PROOF OF CONCEPT OF USING AN EXISTING FOUNDATION STRUCTURAL HEALTH MONITORING SYSTEM TO DETECT ICING

Mustapha Chaar, Pieter-Jan Jordaens, Christof Devriendt, **Wout Weijtjens**

OWI-LAB

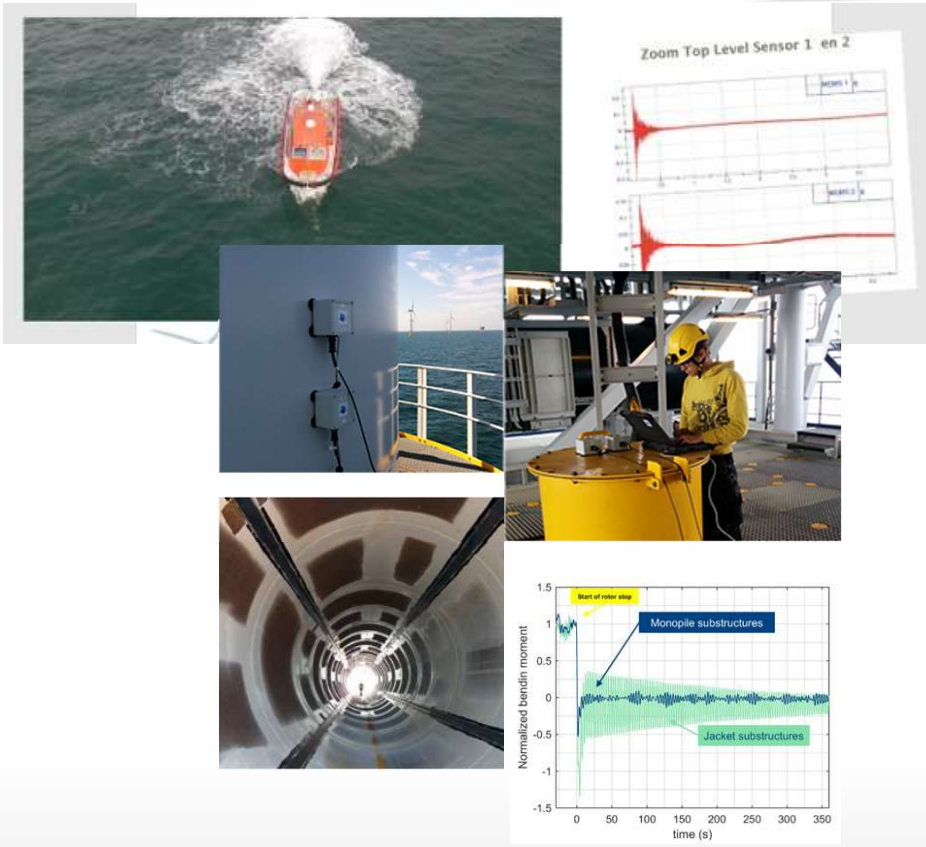
GAINING INSIGHT THROUGH MEASUREMENTS

Since 2011 OWI-lab @ VUB instruments (offshore) wind turbines with measurement hardware to:

- **Close the gap between design and the real world**
- To **quantify the loads** and assess the **residual fatigue life** of operational wind turbines
- Verify the **boundary conditions** of the structure over time, e.g. to detect scouring

To support decisions in future designs and operations of real-world assets.

In 2016 we spun out **24SEA**

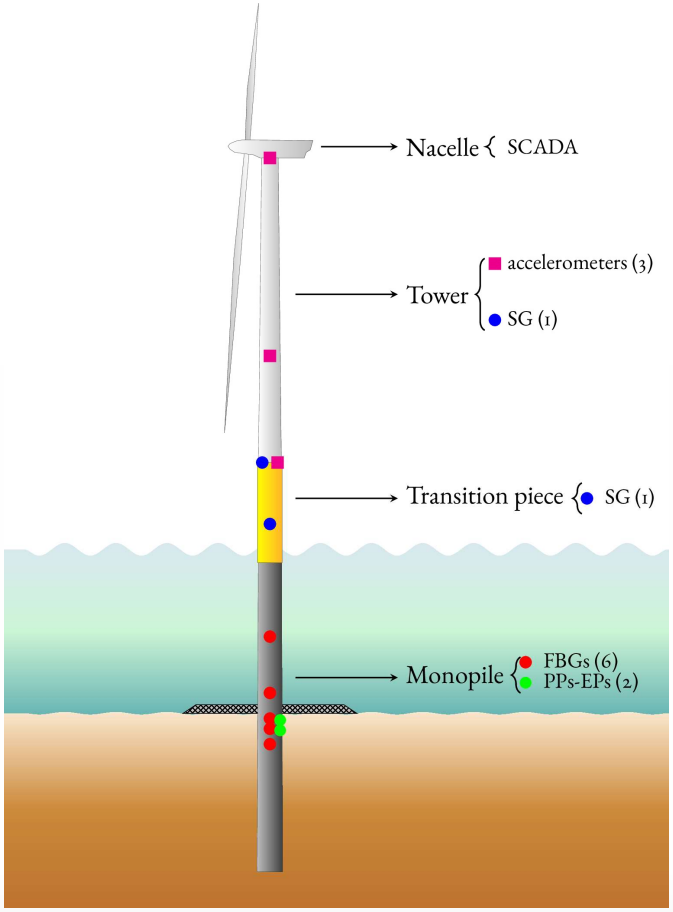


STRUCTURAL HEALTH MONITORING

SHM FLEET LEADER STRATEGY

- **Fleet leaders** are representative for the entire fleet of wind turbines
  - **E.g.** One instrumented turbine per design cluster
- Supported by the **BSH** guideline 10% of farm instrumentation
- **High Quality and broad-scoped instrumentation** is limited to the fleet leaders.
  - Load monitoring
  - Resonance frequency monitoring
  - Rotor unbalance monitoring
  - Inclination
  - Grout slippage
  - Environmental
  - **...**

- **BUT local issues on non-instrumented turbines, such as scouring/imbalance/excessive loads remain unnoticed**



STRUCTURAL HEALTH MONITORING

SUPERSIZED 4.0:TOWARDS FLEETWIDE INSTRUMENTATION

Fleet leaders still play a vital role, they remain the reference turbines.

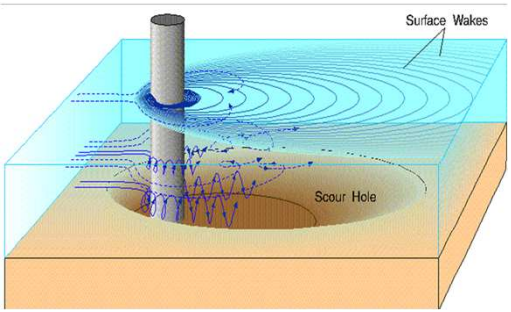
- Direct Fatigue monitoring using strain gauges

Additional instrumentation on every turbine to cover local aspects

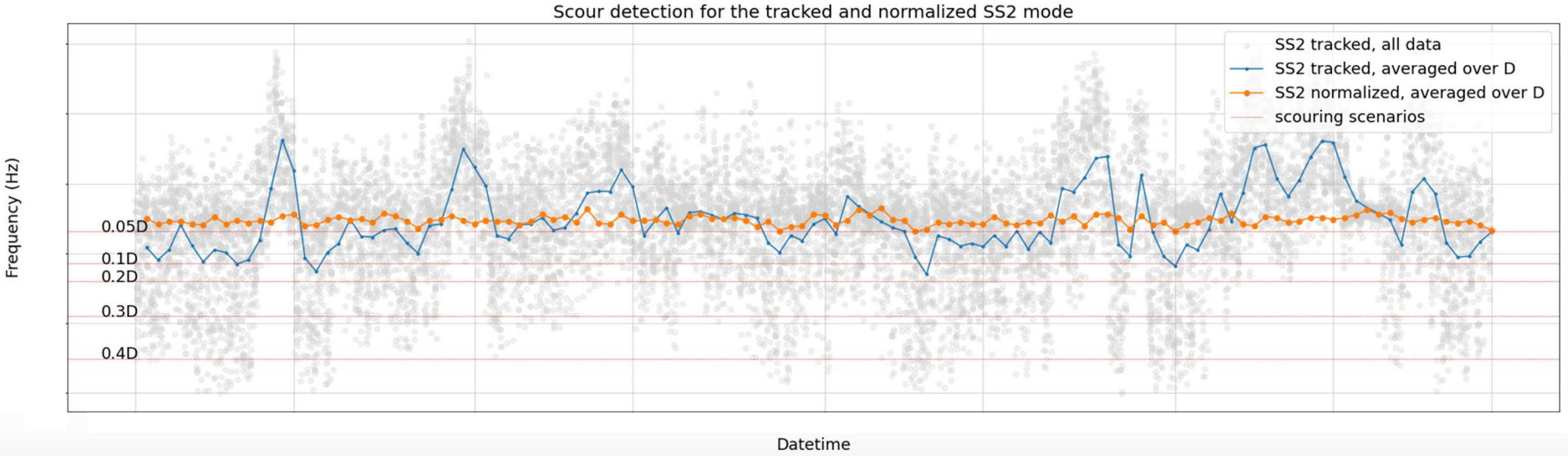
- Accelerometer
  - Direct link between accelerations and fatigue loads
  - Quick installation in the nacelle / tower
  - Vibration monitoring
    - Rotor unbalance detection
  - Resonance frequency monitoring
    - Boundary condition stability
    - Scour monitoring
    - Icing detection

STRUCTURAL HEALTH MONITORING

RESONANCE FREQUENCY MONITORING



E.g. Resonance Frequency monitoring to assess scouring scenarios



STRUCTURAL HEALTH MONITORING

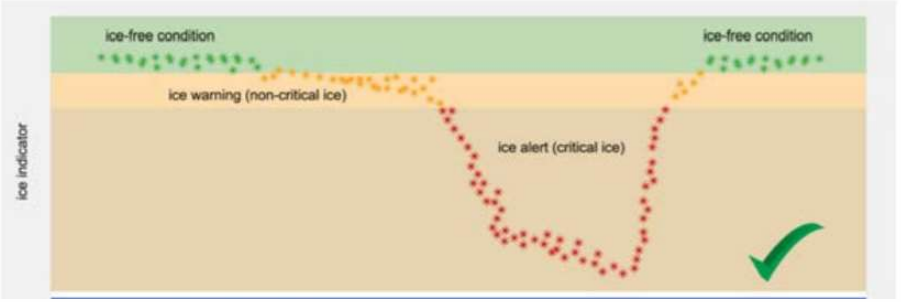
RELATION WITH ICING DETECTION

Detection of ice build due to a change in the resonance frequency of the rotor modes

Increasing build up of ice - > increase rotor mass -> Lowered resonance frequencies of the rotor modes.

To detect this variation in structural dynamics is to detect ice on the blades

Industry examples: Weidmüller/Bosh Rexroth, Wölfel



Vibration-based Ice Detection of Rotor Blades in Wind Turbines—The Industrial Realization of an SHM-System
P. KRAEMER, H. FRIEDMANN, C. EBERT

FIELD VALIDATION

FEASIBILITY OF A TOWER MOUNTED ICE DETECTION

WOULD IT BE POSSIBLE TO USE THE SINGLE SENSOR SHM INSTRUMENTATION FOR DETECTING ICING?

To validate the validity of a tower mounted ice detection system :

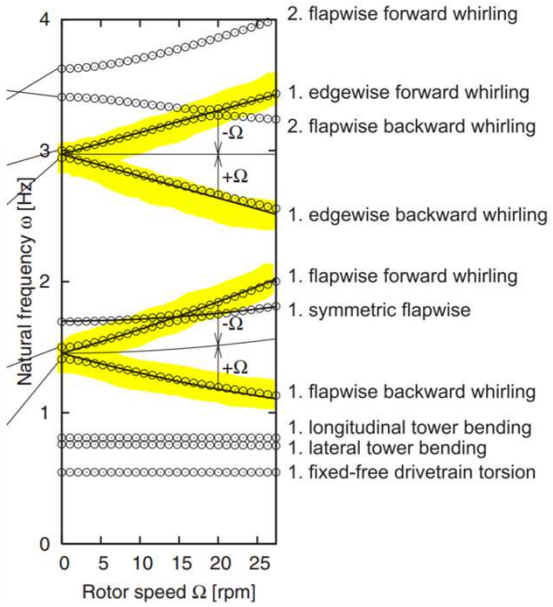
- Prove sensitivity of rotor modes to icing ✓
- Prove observability of rotor modes from the wind turbine tower
- Prove detectibility of icing in real-world conditions
- Prove reliability of icing detection in real-world conditions

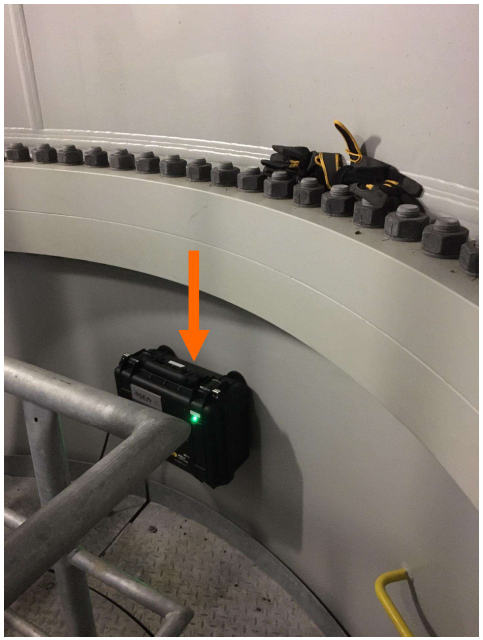
OBSERVABILITY OF WHIRLING MODES

VARIOUS MEASUREMENT CAMPAIGNS

Looking for the so-called '*Whirling modes*'

In-field instrumentation of operational wind turbines





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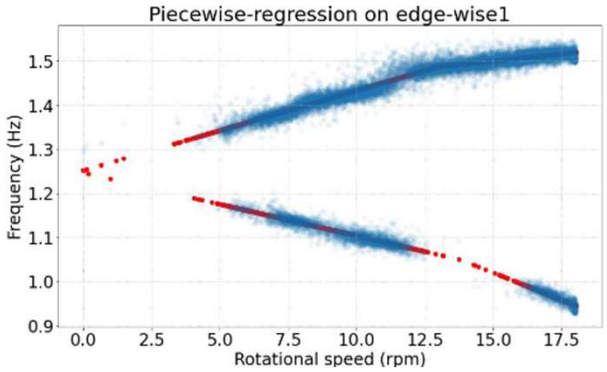


As whirling modes are sensitive to icing but also RPM dependent we need to first train a model (based on the SCADA) to predict the frequency of the whirling mode at a given windspeed

$$f_w(external\ factors) = f_{w,measured} - f_{w,machine\ learning}(EOC)$$

Icing is detected when the measurements are significantly lower (=drop of frequency) than the prediction.

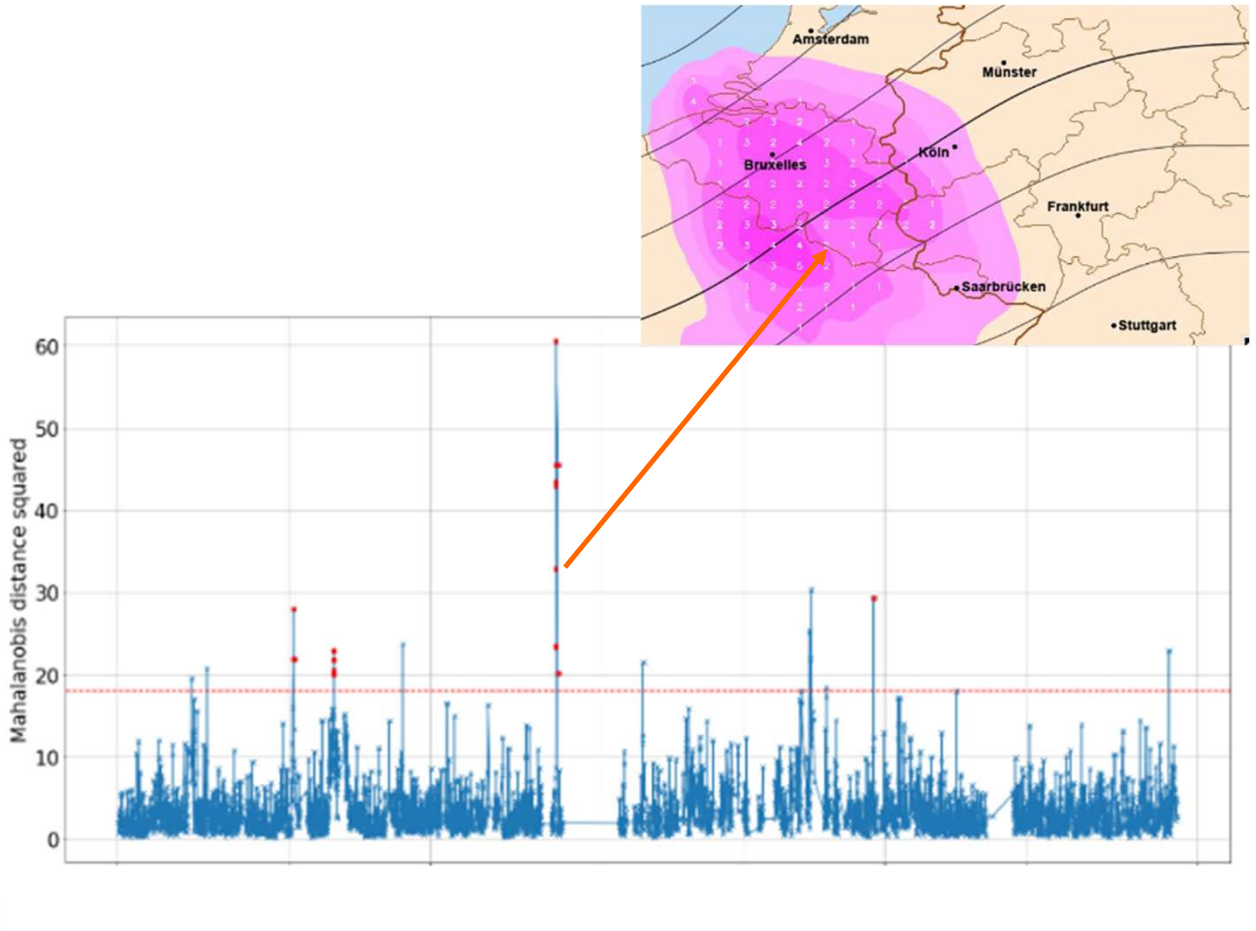
-> Method requires a training period, but models might be transferable for similar turbine types

ICING OBSERVATIONS

IN-FIELD OBSERVATIONS

In-field validation of the concept seems to suggest some detectability of icing (albeit secondhand)

Eg. Ice indicator spiked at day with severe snowfall.



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  - **TODO: Perhaps somewhere with a bit more icing ;-)**

VRIJE UNIVERSITEIT BRUSSEL

innovation forward

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