Experimental investigation of the relation between operating conditions and offshore wind turbine drivetrain dynamics

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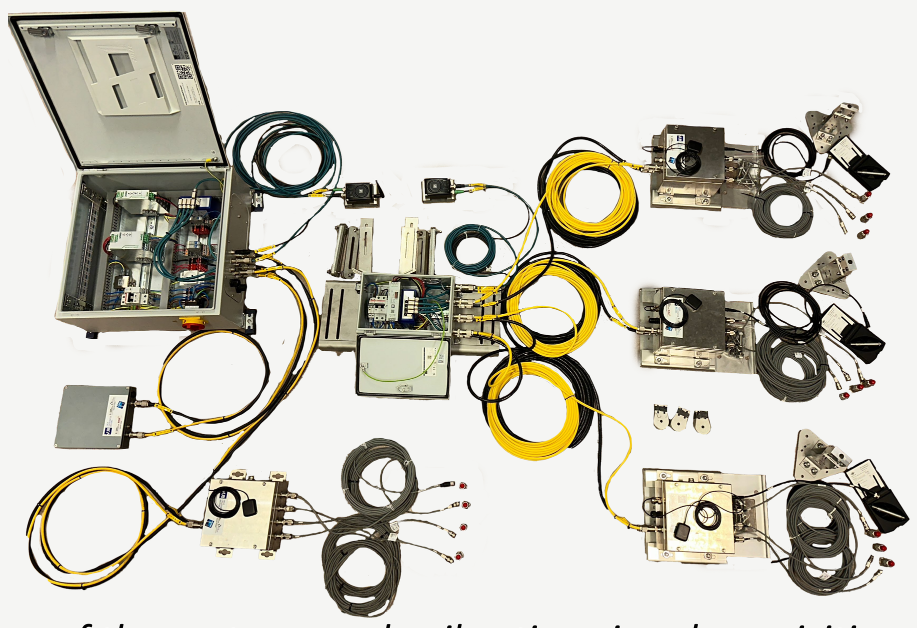
Introduction

The paper aims to comprehend and characterize the global dynamic behaviour of an offshore wind turbine drivetrain under varying operating and external conditions. Furthermore, the role of the main turbine modes coupled with external conditions on the vibration levels is investigated.

An extensive experimental campaign for condition monitoring of an offshore wind turbine drivetrain, using a custom-made vibration acquisition system, equipped with ICP sensors that can target below 0.1 Hz.

Acceleration signals obtained from the main bearing in fore-aft and side-side directions are the core of the study.

The machine's response is influenced by blade and tower modes, coupled with localized drivetrain behaviour. Information on global system dynamics is embedded in low frequencies, typically within a few Hertz; thus, low-frequency vibration content is investigated.



A picture of the custom-made vibration signal acquisition system

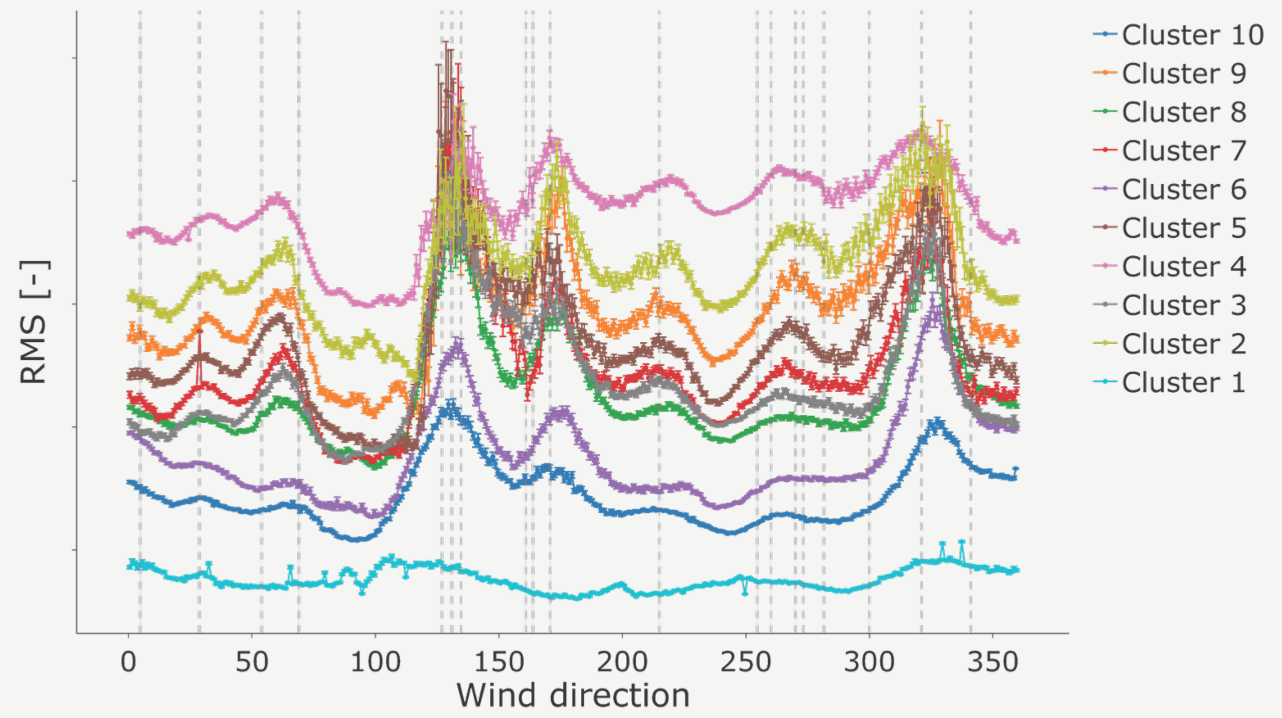
Global dynamic behaviour

RMS levels, as a measure of signal power, are linked to operational parameters like active power, rotor speed, and wind speed.

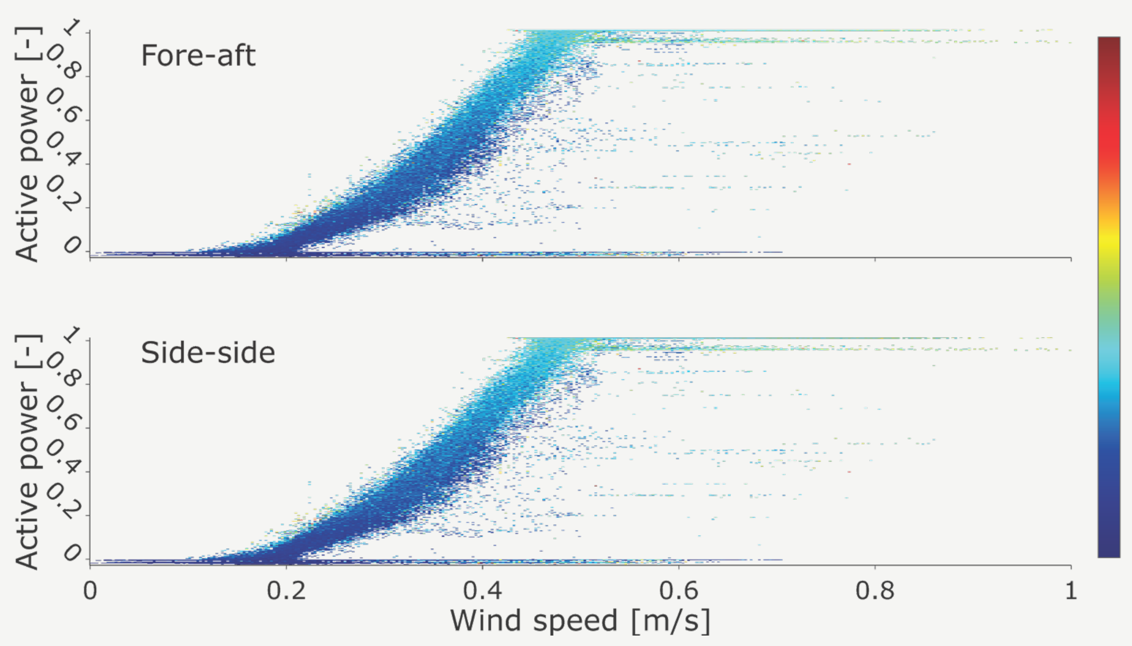
Vibration levels increase with higher wind speed and power production, validating measurements and conditions' influence.

The impact of wake effects on turbulence intensity is examined, with higher RMS levels when the turbine is in the wake of other turbines while wind direction changes.

Clustering based on operational conditions shows elevated RMS levels in turbine wakes, indicating turbulence intensity as an influential parameter consistent with prior research.



RMS levels of vibration signals clustered using operating/external conditions versus wind direction

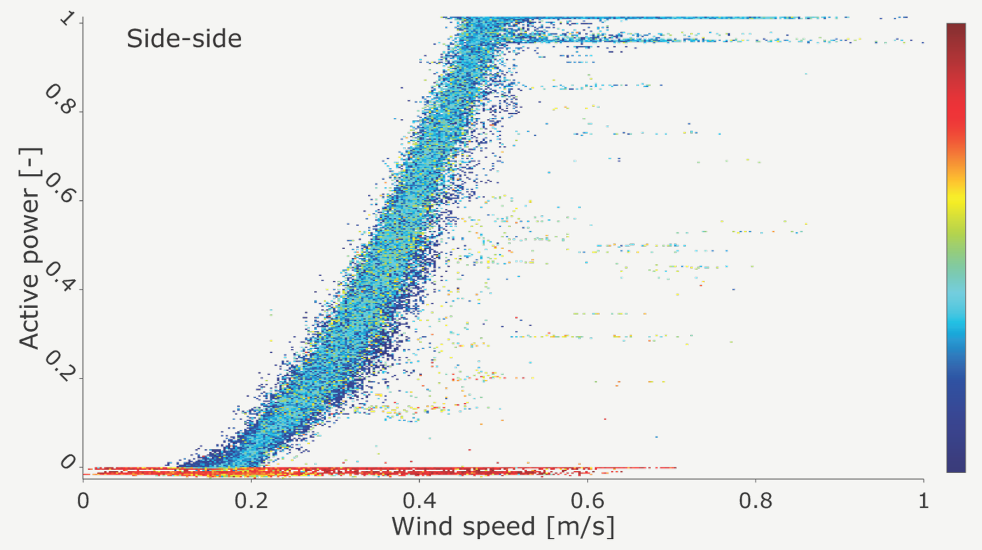


RMS levels of overall signals with respect to active power and wind speed

Investigation of the main turbine modes

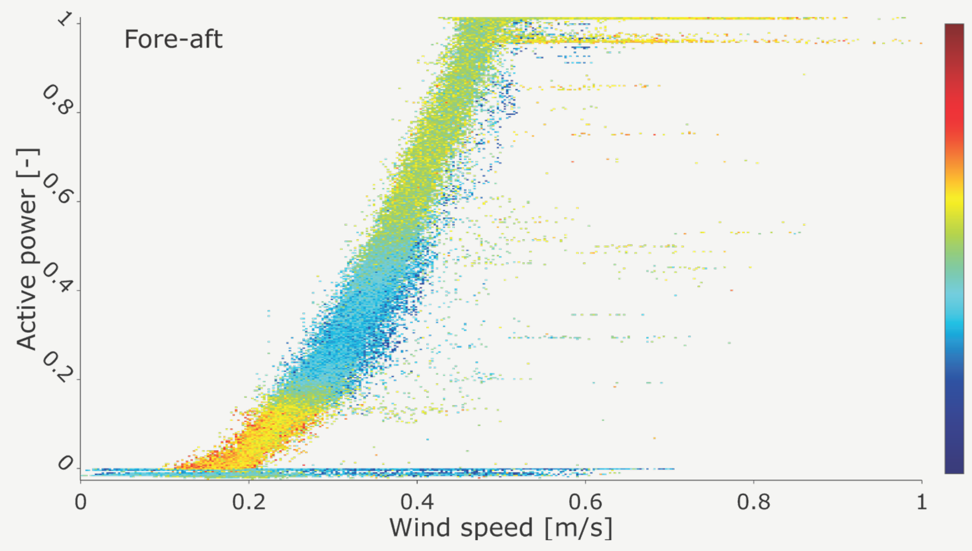
Vibration signals are bandpass-filtered for the frequencies obtained from modal analysis to understand the impact of the main turbine modes on drivetrain vibrations. Four structural modes are identified, with the first and fourth linked to tower motion and the second and third corresponding to axial and side-side blade motion.

Structural modes' contribution to RMS levels is assessed, with the first tower mode dominating at standstill, while the second, third, and fourth modes become pronounced during operation.



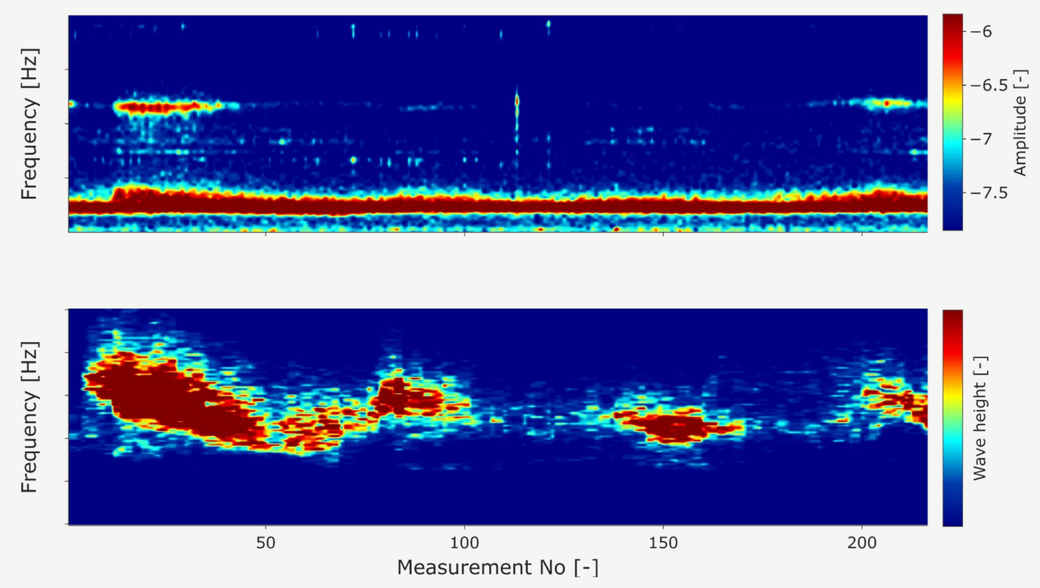
RMS distribution of signals bandpass filtered for the first main turbine mode

Regions where machine kinematics' frequencies coincide with the third main mode frequency band are observed in the RMS distribution.



RMS distribution of signals bandpass filtered for the second main turbine mode

The source of excitation of the first main mode can be the wave-turbine interaction.



PSDs of vibration signals and wave height-frequency spectra at standstill

Key findings

A rise in vibration levels with higher wind speed, active power, and turbulence intensity indicates the significant influence of drivetrain and blade-induced vibrations on global drivetrain dynamics. The study explores the intricate interlink between structural modes and varying environmental and operating conditions, emphasizing the contribution of the first mode, influenced by wave motion at low wind speeds when no aerodynamic load exists. The second mode is only visible in the accelerations in the fore-aft direction, and its contribution to side-side vibration is insignificant.

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