Wind-wave sensitivity assessment of a TLP wind turbine

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DNV GL Renewables Certification

Analysis of loads for a floating TLP wind turbine

- The project had two scopes:
  - Comparison of the results from three codes and with model scale
  - Analysis of the Concept

- Glosten Associates kindly agreed to share the data on the TLP concept *Pelastar.*

- Scope of the presentation is limited to the wind-wave sensitivity investigation using HAWC2 model

http://www.eti.co.uk/project/floating-platform-system-demonstrator/

Overview

- TLP wind turbine numerical model
- Model calibration
- Test cases
- Observations and Conclusions
- Future work
- References

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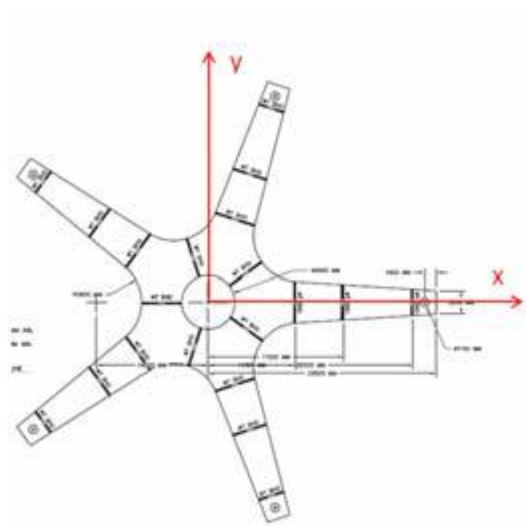
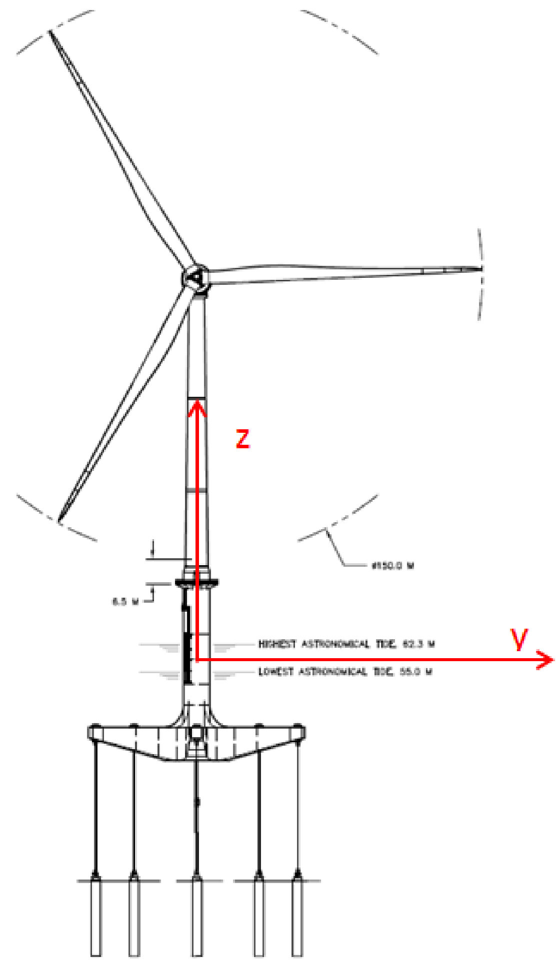
TLP wind turbine numerical model

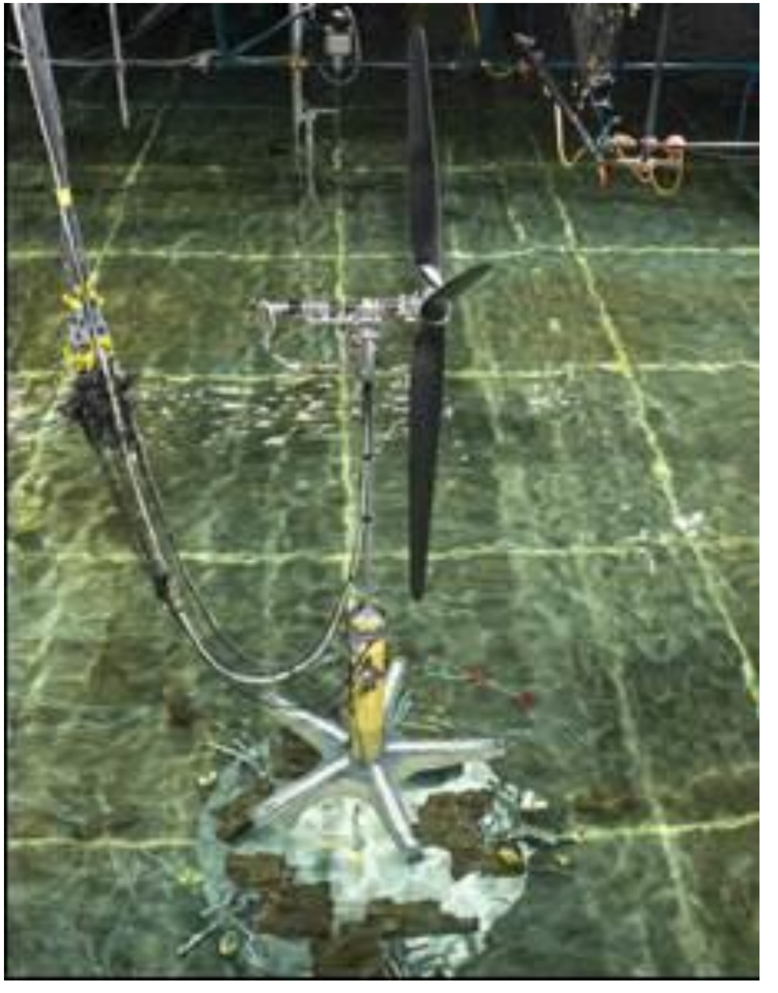
- The platform model is shown below:
  - 5 arms
  - Water depth of 54.7 m
  - Wave kinematics corresponding to the model tests
  - Hydrodynamic coefficients are calibrated based on tank test results
  - Morison’s equation for the hydrodynamic loads
- Wind turbine model – Tuned NREL 5-MW reference wind turbine





Model Calibration

- Aero-elastic model for the TLP turbine is modelled using HAWC2
- The aero-elastic model is calibrated using model test data
- In order to match the ocean basin model, the wind turbine is tuned – such as additional mass and inertia has been included in the RNA, which might cause larger inertial loads.
- For model test data validation, please refer to the reference paper OMAE2015-41874, Vita, *et al.*

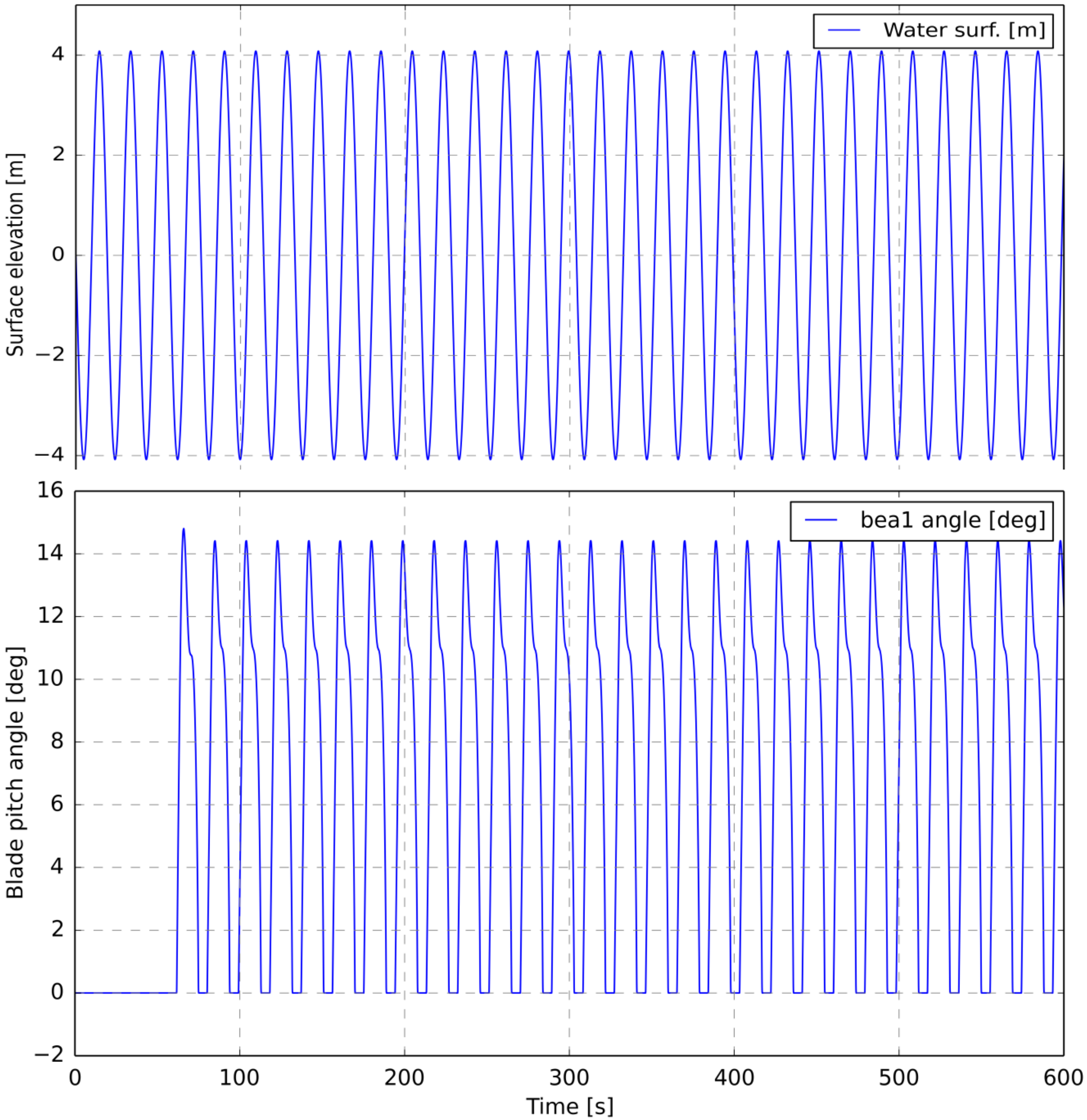


Objectives of the Investigation

- **Motivation**
  - Using onshore controller showed larger variations of pitch angle and loads at above rated wind speed.

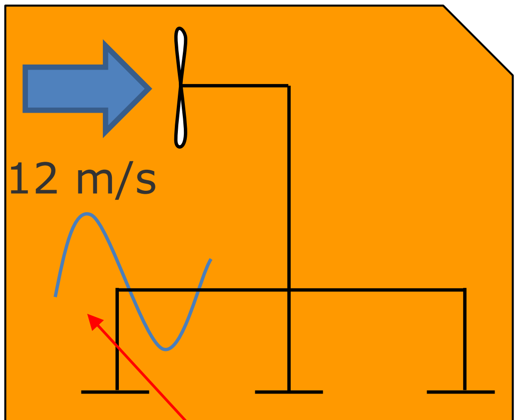
- **Objectives**

  To identify the influence of:
  - Wind
  - Waves
  - Inertia loads
  - Controller

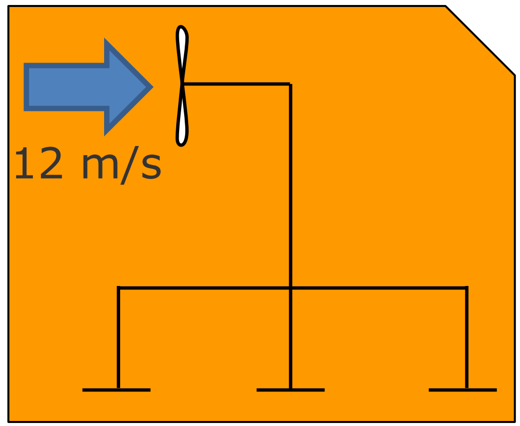


Test cases

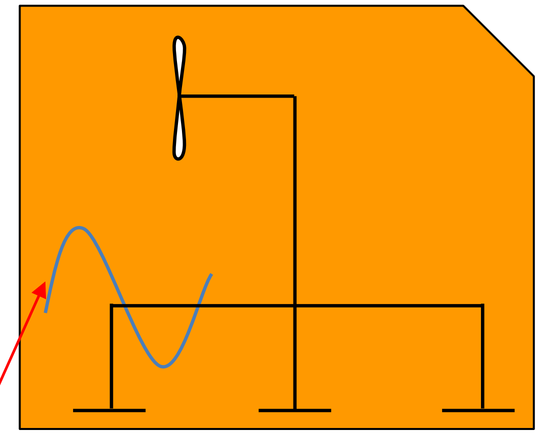
- **Case0**
  - Wind+Waves



- **Case1**
  - Wind alone



- **Case2**
  - Waves alone

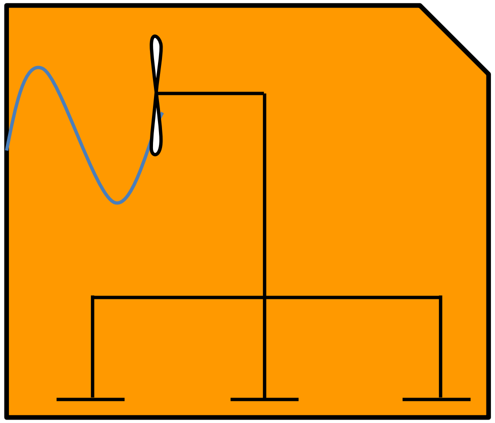


Regular waves, H=8.16 m, T = 19s

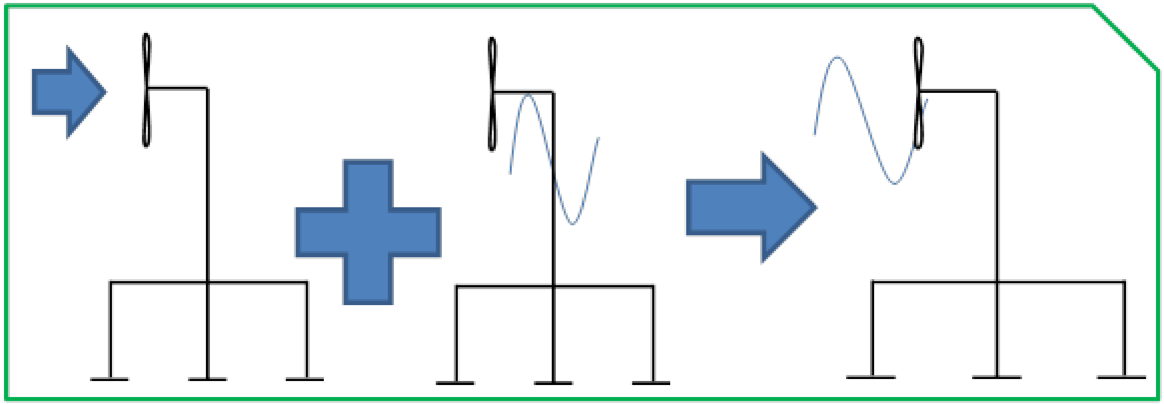
- Large variation of pitch angle and tower bottom loads are observed beyond rated wind speed.
- Influence of basic aerodynamics can be observed.
- Influence of inertia loads can be observed.

Test cases

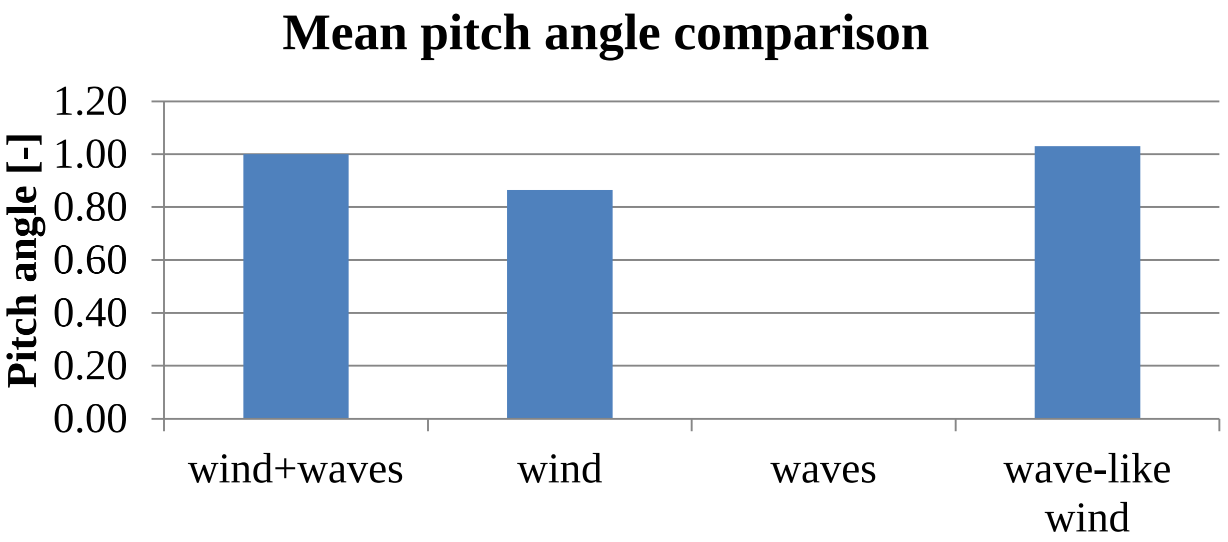
- **Case3**
  - Wave-like wind
  - Steady wind speed of 12 m/s +/- 4 m/s with a time period of 19 s.
  - No waves
  - Onshore controller

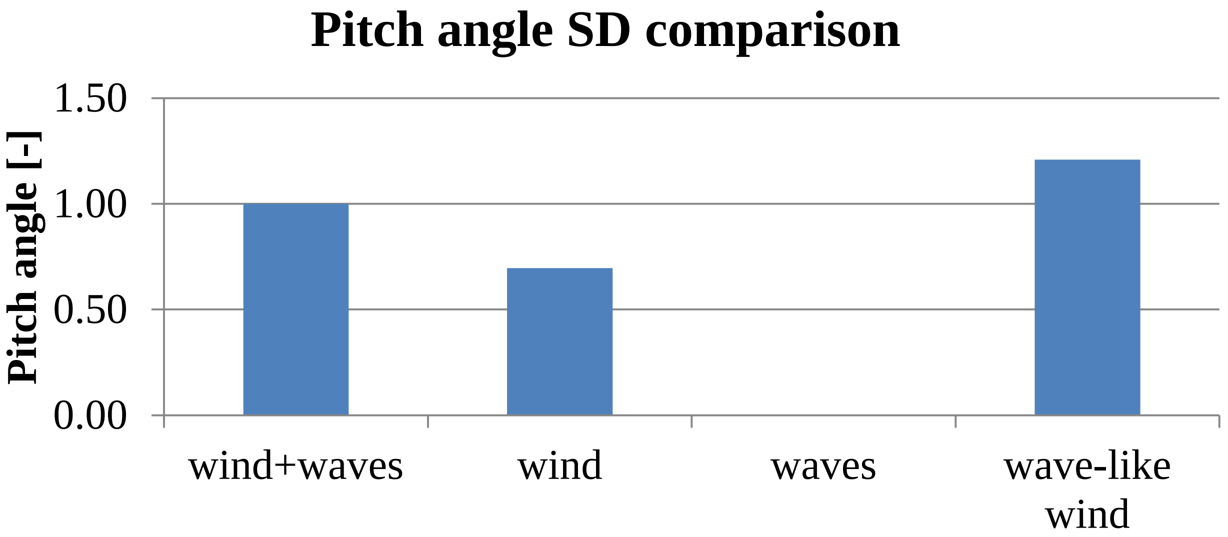


  - Influence of basic aerodynamics + aerodynamics due to onshore controller. But no inertia loads.



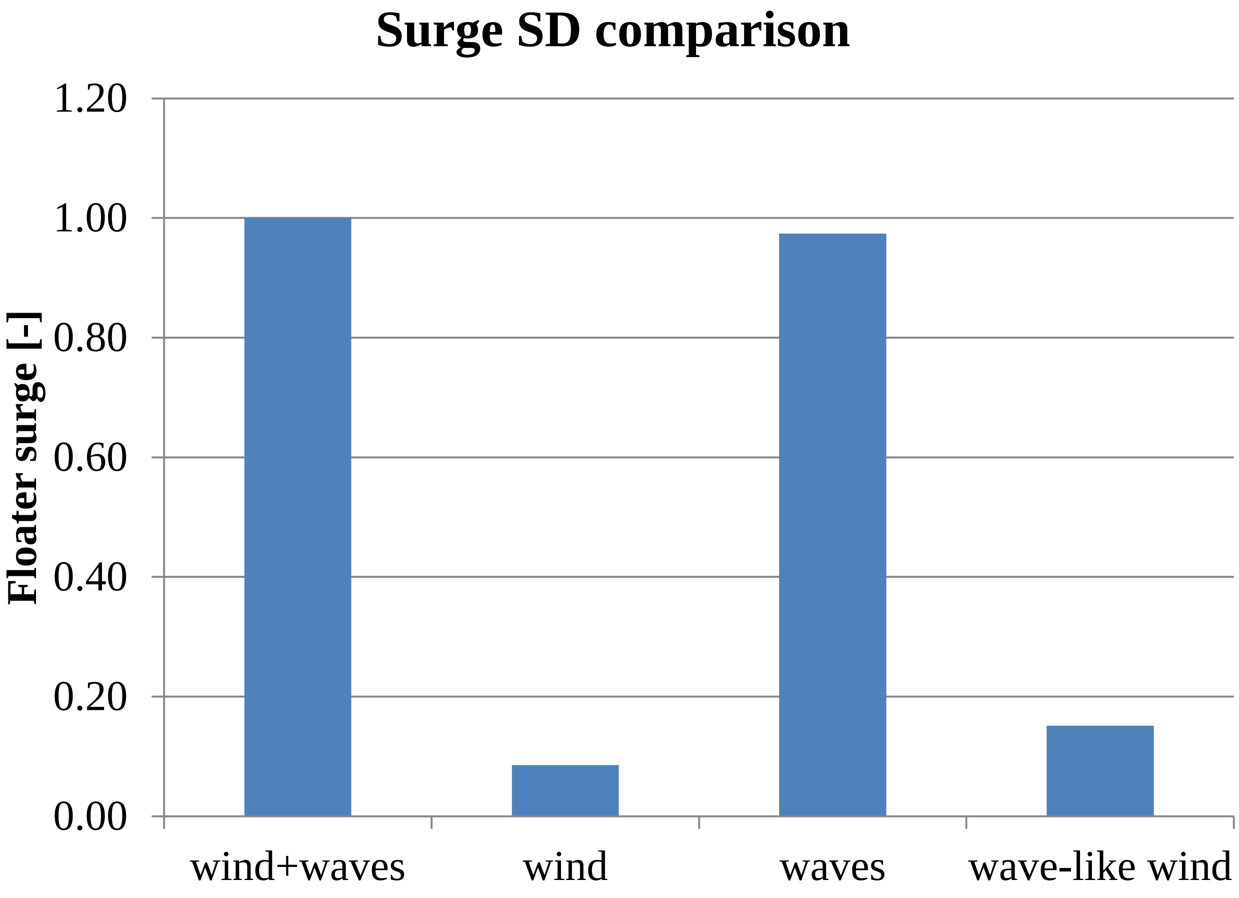
Results – Blade pitch angle comparison (Normalized)





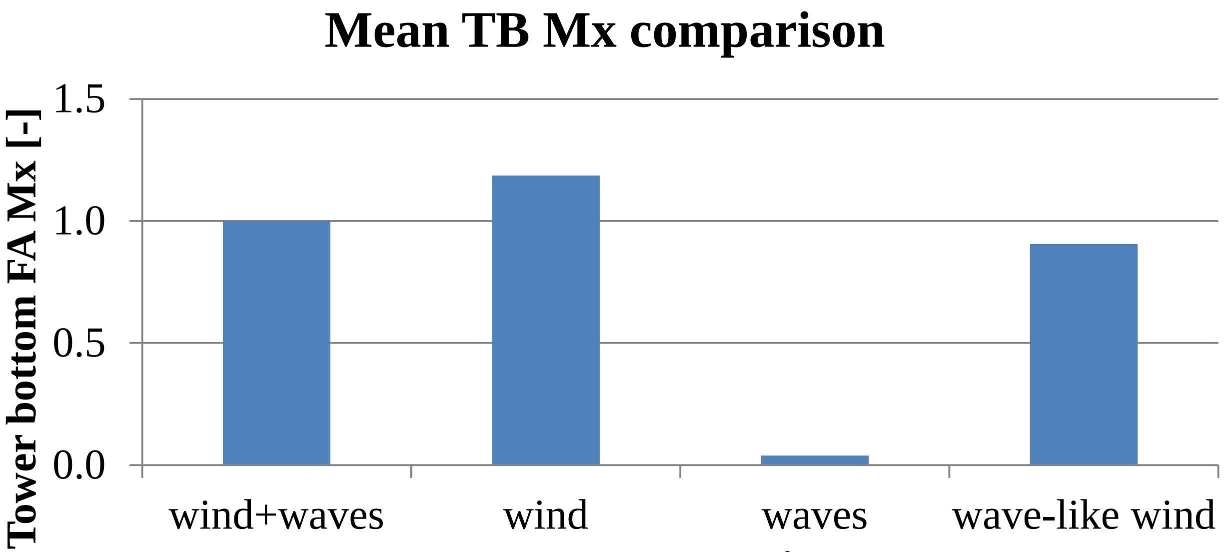
- Pitch angle is not very much affected between the wave-like wind case and base case!!

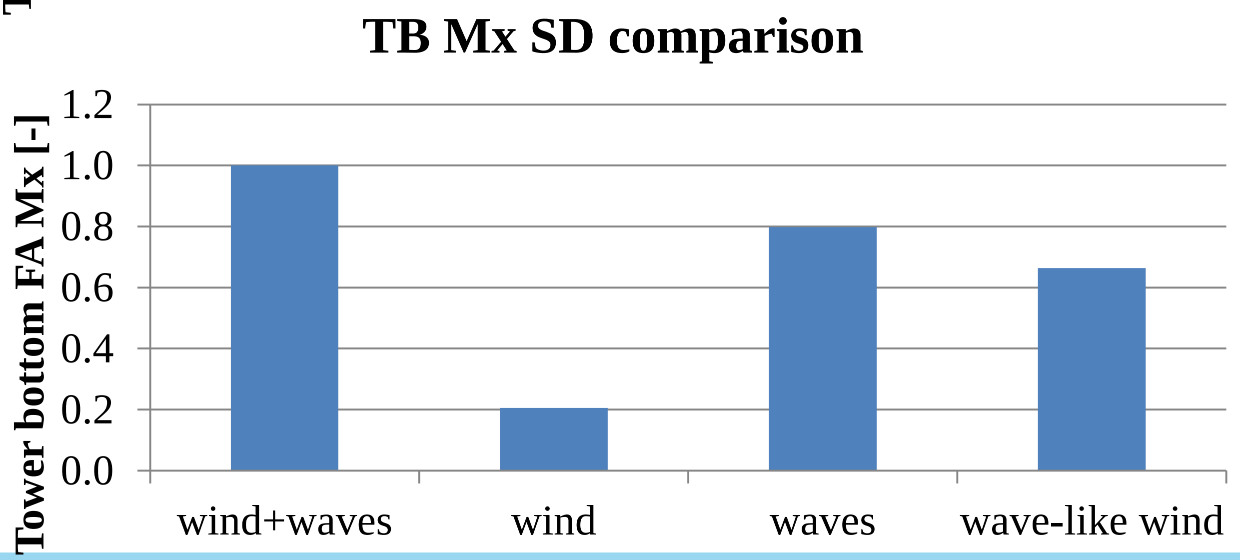
Results – Floater surge comparison (Normalized)



– In the case of wave-like wind, the SD is much lower than the base case..

Results – Tower bottom FA moment comparison (Normalized)





– In the case of wave-like wind, the SD is much lower than the base case..

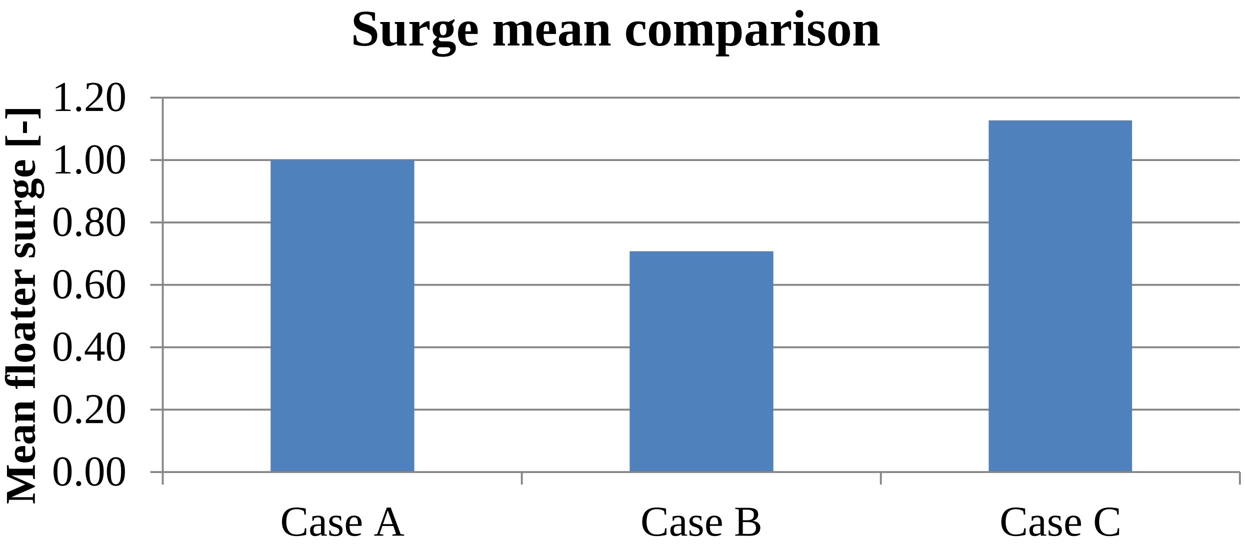
Wave-like wind simulation – Frequency sensitivity analysis

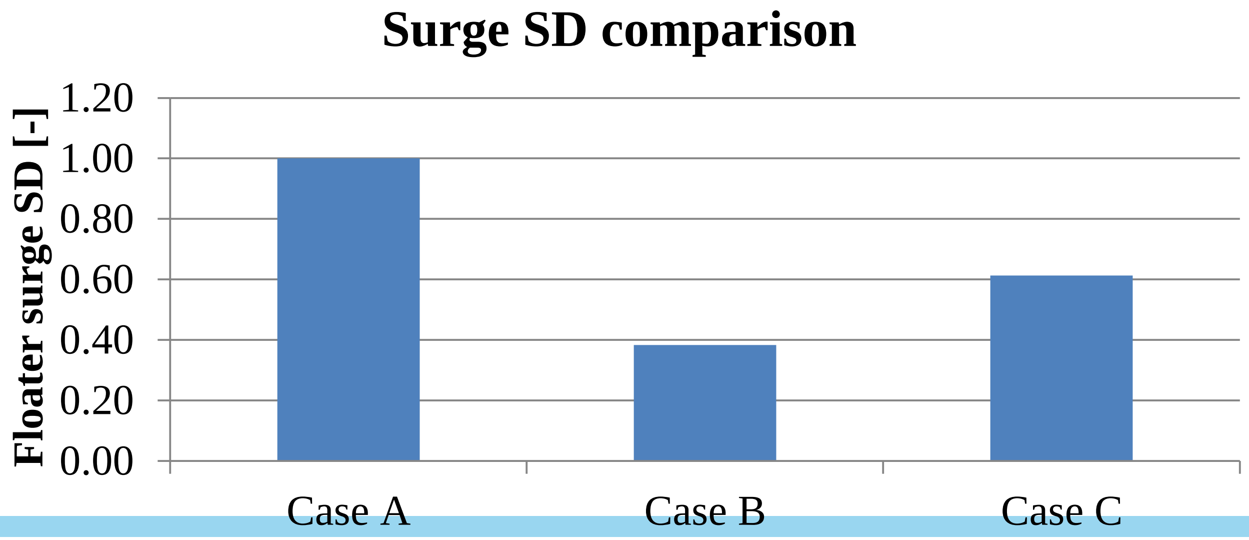
- **Description**

  – In order to understand the wave-like wind frequency-dependency, the following cases are considered:

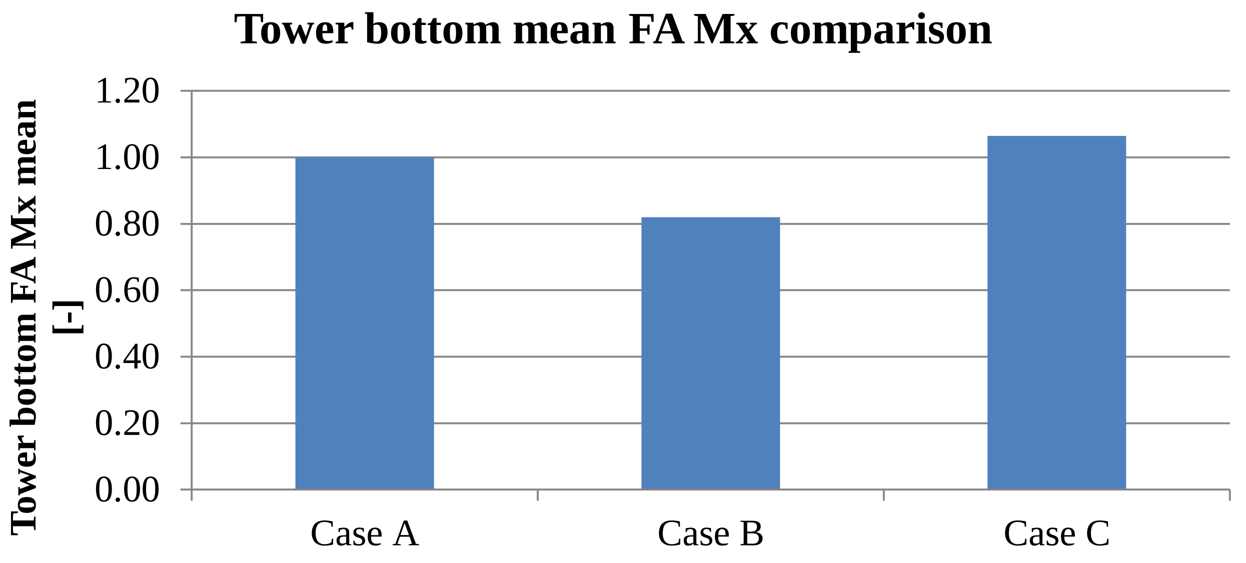
Case A	No waves + wave-like wind with wave period of 19 s
Case B	No waves + wave-like wind with wave period of 10 s
Case C	No waves + wave-like wind with wave period of 5 s

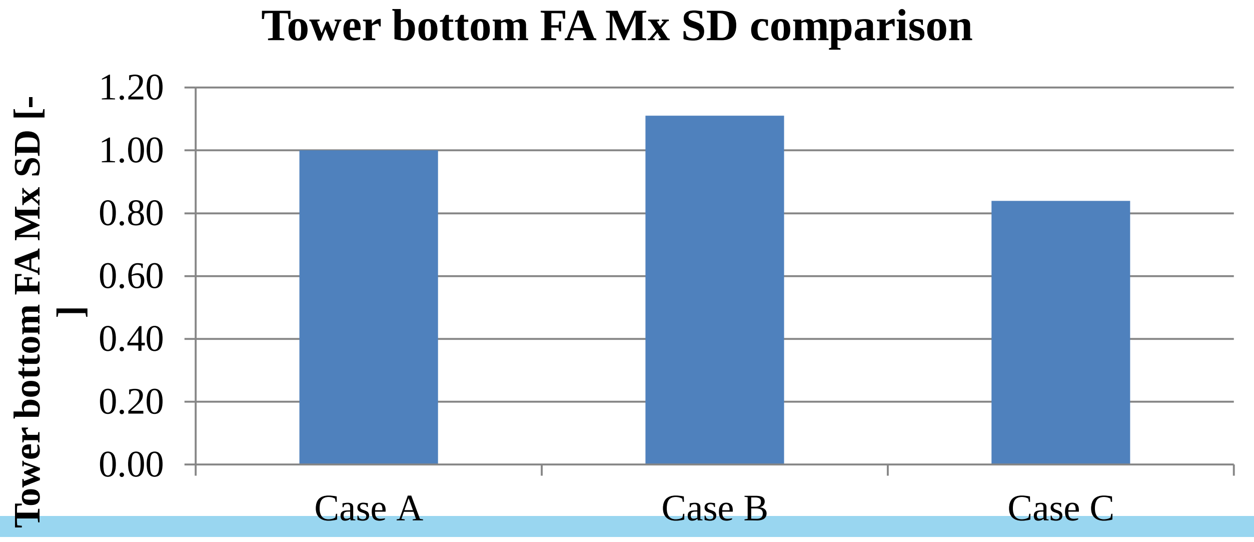
Frequency sensitivity – Floater surge comparison (Normalized)





Frequency sensitivity – Tower bottom FA moment comparison (Normalized)





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Observations / Conclusions

- Model test-based tuned aero-elastic model of a TLP wind turbine is investigated for wind/wave sensitivity.

- Investigations showed the following:

  – Larger surge motion together with high RNA inertia caused larger variation in loads – influence of inertial loads.

  – The tower bottom fatigue loads are dominated by the waves.

  – The wave-induced wind at the tower top influences the blade pitching and hence larger blade pitch angle variations.

Future work

- The following aspects are planned for future work:
  - The conclusions are not indicative of the full scale real design, as the turbine is tuned to resemble the model test. Hence, the analysis will be repeated for the full scale real design.
  - Influence of the controller parameters will be investigated.
  - It seems that the system is sensitive to the wave frequency, which may be due to the time constants involved in the dynamic inflow calculations in the BEM. However, this needs further investigations.

References

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Acknowledgements

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Thank you for your kind attention..

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