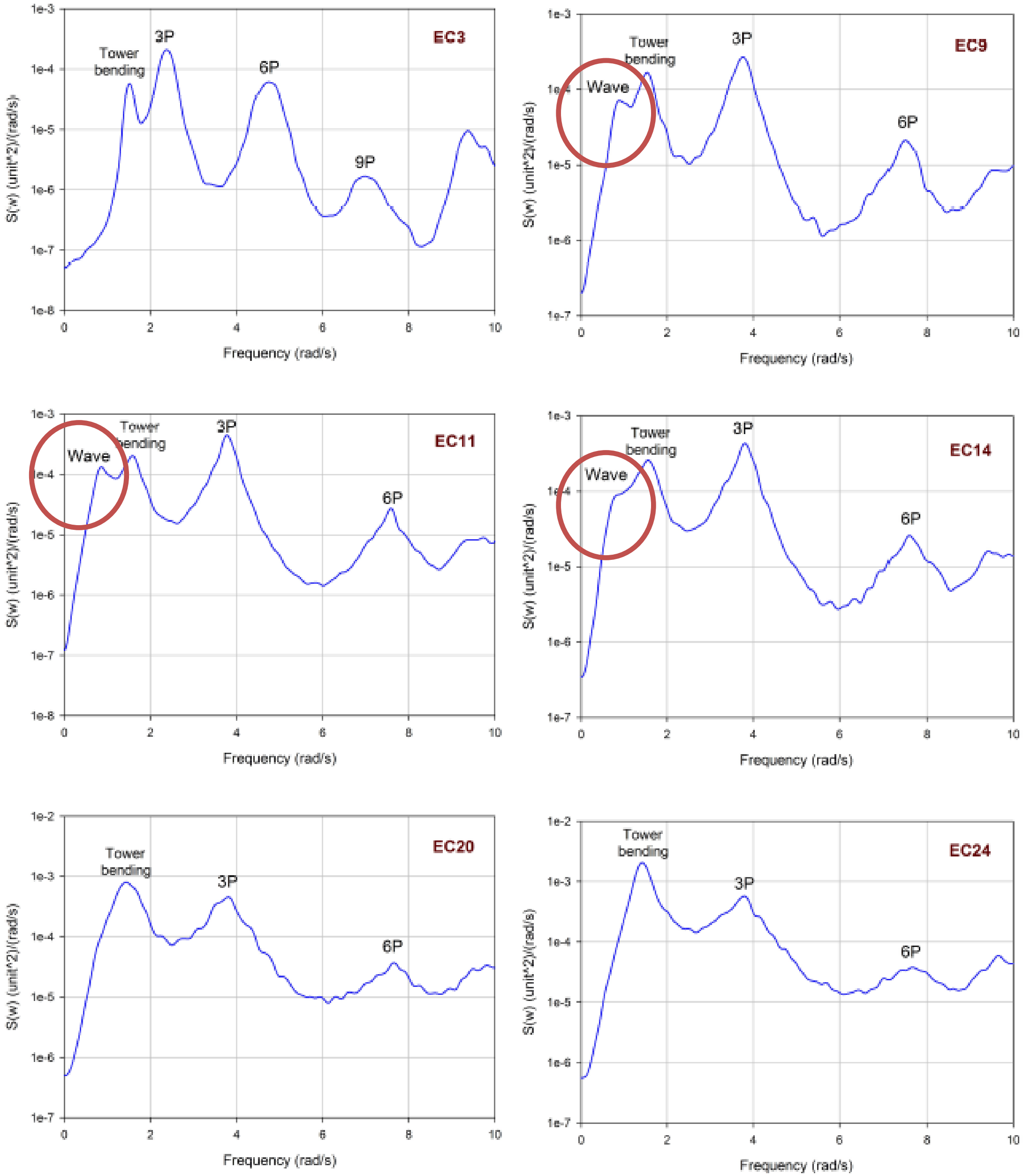
EC	*1*	2	*3*	4	*5*	6	*7*	8	9	*10*	11	*12*
U_w (m/s)	3	4	5	6	7	8	9	10	11	11.4	12	13
H_s (m)	0.59	0.72	0.85	1	1.17	1.34	1.52	1.72	1.92	2	2.13	2.35
T_p (s)	6.38	6.32	6.28	6.27	6.31	6.35	6.41	6.5	6.59	6.62	6.69	6.81
used in MBS	√		√		√		√			√		√
EC	**13**	**14**	**15**	***16***	**17**	**18**	***19***	**20**	**21**	***22***	**23**	***24***
U_w (m/s)	14	15	16	17	18	19	20	21	22	23	24	25
H_s (m)	2.57	2.81	3.05	3.3	3.55	3.81	4.08	4.35	4.63	4.92	5.21	5.5
T_p (s)	6.92	7.06	7.19	7.33	7.47	7.62	7.78	7.93	8.09	8.27	8.43	8.6
used in MBS				√			√			√		√

- 10 min. simulation, 6 seeds
- Results from all EC were used for evaluating main shaft responses
- Results from selected EC were used for MBS analysis and calculating forces on bearings and gears

Results



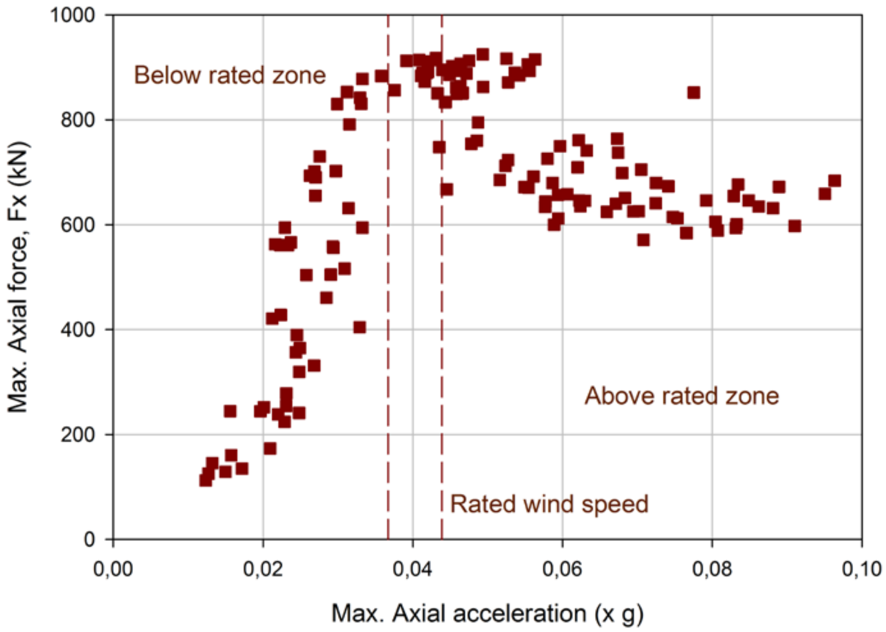
Max. axial acceleration vs. wind speed



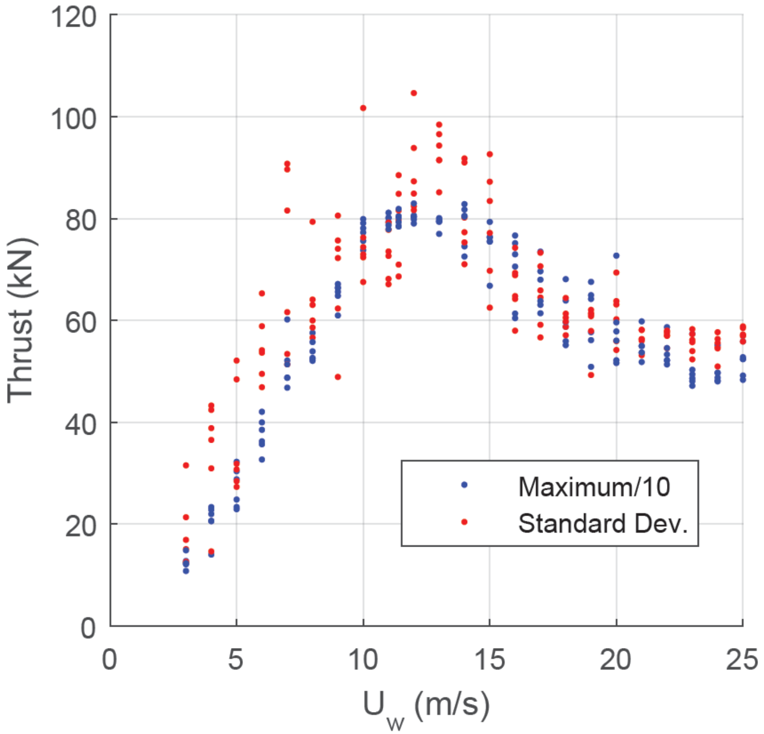
Spectrum of axial acceleration in different environmental conditions

Results

Axial force:



Max. Axial force on tower-top vs. max. axial acceleration



Thrust force vs. wind speed

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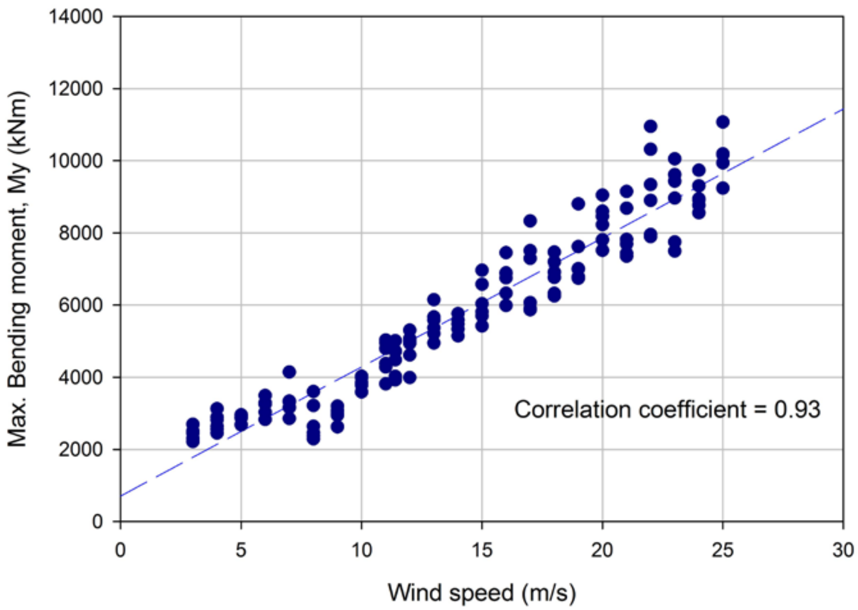
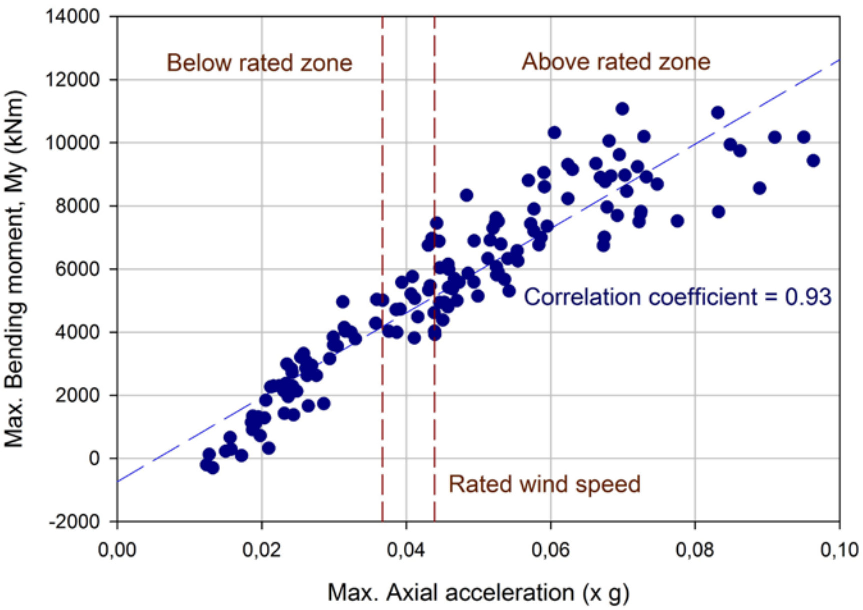
Results

Bending moment:



Max. bending moment vs. wind speed



Max. bending moment on tower-top vs. max. axial acceleration

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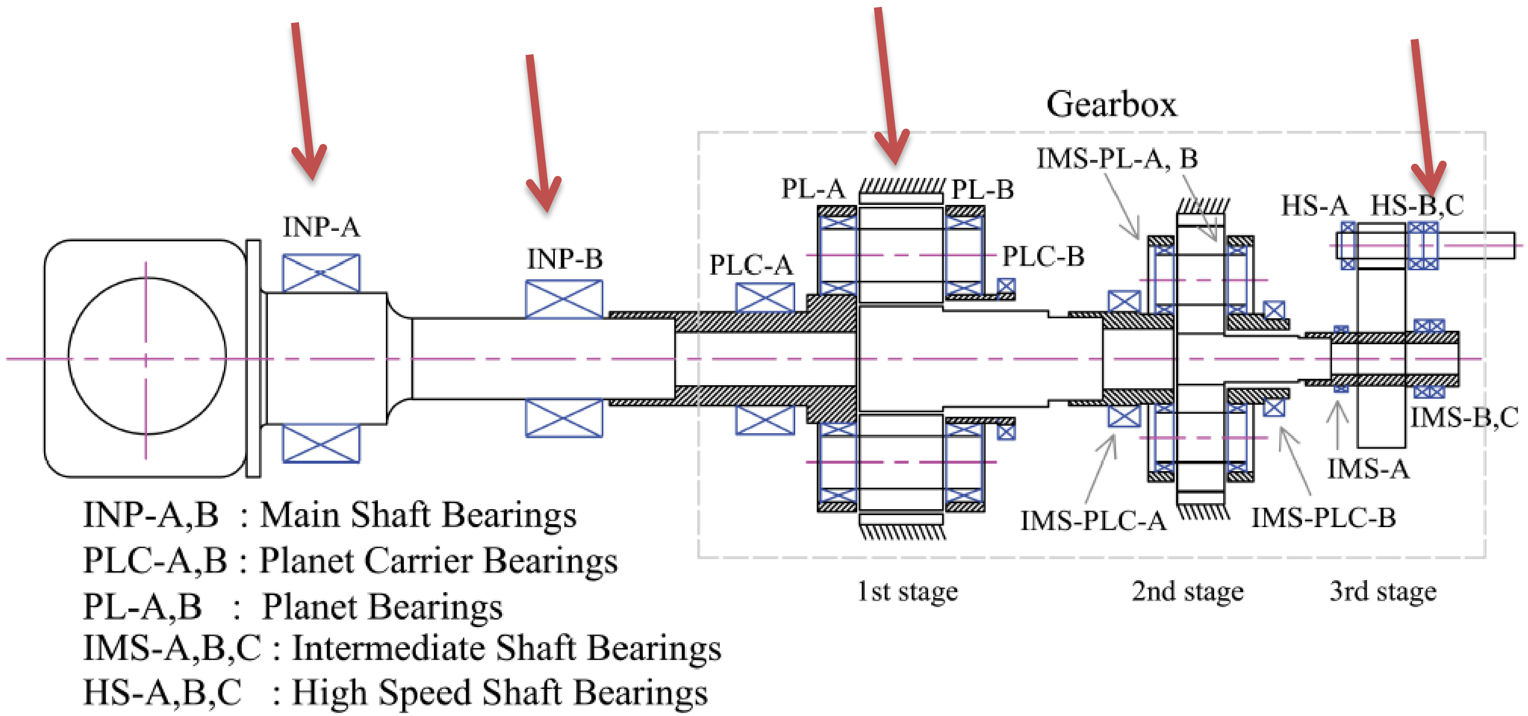
Results

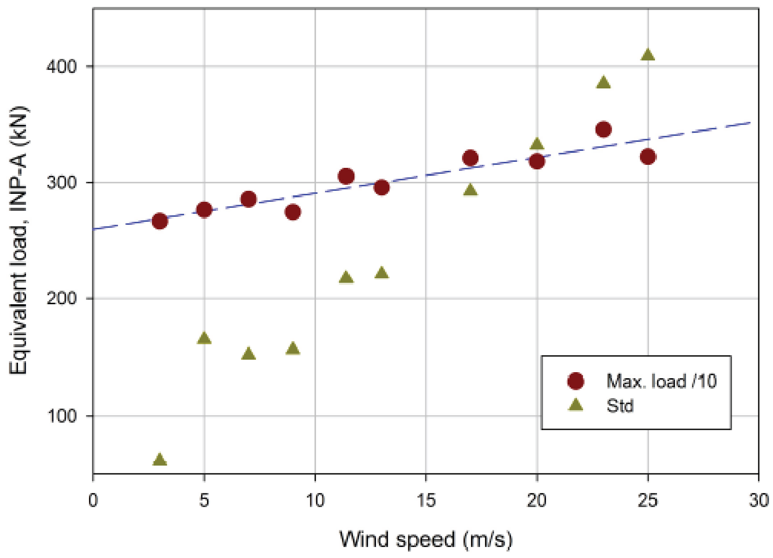
Drivetrain components:



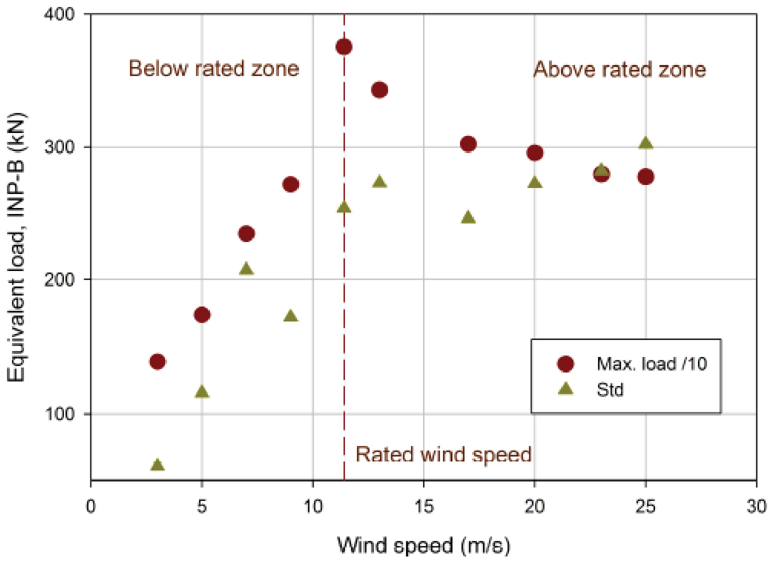
Nowitech/NREL 5 MW Reference Drivetrain

Results

Drivetrain components:



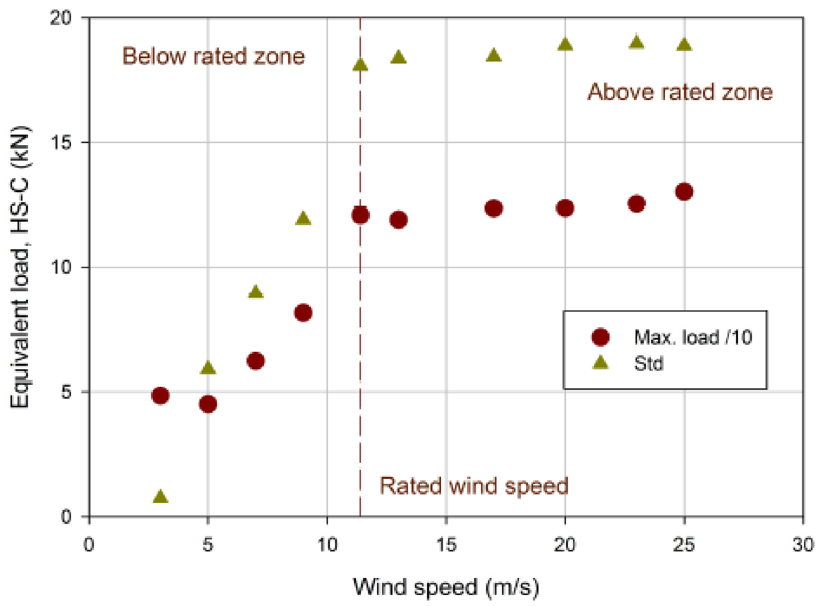
Main bearing: INP-A



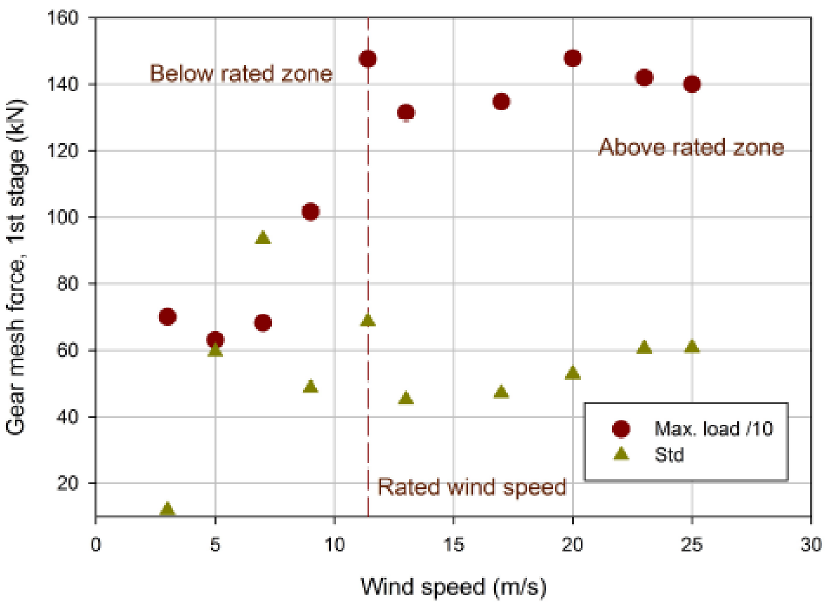
Main bearing: INP-B

Results

Drivetrain components:



High speed stage bearing: HS-C



1st stage gear mesh force

Discussion & Conclusion

- The results showed that the maximum tower-top acceleration is about 0.1g for this case study monopile.
- The axial acceleration increases with the wind speed.
- No correlation was found between the maximum axial force on the tower-top and the maximum axial acceleration. The axial force follows the thrust force mainly. (In a 4-point support configuration, the axial force on the main shaft is the design driver for the second main bearing).

Discussion & Conclusion

- The tower-top bending moment was found to increase as the wind increase. (The bending moment is a design driver for the main shaft and the main bearing).
- The load effect of the components, gears and bearings, inside the gearbox were found to be <u>not correlated</u> with the axial acceleration. They mainly follow the torque and are influenced by the power control system.

References

- 5 MW reference offshore gearbox:

Nejad A.R., Guo Y., Gao Z., and Moan T. *Development of a 5 MW reference gearbox for offshore wind turbines*. **Wind Energy**, DOI:10.1002/we.1884, 2015.

- Environmental data:

Li L., Gao Z., and Moan T. *Joint long-term environmental conditions at five European offshore sites for design of combined wind and wave energy devices*. **Journal of Offshore Mechanics and Arctic Engineering**, 137(3), 2015.

Thank you