Autonomous calibration and optimisation of blade based ice detection systems

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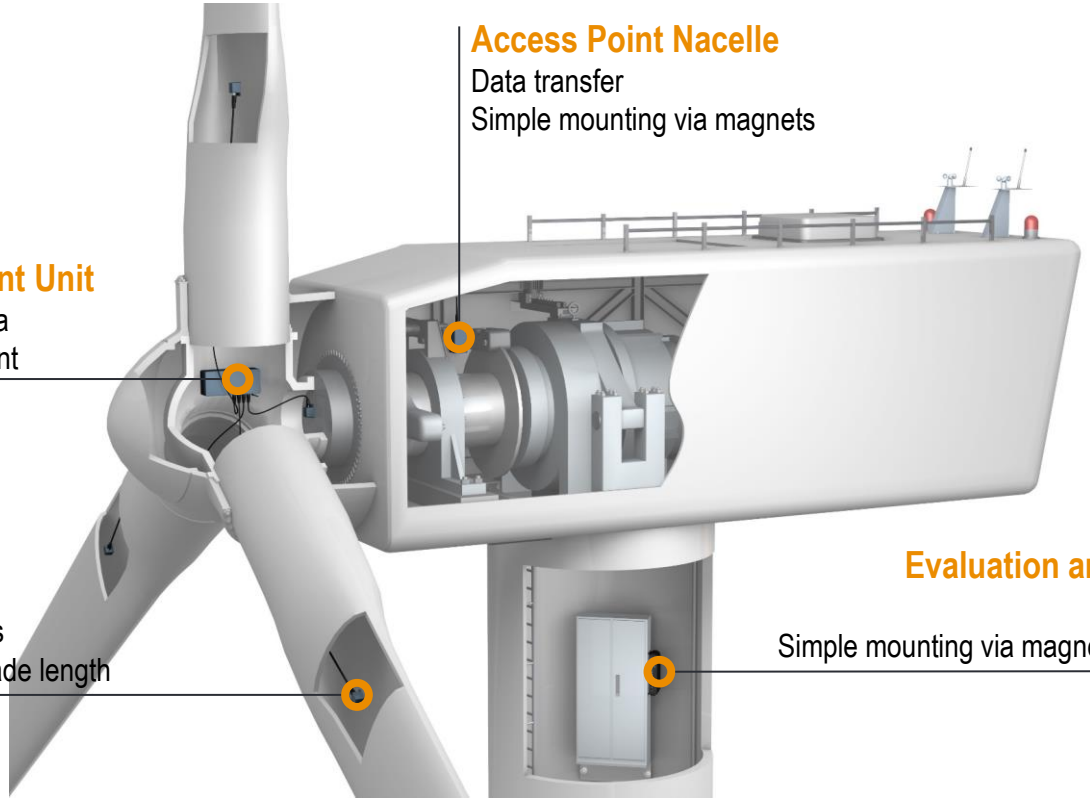
www.bladecontrol.de

Weidmüller

Agenda

- blade based ice detection system
- Natural vibrations
- Critical Ice accretion
- Influence of operating condition
- Influence of productional tolerances and how to cope with productional tolerances
- Site specific influences (gearbox, noise reduced mode) and how to cope with Site specific influences

Architecture



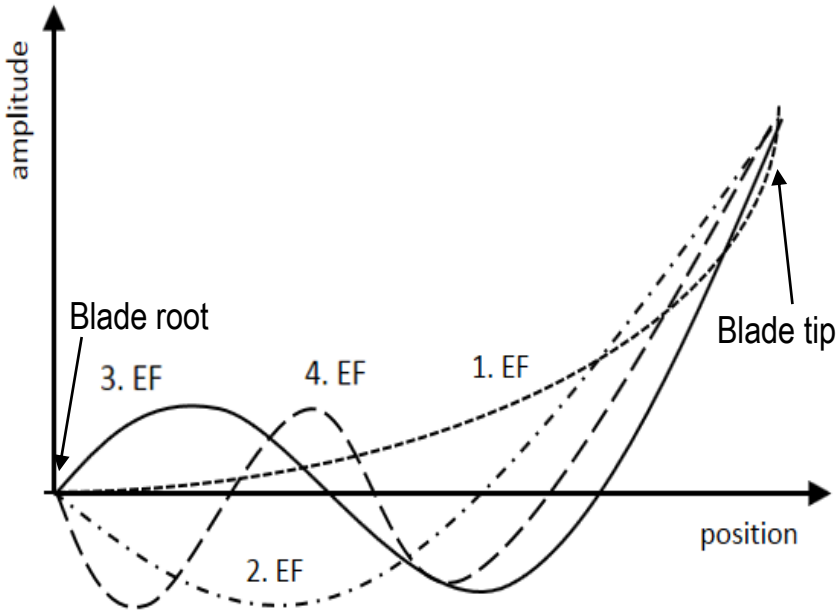
Access Point Nacelle
Data transfer
Simple mounting via magnets

Hub Measurement Unit
Pre-treatment of data
Including access point

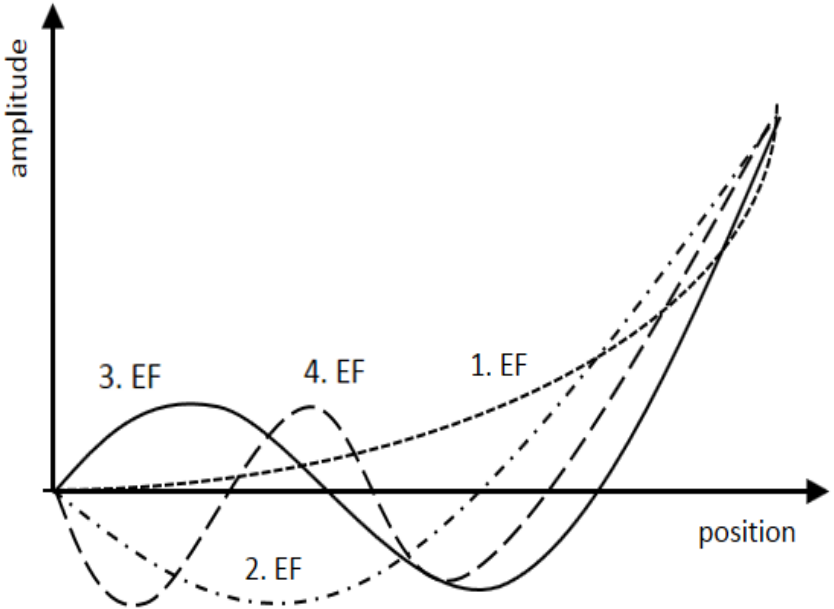
Sensors
Acceleration sensors
Installed at 1/3 of blade length

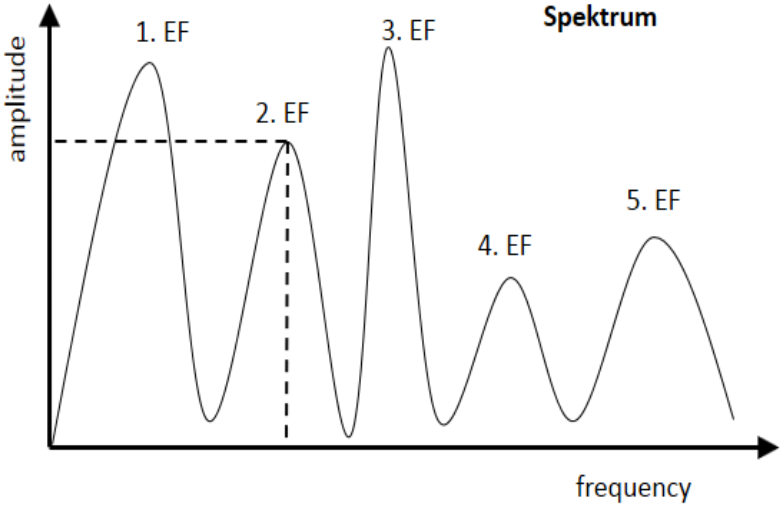
Evaluation and Communication Unit
Data evaluation
Simple mounting via magnets in nacelle or tower bottom

Are there good vibrations?



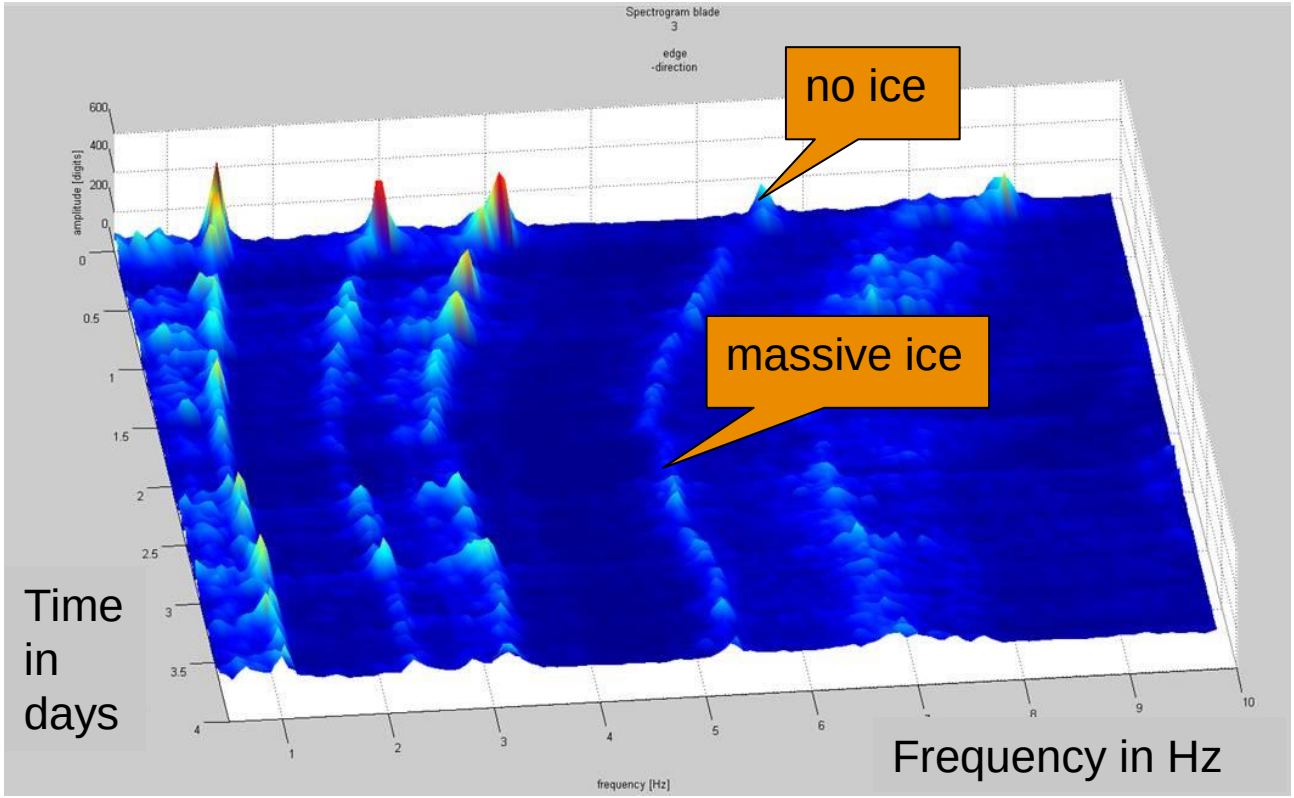
Are there good vibrations? Yes!





Usage of blade‘s vibration (EF – Eigenfrequency) for accurate ice detection

Influence of icing on vibration frequencies



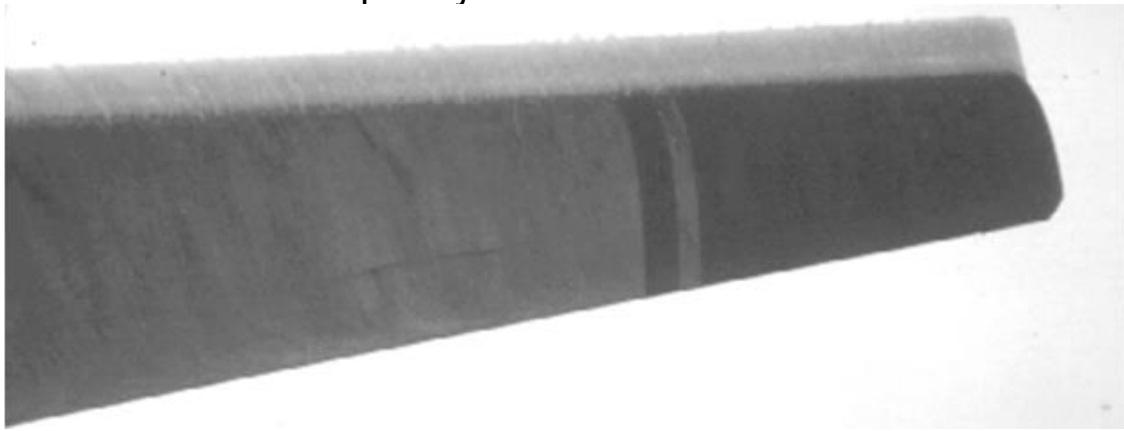
Icing event with over 250 kg ice per blade

- All natural oscillations decrease due to ice
- Blades natural frequencies as well as whole rotor natural frequencies

Definition of critical ice accretion

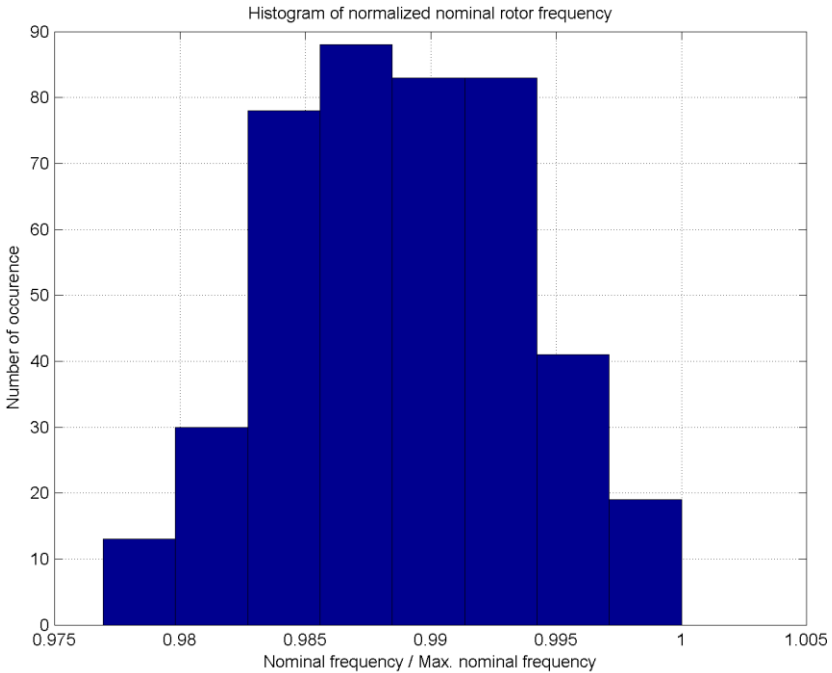
- According to DNV: Maximum ice thickness of 1.5 – 2.0 cm for worst case ice distribution (only on outer Third of Leading Edge, with ice density of 0.9 g/cm^3)
- Test campaigns with OEMs: Measurements with extra masses of lead put on the leading edge
- **Result**: Correlation between additional mass and frequency reduction

Threshold for **ice alarm** (critical ice accretion): approx. **1 %** of the natural vibration frequency (Average value, depending on blade type)



Source: H. Seifert, AERODYNAMICS OF ICED AIRFOILS, presented at the European Wind Energy Conference, October 1997, Dublin Castle, Ireland

Calibration: Scattering of natural vibrations due to productional tolerances (1)

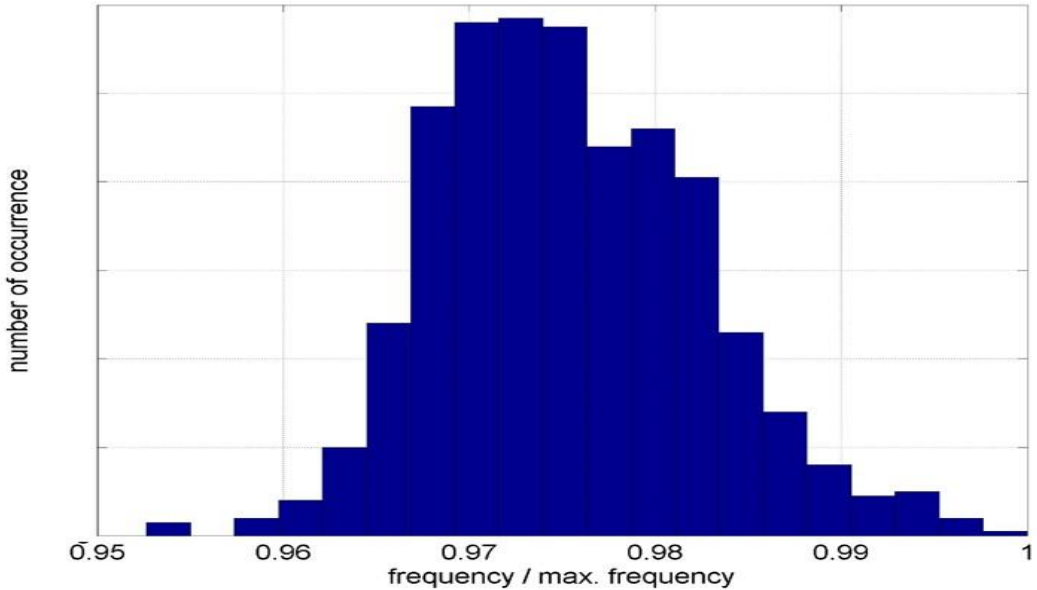


- evaluation of > 300 blades of same type
- variation of blade mass and stiffness
- variation of rotor vibration of +- 1 %

Threshold for **ice alarm** (critical ice accretion): approx. **1 %** of the natural vibration frequency (Average value, depending on blade type)

Calibration: Scattering of natural vibrations due to productional tolerances (2)

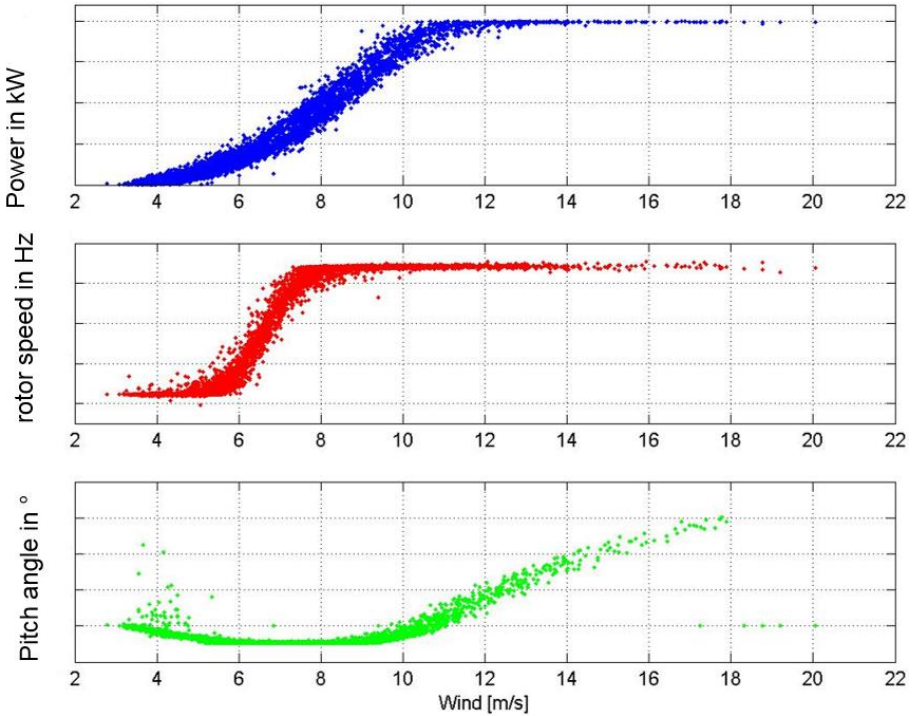
- evaluation of > 300 blades of same type
- variation of blade mass and stiffness
- variation of blades natural vibration of +- 2 %



Threshold for **ice alarm** (critical ice accretion): approx. **1 %** of the natural vibration frequency (Average value, depending on blade type)

Solution: Automatic ***Calibration*** of natural vibrations with blades free of ice (24 hours at temperatures above +5°C)

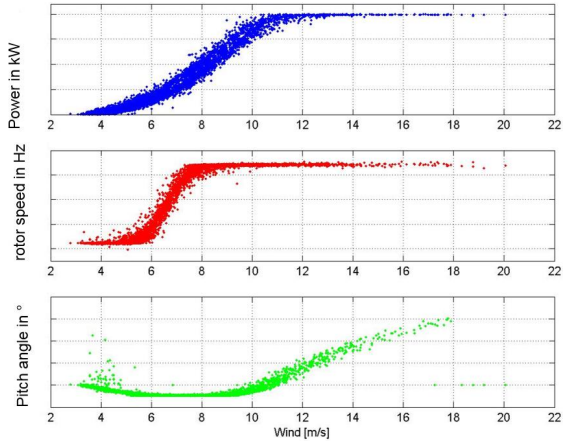
Validation: Vibration depend on operational condition (1)

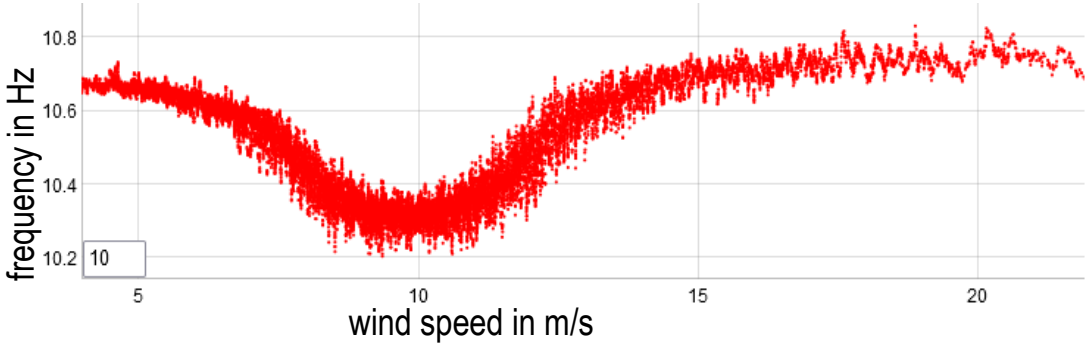


Influence of:

- Wind speed
- Generated power
- Rotor speed
- Pitch angle of the blades
- temperature

Validation: Vibration depend on operational condition (2)



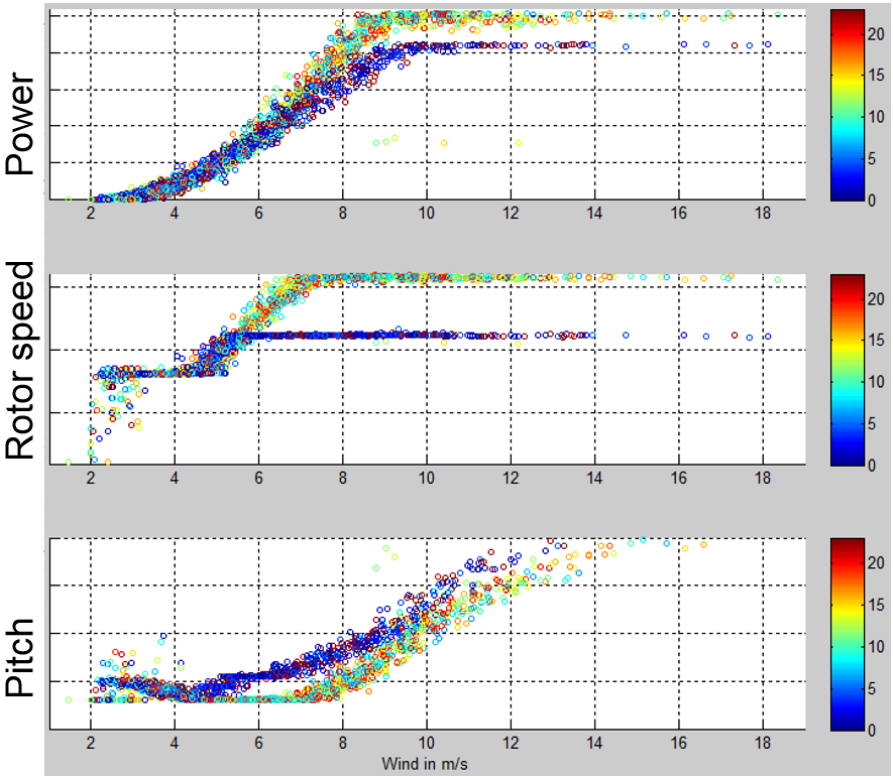


Solution: ***Validation*** for new blade types during all operating conditions with blades free of ice
(at temperatures above +5°C)

Optimisation: Resonance by drivetrain excitation

- Tooth meshing frequency of the gearbox excites natural vibration
- Leading to resonance with high vibration amplitudes

Optimisation: Site specific operational modes

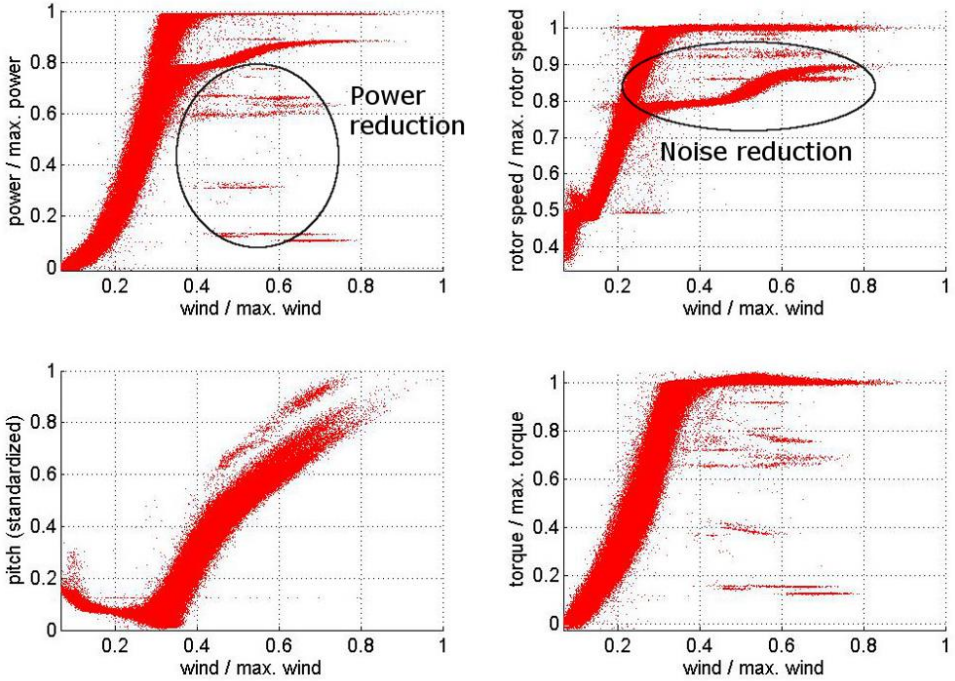


Color represents daytime in hours

➢ Noise reduced mode at night with lower rotor speed, power & pitch

-> Change of natural vibrations daytime dependant

Optimisation: Site specific operational modes



Solution: Automatic ***optimization*** for adaption to turbine and site specific operating conditions with blades free of ice
(at temperatures above +5°C)

Summary

- Usage of natural vibrations for ice detection
- Definition of critical ice accretion
- Determining the influence of operating conditions (**validation**)
- How to cope with the influence of productional tolerances and aging? Automatic **calibration**
- Site specific influences (gearbox, noise reduced mode) -> **optimisation**

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