Temporal evolution of stiffness for offshore monopile foundations

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Abstract

Since 2011 OWI-lab has been conducting acceleration measurements on an offshore wind turbine with a **monopile** substructure at the Belwind wind farm. A site with layers of clay and sand.

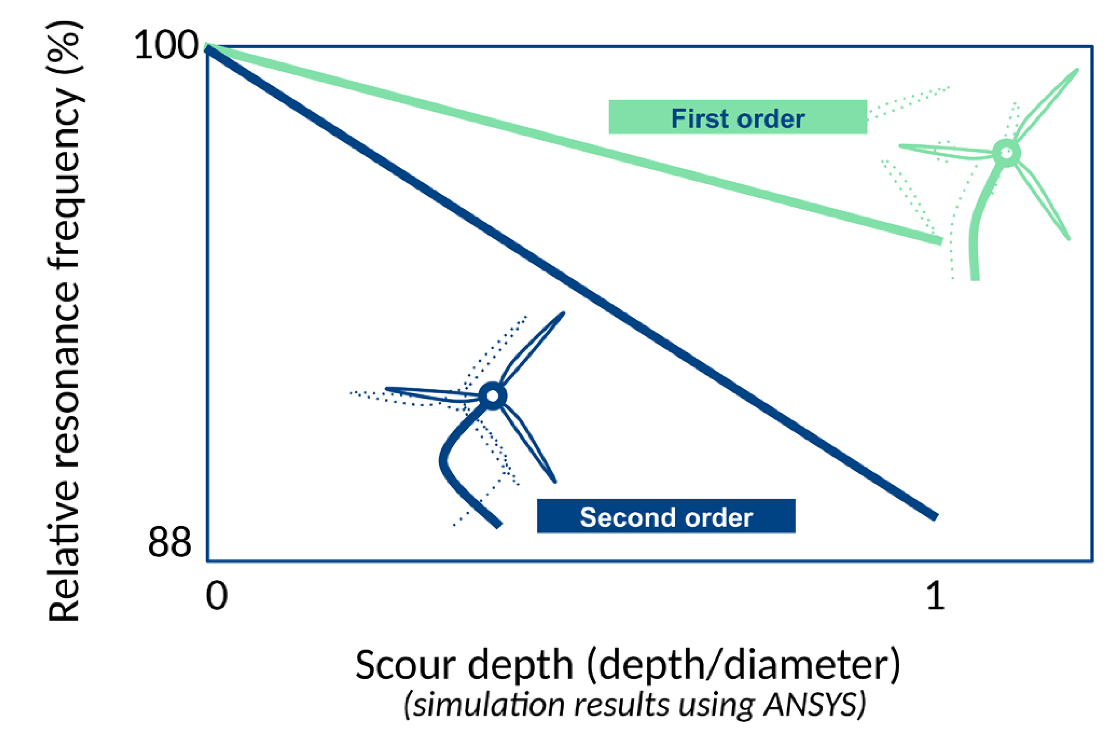
The main goal of the campaign was to validate the design with in-situ measurements on the operational turbine. **Initial results confirmed that the actual resonance frequency was well above the as-designed values.** Other researchers noted similar observations at different wind farms, concluding that in design the soil-stiffness was underestimated.

Methods

At Belwind a continued monitoring campaign using accelerometers in the tower was installed to track the evolution of the resonance frequencies over time. This contribution discusses these long-term results.

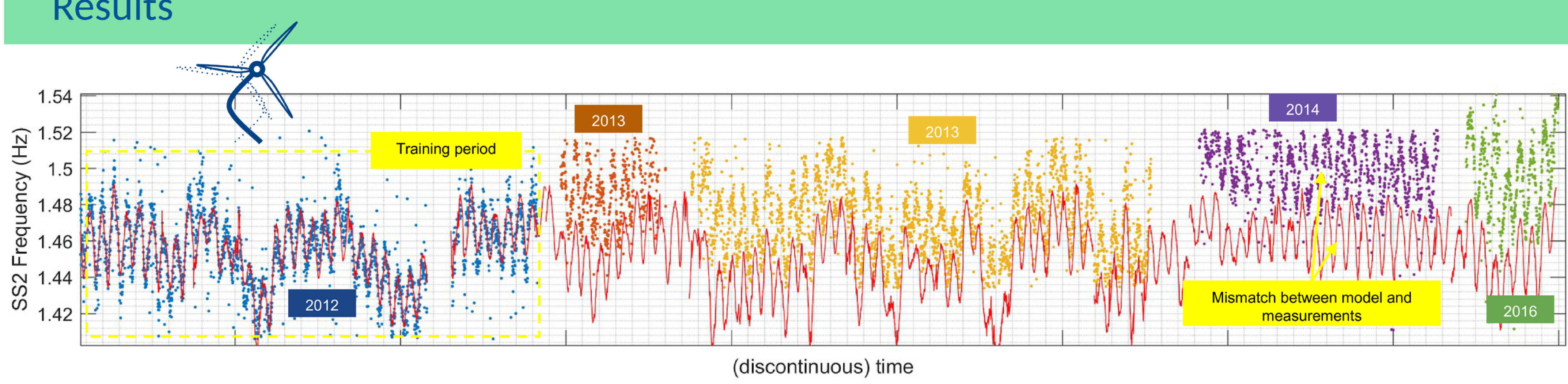
The original concept of the setup was to detect the development of scour using the second order mode.

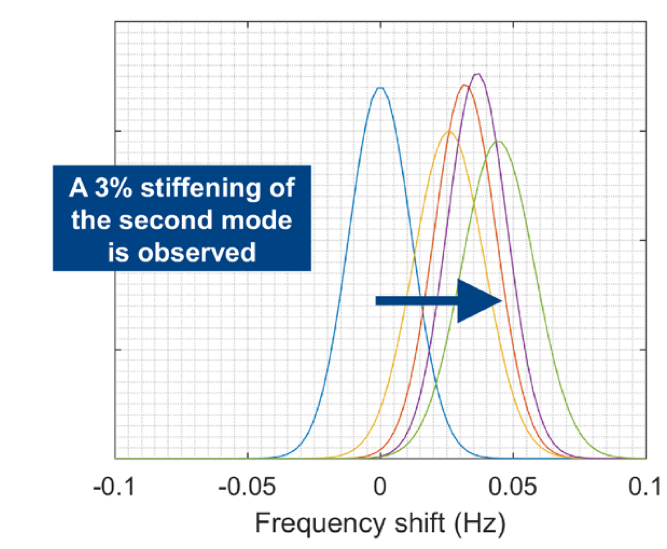
However earlier research showed that this second order mode also varied with additional parameters such as the tidal level[1]. Motivating the use of regression models.



The second order mode, which has a larger mode shape component at the soil is more sensitive to scour and the soil conditions in general.

Results





In this figure the evolution of the second order mode over 5 periods of parked conditions is shown. Representing a total period of 4 years.

One can clearly see the variations present in the resonance frequency due to :

- Tidal level
- Wave height
- Directional stiffening (e.g. due to J-tubes)

To compensate for these natural variations a model was trained **(red line)** on the data available during the first period.

This model was then used to predict the resonance frequencies in the later periods, using data from wave radars and the wind direction in the turbine SCADA.

The water temperature was also considered but did not seem a major contributor in the analysis of this mode

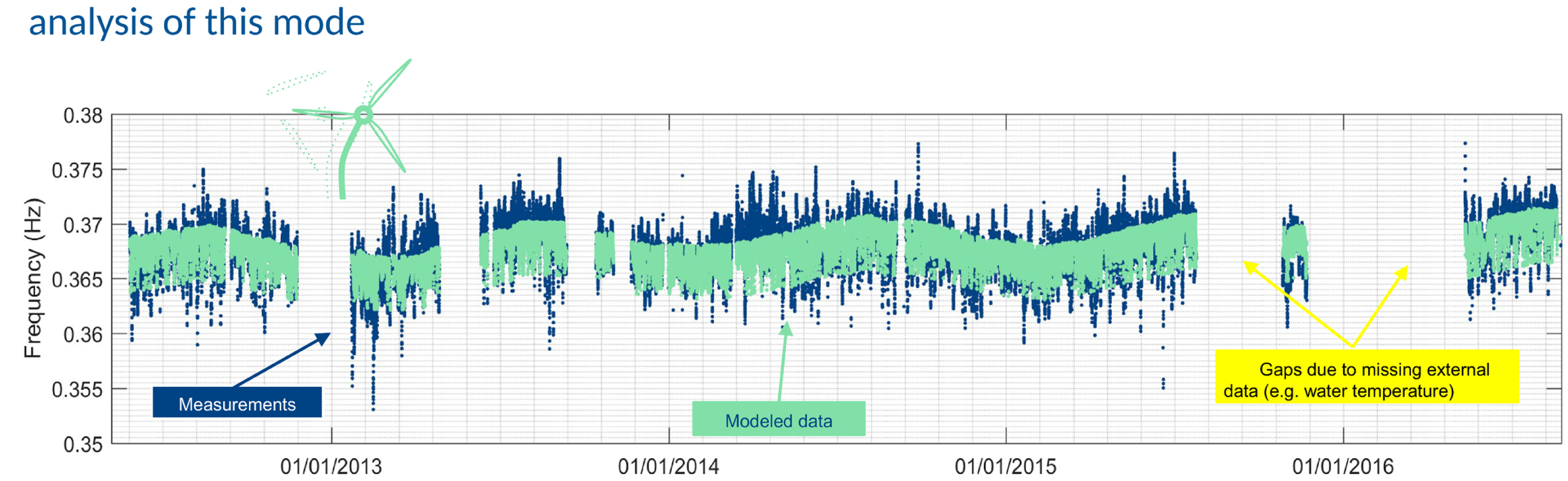
The results show a clear increase of the resonance frequency over time. This is also shown in the histograms on the right.

Over the course of 4 years the resonance frequency has increased with 0.05Hz or 3%.

However this analysis **only considered parked conditions** and extension of the technique in operational conditions is still under development.

Evolution of the first mode

In addition the behavior of the first mode was also investigated during all operational conditions. For this mode the effect of the water temperature is clearly visible. And while less pronounced the frequency is increasing.



Conclusions

Measurements show that the turbine structural resonance frequencies are increasing over time. After data normalization a 3% increase of the second order resonance frequency was found.

While less apparent the first order mode is also stiffening over time.

Future work

The current observations have not been linked to actual soil parameters, such as the stiffness.

OWI-lab plans to use a simplified model of the structure to perform sensitivity analysis. But would also like to invite external researcher to help us understand these observations

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References

1. Foundation structural health monitoring of an offshore wind turbine—a full-scale case study, *Structural Health Monitoring*