Estimating Damping of an Offshore Wind Turbine on a Monopile Foundation

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Relevance for estimating damping

Many large scale offshore wind farm projects use monopile foundation to realize a cost effective design even in greater water depth (> 35 m). During the design of these monopile structures fatigue due to combined wind and wave loading is one of the most important problems to face. The damping significantly influences the dynamic response of the wind turbine reaction and thus also the predicted lifetime.

Damping Effects

The overall damping of the first bending mode of an offshore wind turbine consists of a combination of

- **aerodynamic damping**
- **material damping of steel**
- **damping from wave creation**
- **viscous damping due to hydrodynamic drag**
- **soil damping due to inner soil friction**

The soil damping is the most complex parameter having the highest damping contribution next to the aerodynamic damping. The aerodynamic damping does depend on the wind speed and the operating condition of the wind turbine.

Aproach

The main goal of this campaign was to identify the damping ratios of the first fore-aft bending mode excluding the aerodynamic damping.

For the determination of the offshore damping several approaches have been tested

- **a boat impact**
- **yaw actuation**
- **wind and wave excitation**
- **an over-speed stop**

An emergency stop with vanishing aerodynamic damping has been examined. Damping has also be estimated using ambient excitation coming from the wind and waves while the pitch angle was above 80 degrees in order to minimize the effect of aerodynamic damping.

Ambient vibration tests have the strong advantage of being more practical and less demanding for the wind turbine in comparison with the over-speed stop.

Results

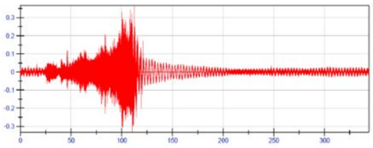

Fig. 1: Time series of acceleration during an over speed stop

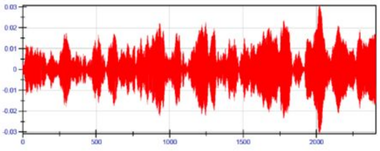

Fig. 2: Time series of acceleration during wind wave excitation

The damping ratios can be obtained by the standard logarithmic decrement method or by fitting an exponential function to the relative maxima of the decaying time series.

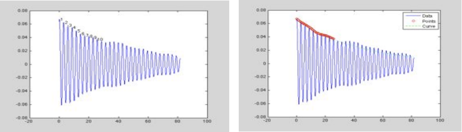

Fig. 3: Logarithmic Decrement Method (left) and exponential fit (right)

	Logarithmic Decrement	**Exponential Decay**
Damping (%)	1.01	1.02

Table. 1: Damping Estimates using different methods

Operational modal analysis allows the identification of model parameters of output-only data obtained during ambient excitation. Operational modal analysis, using the least-squares complex exponential estimator and a maximuum likelihood Approach have been performed in the frequency range 0.05 –1 Hz.

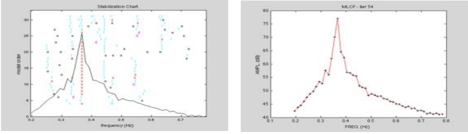

Fig. 4: Least-squares complex exponential fit (left) and maximuum likelihood estimator (right)

	LSCF	**MLE**
Damping (%)	1.03	1.05

Table. 2: Damping Estimates using different methods

Conclusions

We can conclude that the analysis of the measured data showed that the ambient vibration tests together with the application of state-of-the-art output-only identification techniques can provide good estimates of the modal damping ratios of an offshore wind turbine. The results have been compared with the ones obtained from the commonly used over-speed tests.

Acknowledgments

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References

1. M.F.Cook, J.K. Vandiver, MIT, 1982: „Measured and predicted dynamic response of a single pile platform to random wave excitation", OTC 4285 (Offshore Technology Conference report)
2. N.J. Tarp-Johansen, DONG Energy, Comparing sources of damping of cross-wind motion", EOW 2009
3. Guillaume, P.; Verboven, P.; Vanlanduit, S.; Van der Auweraer, H.; Peeters, B. (2003) A Poly-Reference Implementation of the Least-Squares Complex Frequency-Domain Estimator. In Proceedings of IMAC 21, International Modal Analysis Conference, Kissimmee, Florida, USA