First 3D Accelerometer-Based Measurements at the Blade Tip:
What's the Benefit of the Data?

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Introduction

Accelerometers are very promising for measuring the characteristics of rotor blades over time

(e.g. deterioration of structural integrity, ice accretion, blade)

Issues with traditionally used accelerometers:

- Positioning of accelerometers due to restrictions in accessibility and by design
- Restrictions of conductive matter in the blade (such as signal cables etc.)

Proposed Solution:

- Usage of low power microelectromechanical (MEMS) accelerometers
- Usage of wireless sensor systems

Benefits:

- High flexibility in the choice of mounting positions allows all critical points to tip to be monitored.
- Continuous monitoring for predictive maintenance throughout the lifetime of the turbine.

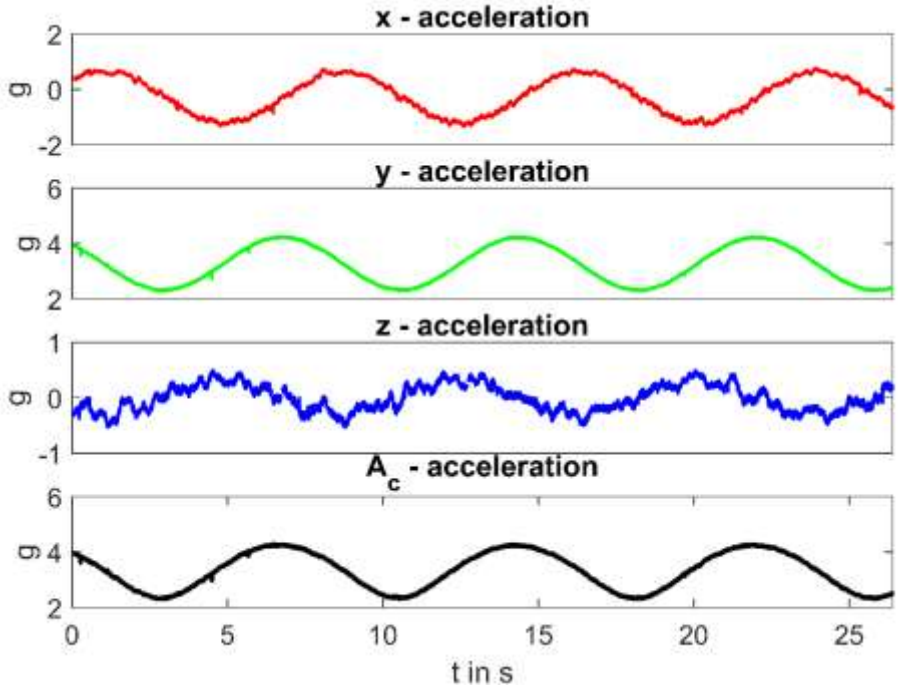
Methods

- An eologix sensor with a MEMS acceleration sensor placed at >90% of the rotor blade length
- 3D acceleration measurement test period: 12/2017 – 01/2018
- Burst measurements of ~26 s length at a sampling rate of 152 Hz to fulfil energy budget requirements
- Wireless power supply and wireless data transmission

Sensor position on the rotor blade under test

Methods

Example of a burst measurement:



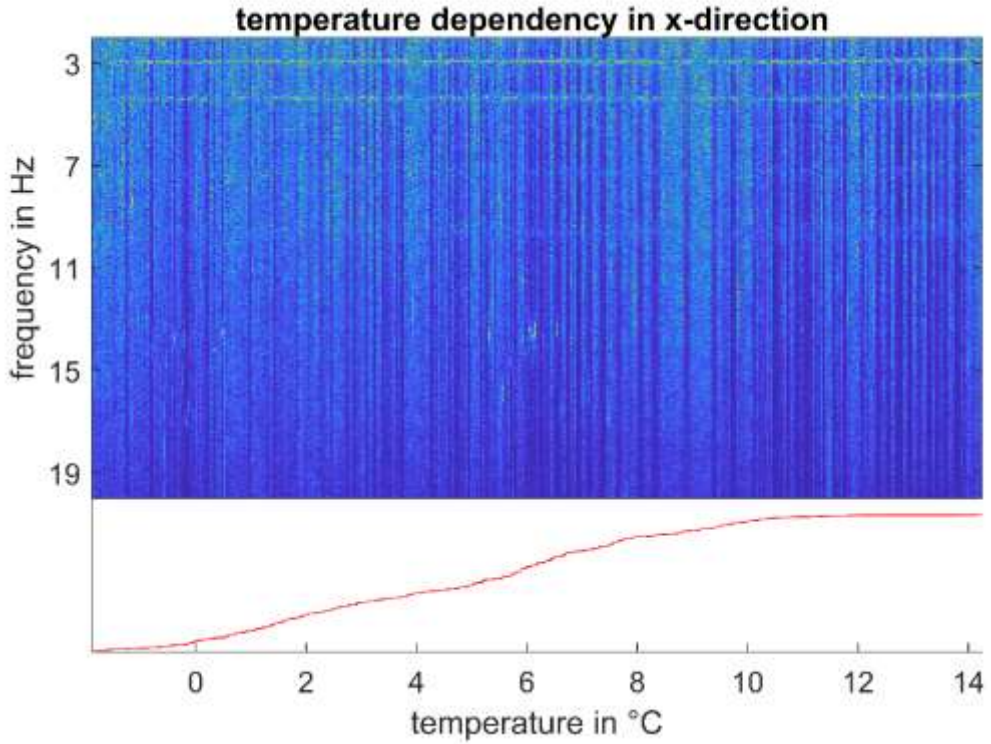
Data of one snapshot in x, y and z direction,
centripetal acceleration $A_c = \sqrt{x^2 + y^2 + z^2}$

Results

Analysis of eigenfrequencies

Eigenfrequencies of a rotor blade are expected to vary with changes in

- the temperature of the blade
- the stiffness of the blade depending on the fundamental frequency, load etc.
- the mass of the blade, e.g. ice accretion



Correlation of changes in eigenfrequencies and temperature of the blade

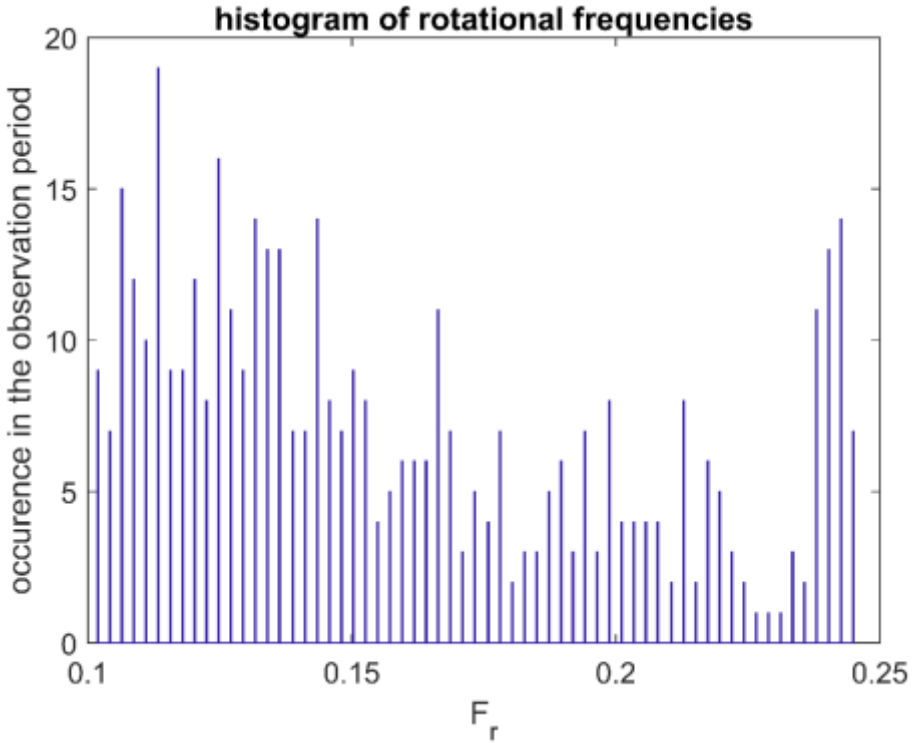
Results

Measurement of the rotational frequency

The 3D accelerometer allows for estimating the rotational frequency F_r of the wind turbine.

Benefits of F_r measurements:

- Identification of mismatches between set parameters and measured F_r
- Analysis of high fluctuations in F_r (identify unstable settings)
- Measurement of ice accretion, pitch angle deviations etc.



Histogram of rotational frequencies F_r of the monitored wind turbine

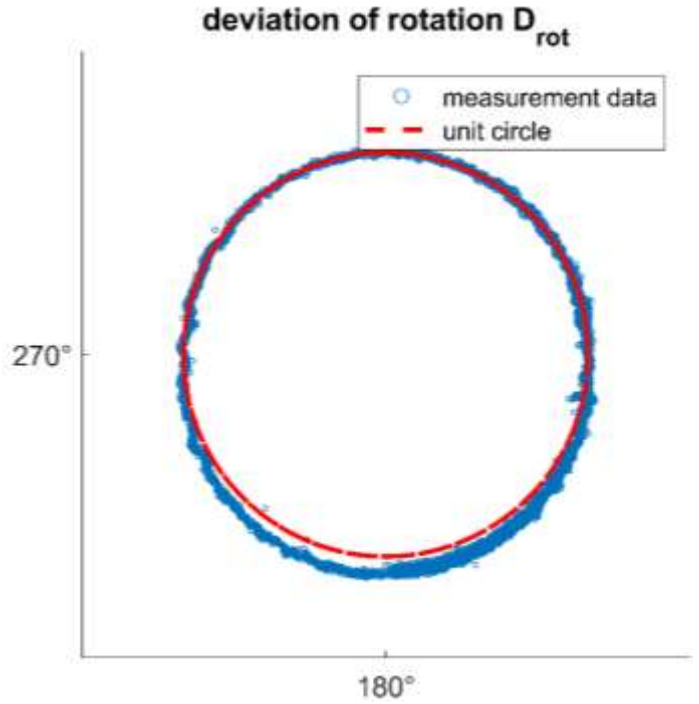
Results

Angle estimation of the rotor blade

The movement of the blade tip deviates from the ideal circular movement. Analysis can be based on:

1. fixing the inflection points of the measurement data at [90°, 270°] and estimating the position of the accelerometer.
2. fixing the distance of the accelerometer and comparing the estimated angle with the equally spaced angle of the ideal circular movement.

Results can be used to relate deviations D_{rot} to influences such as yaw control, pitch angle, increased loads etc.



Deviations of the blade movement from the ideal circular movement (Estimation 1)

Results

Analysis of high-frequency components

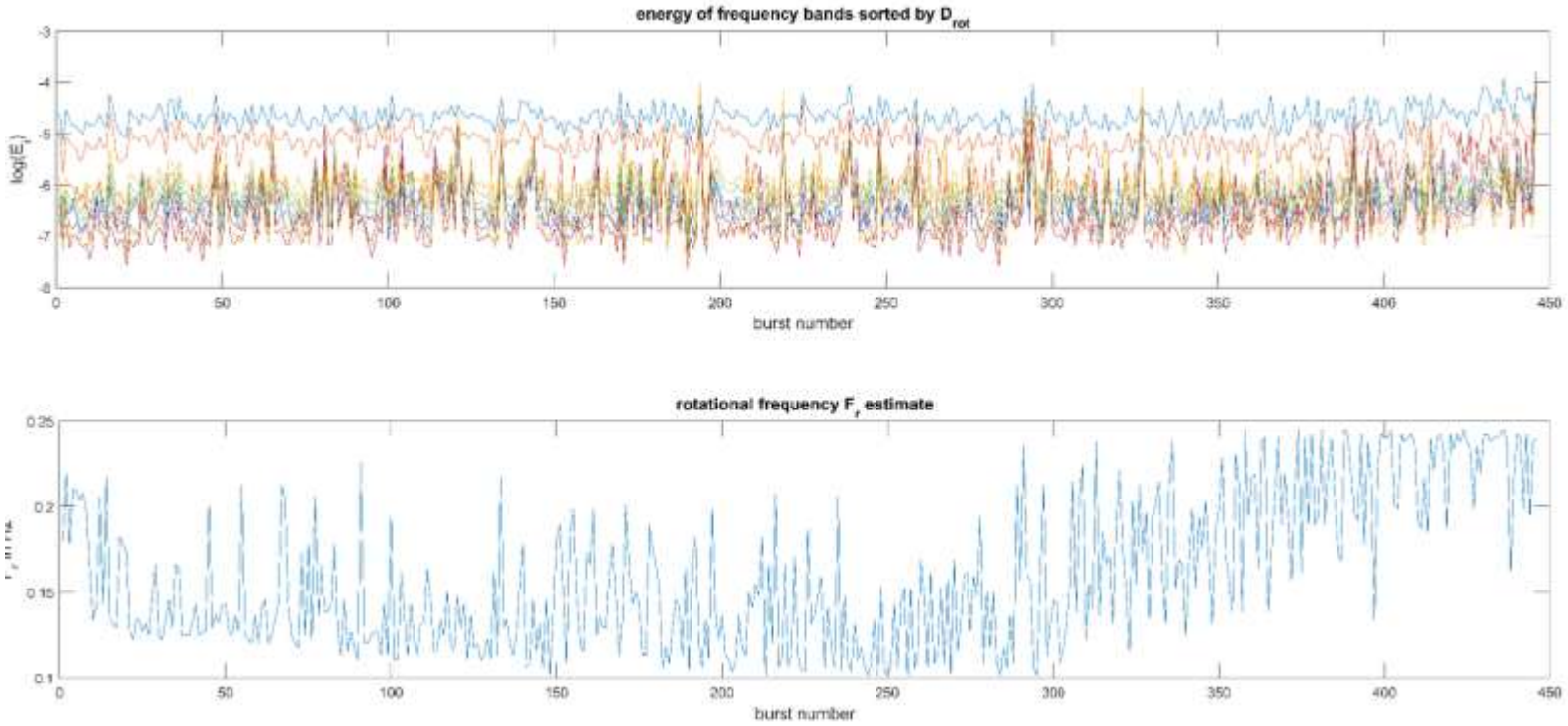
- Monitoring of high-frequency components for detecting uncontrolled movements of the blades
- Increase in the rotational frequency ⟹ increase in deviations from the ideal circular movement (D_{rot}). ⟹ increase in high-frequency components, ⟹ indication of higher loads and influences such as wind shear, tower shadow etc.

Benefits:

- Detect turbulences and analyse fluttering
- Prevent blade damage

Results

Analysis of high-frequency components



Correlation of rotational frequency F_r and high-frequency components.

Top panel: logarithmic energy of 10 frequency bands between 0 and 75 Hz sorted by D_{rot}.

Bottom panel: Corresponding rotational frequency F_r sorted by D_{rot}.

Outlook

- Verification of additional measurements with theoretical findings to correlate further influences such as wake, pitch or differing loads
- Performance improvement (e.g. standardized sampling rate)
- Joint analysis of blade root and blade tip acceleration data with future blade root data
- Evaluation of effects of ice accretion on the blade under icing conditions

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