Performance study of the QuLAF model

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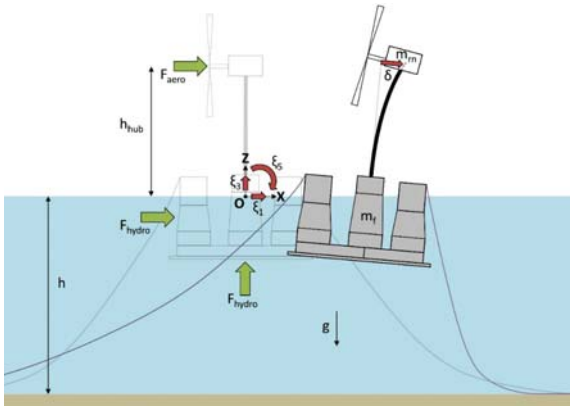
Integrated analysis at ~2000 x real time



QuLAF [1] is a floater pre-design tool based on linearized equations of planar motion, precomputed rotor loads, parameterized aerodynamic damping and WAMIT output for the floater motion.

Present study:

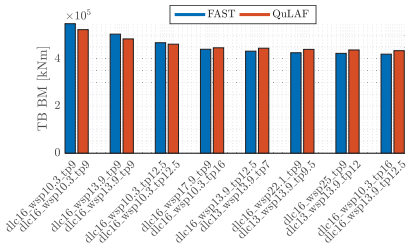
- DTU 10MW Reference Wind Turbine on the LIFES50+ OO-Star Wind Floater Semi 10MW platform [2].
- 2 x 480 load cases (DLC 1.2, 1.3, 1.6, 2.1, 6.1): The state-of-the-art FAST model [3] and the simplified model QuLAF.

Two questions addressed:

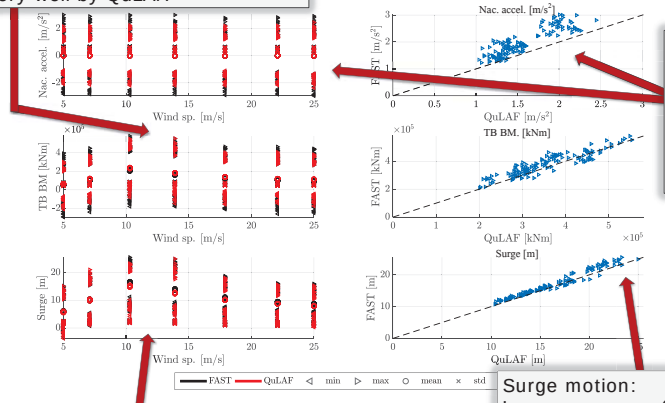
- How accurate results can be obtained from simplified models for different load cases?
- In what load cases is it sufficient to apply the simplified models?

Detailed results of DLC 1.6

- QuLAF has been found to be a fairly accurate load and response prediction tool for aligned wind-wave load cases, despite the model limitations.
- Comparing the maximum values of the tower-base bending moment across all design load cases, QuLAF has also found to generally predict the same ranking of cases.



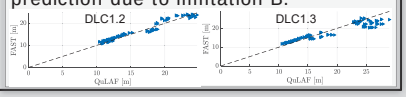
The largest tower-base bending moments are obtained around rated conditions and are matched very well by QuLAF.



The maximum values of the nacelle acceleration are wave dominated, but generally under-predicted up to 25%, which is due to limitation C.

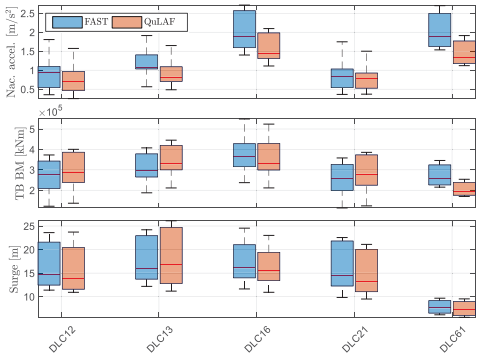
The largest surge response is obtained around rated conditions and a slight under-prediction in QuLAF, due to a combination of limitation A and B

Surge motion:
Larger waves (DLC1.6) lead to an under-prediction in QuLAF. Extreme wind (DLC1.3) hower, leads to an over-prediction due to limitation B.



Main results in Ultimate Limit State

- The ultimate nacelle accelerations are governed by the extreme sea states (DLC1.6 and DLC6.1), with an under-prediction of the values in QuLAF.
- The ultimate tower base bending moments are obtained in DLC1.6 and both models agree very well.
- The largest surge motions are obtained in DLC1.3 with a slight over-prediction in QuLAF.



Limitations

Approximations have been made to allow for the linearization and fast solution in the frequency domain. Three limitations have been identified from the results and from [1]:

A. Under-prediction of hydrodynamic loads in severe sea states due to the omission of viscous drag forcing

B. Difficulty to capture the complexity of aerodynamic loads around rated wind speed, where the controller switches between the partial- and full-load regions

C. Errors in the estimation of the tower response due to under-prediction of the coupled tower natural frequency and over-prediction of the aerodynamic damping.

Perspectives

QuLAF can be used as a fairly accurate load and response prediction tool for aligned wind-wave load cases. After the necessary pre-computations, it runs about 1300-2700 times faster than real time.

QuLAF can thus be used to speed up pre-design of floaters where many designs are evaluated and where early decisions on feasibility and cost are taken.

Further details on the simulation setup, the results and the model availability can be found in [4].

Literature cited

[1] Pegalajar Jurado, A., Borg, M., & Bredmose, H. (2018). "An efficient frequency-domain model for quick load analysis of floating offshore wind turbines", *Wind Energy Science*, 3(2), 693-712. DOI: 10.5194/wes-3-693-2018

[2] W. Yu, K. Müller and F. Lemmer, "LIFES50+ D4.2: Public definition of the two LIFES50+ 10MW floater concepts," University of Stuttgart, 2018

[3] Pegalajar-Jurado et al., 2018. "State-of-the-art model for the LIFES50+ OO-Star Wind Floater Semi 10MW floating wind turbine", *Journal of Physics: Conference Series.* **1104** 012024.

[4] Madsen et al., 2019. "Performance study for a simplified model of a floating wind turbine across various load cases", *Journal of Physics: Conference Series*. Unpublished.

Acknowledgments

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LIFES50+