Design verification of offshore wind turbines for foundation optimization and scour monitoring

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Abstract

The **Offshore Wind Infrastructure Lab (OWI-Lab)** develops short- and long-term **monitoring solutions** for offshore wind turbines. The **motivation** is gaining the insights that are crucial to **minimize construction and installations costs** of future offshore wind farms and to **extend the life time** of existing structures and **reduce** their **operation and maintenance costs**.

The main goal of this poster is to share the results of an extensive design verification camping. The results will allow improving current standards. Ultimately, reducing the cost of offshore wind energy.

Objectives

In **design verification** the resonance frequencies of the fundamental tower modes are identified using a mobile measurement system and state-of the art operational modal analysis techniques. The obtained frequencies are compared with the as designed values.

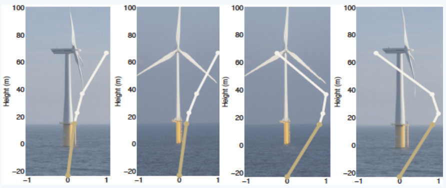

Figure 1: Fundamental tower/foundation modes in parked conditions. From left to right: first for-aft mode, first side-side mode, second for-aft mode, second for-aft mode

Foundation optimization

Monopile foundations, currently the most common foundation concept, make up about 20% of the CAPEX of the entire offshore wind turbine structure. **It is not conservative to both over-predict and under-predict the soil stiffness.** Only an exact prediction is conservative. Underestimating the stiffness in the design phase, inevitable results in the use of more steel and thus higher constructions and installation costs.

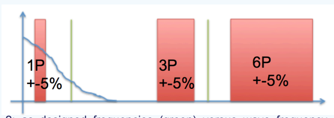

Figure 2: as designed frequencies (green) versus wave frequency spectrum (blue) and blade passing frequency bands at rated speed (red zones)

Scour Monitoring

Scour holes have a significant effect on the resonance frequencies. **With increasing scour depth the resonance frequency will decrease.** This can potentially induce resonant behavior.

Bathymetric surveys are used to monitor the seabed. However, these results do not provide information about the structural integrity. By performing a design verification campaign it is possible to assess the influence of the actual seabed level on the natural frequencies. By analyzing the natural frequencies the risk can be constantly monitored, with greater accuracy, and more economically compared with bathymetric surveys.

Measurements

During 2014 a short-term measurement campaign at the Belwind windfarm has been performed at 4 turbines.

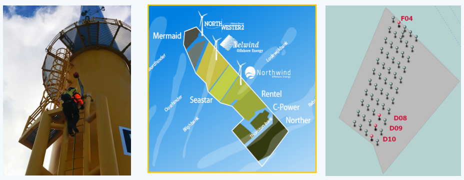

Figure 2: climbing on transition piece with measurement system (left) Belgian offshore wind farms (middle) measured turbines (right)

Biaxial accelerometers have been magnetically mounted on tower just above the transition piece of each turbine. Measurements have been performed during 20 minutes.

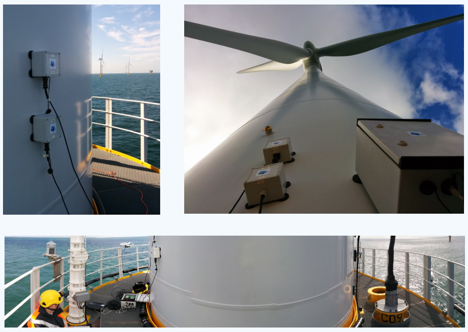

Figure 3: magnetically mounted accelerometers and data acquisition system (top) panorama picture during measurements (bottom)

Operational Modal Analysis

The vibration data has been processed using state-of-the-art operational modal analysis techniques. This approach allowed to identify the resonance frequencies of the first 2 bending modes in both the for-aft and side-side direction with great accuracy.

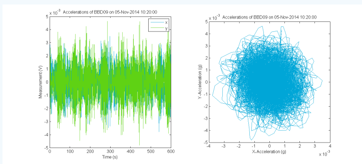

Figure 4: Example measured vibrations in for-aft and side-side direction (left) topview of motion (right)

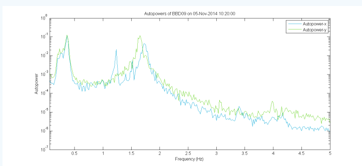

Figure 5: Example of auto-power spectra of the measured vibrations in for-aft and side-side direction

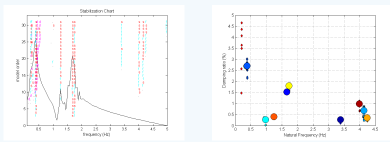

Figure 6: automated operational modal analysis: stabilization diagram (left) frequency damping cluster plot (right)

Results

When performing a design verification campaign one needs to take into account that the resonance frequencies can shift significantly due to changing operational and environmental conditions. The results have to be corrected for these influences.

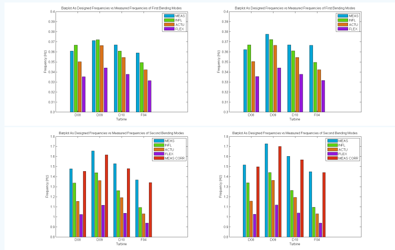

Figure 7: Measured frequencies and corrected frequencies versus designed frequencies for the first for-aft mode, first side-side mode, second for-aft mode, second side-side mode

The resonance frequencies of the higher modes differ significantly from the designed resonance frequencies. This can result in higher vibration levels, due to an increased interaction with the blade passing frequencies.

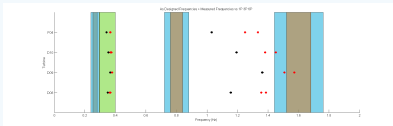

Figure 8: Measured frequencies , corrected frequencies and as designed frequencies versus blade passing frequencies

Finally a detailed analysis of the obtained resonance frequencies is performed versus e.g. waterdepth, monopile length and monopile fixity.

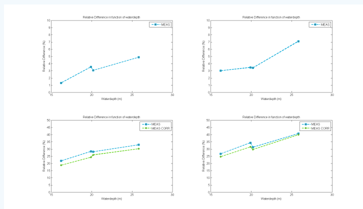

Figure 9: Relative difference between measured frequencies and as designed values versus waterdepth

Conclusions

Results indicate a general underestimation of the soil stiffness. The first resonance frequency is between 5% and 10% higher then designed. The second resonance frequency is between 15% and 40% higher then designed. It was found that the relative difference with as designed values increased with water depth and was independent of the monopile length. Moreover it was found that the second bending mode frequencies coincided with the 6P blade passing frequencies. This can result in higher loads and therefore reduced life-time or increased O&M costs.

Acknowledgements

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