Low temperature autonomous calibration of blade-based ice detection systems

Dr.-Ing. Daniel Brenner
Head of Monitoring

Åre, March 19th 2024

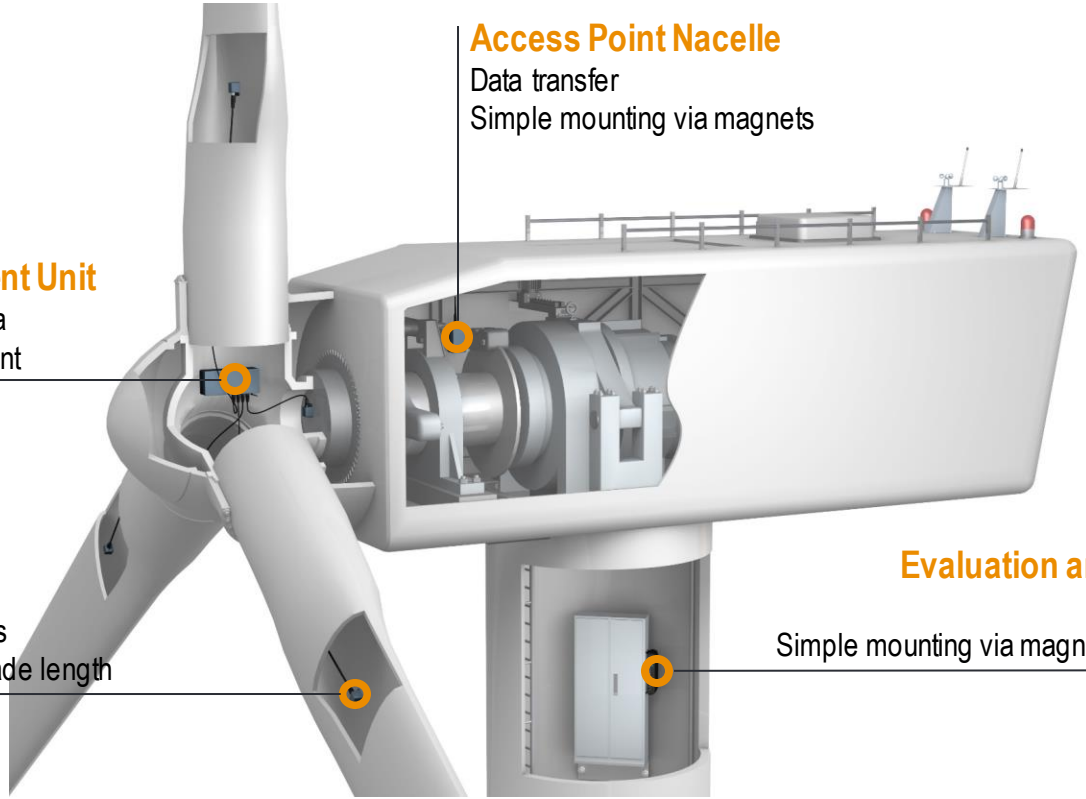
www.bladecontrol.de

Weidmüller

Agenda

- Blade based ice detection system
- Natural vibrations
- Influence of productional tolerances and how to cope with productional tolerances
- Problems with automatic calibration in winter season
- … and how to solve this
- It even works in turbine standstill !

Architecture



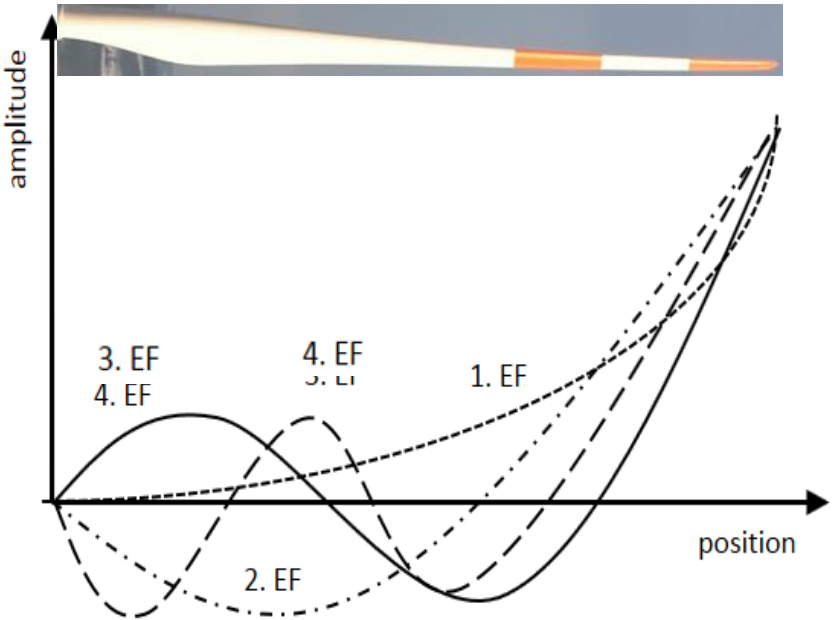
Access Point Nacelle
Data transfer
Simple mounting via magnets

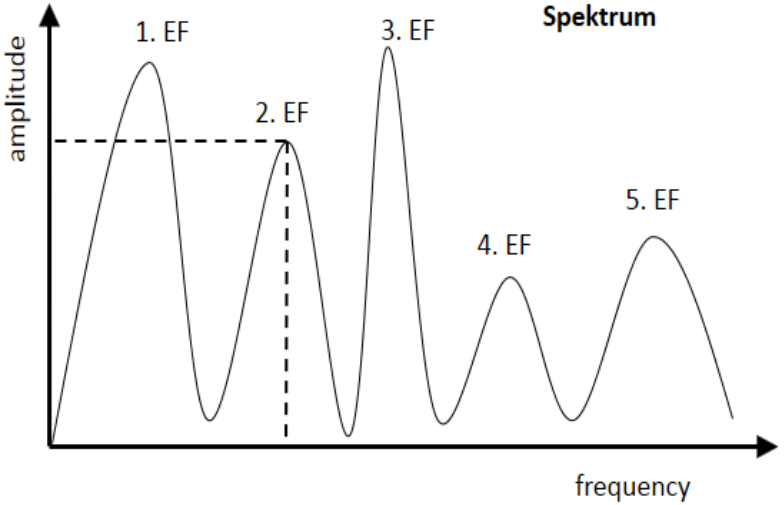
Hub Measurement Unit
Pre-treatment of data
Including access point

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

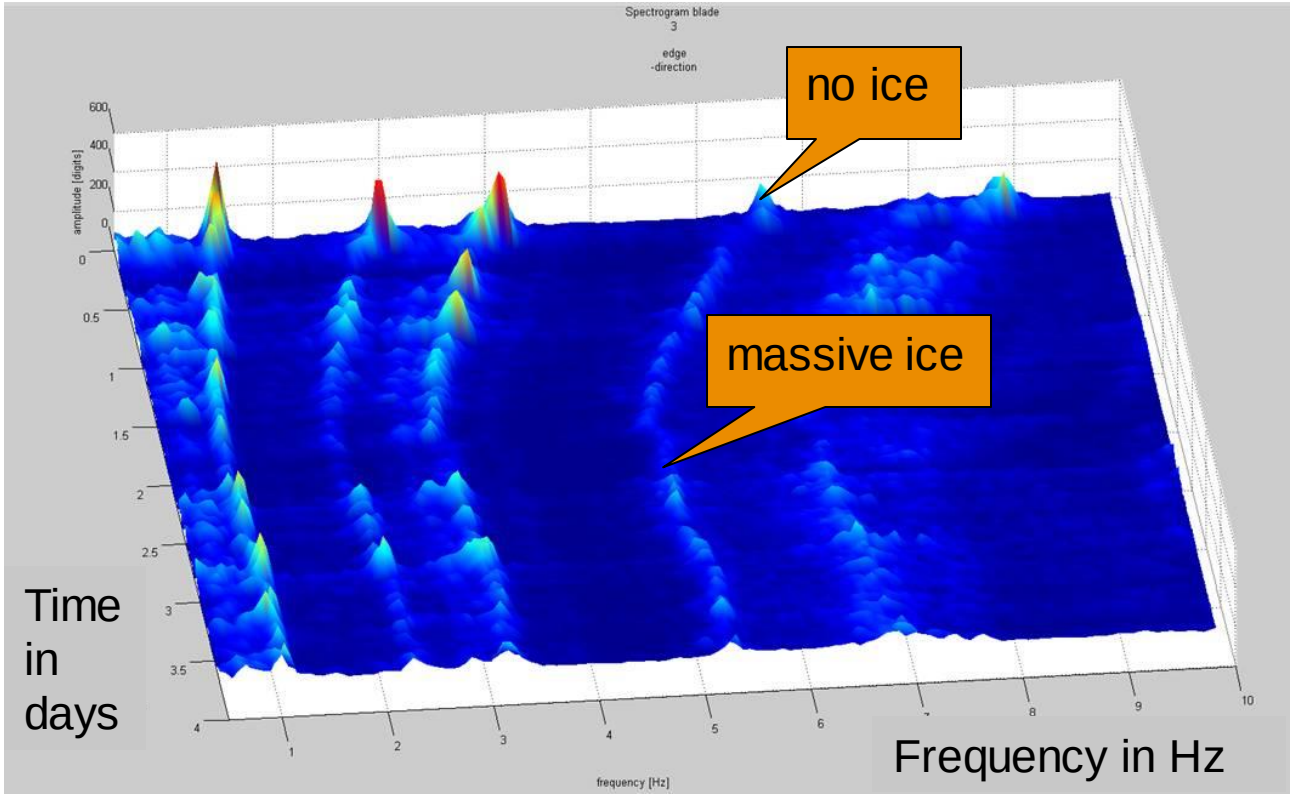
Are there good vibrations? Yes!





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

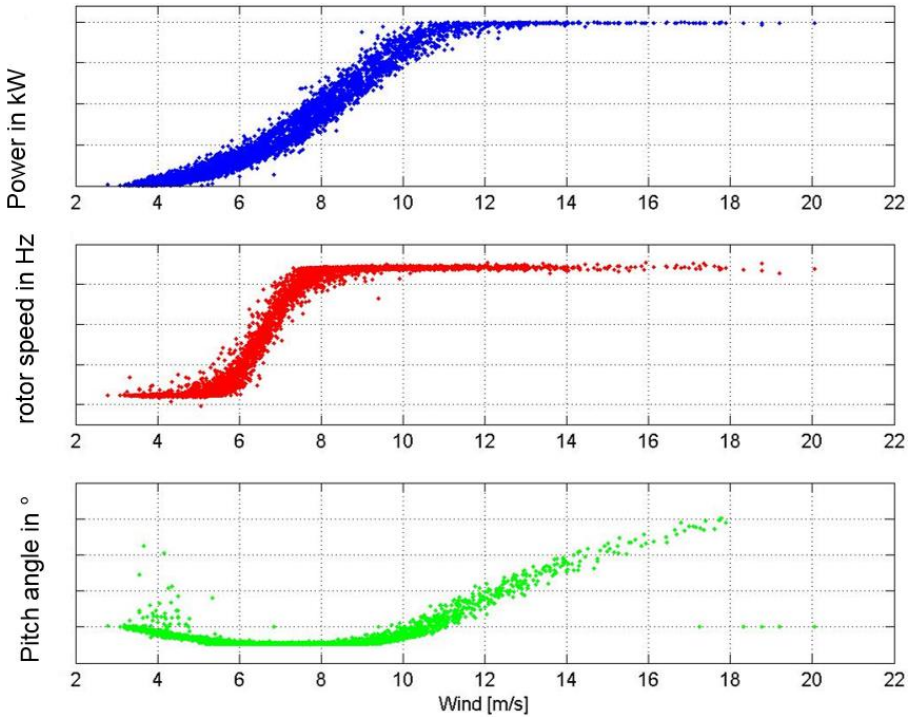
Influence of icing on vibration frequencies



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

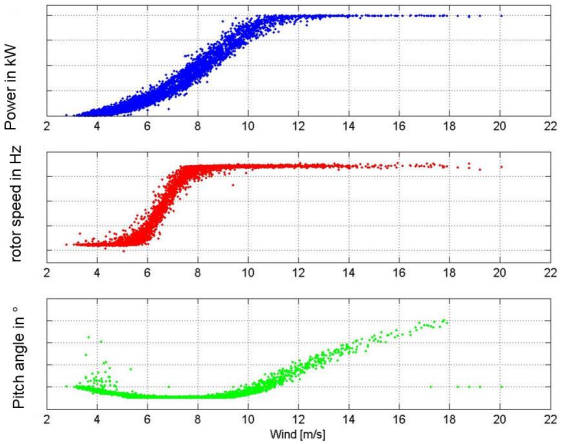
Validation: Vibration depends on operational condition (1)

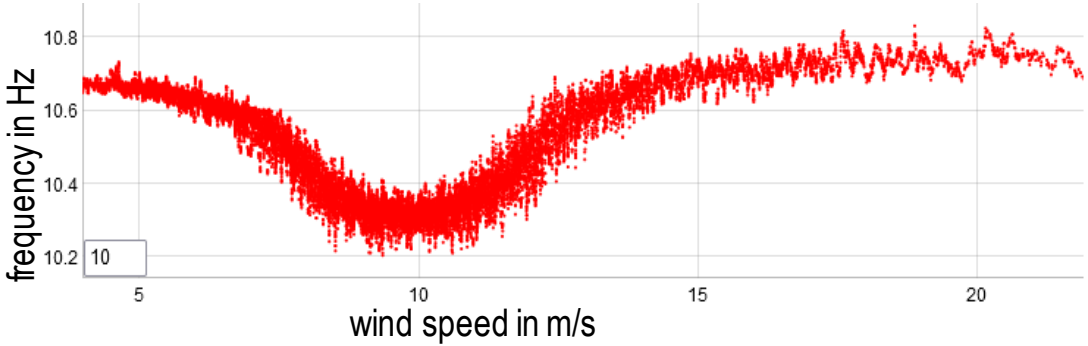


Influence of:

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

Validation: Vibration depend on operational condition (2)



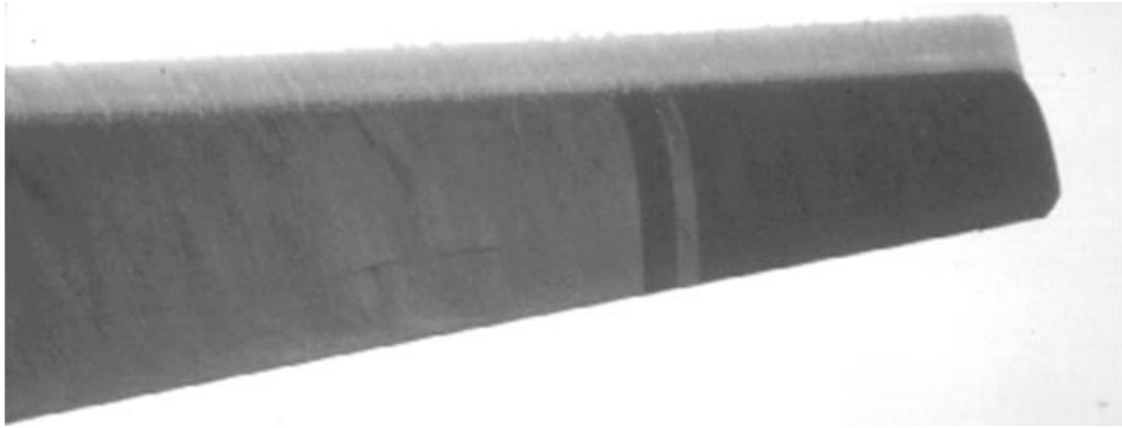


Solution: ***Validation*** for new blade types during all operating conditions when blades free of ice
(at temperatures above +5°C)

Definition of critical ice accretion

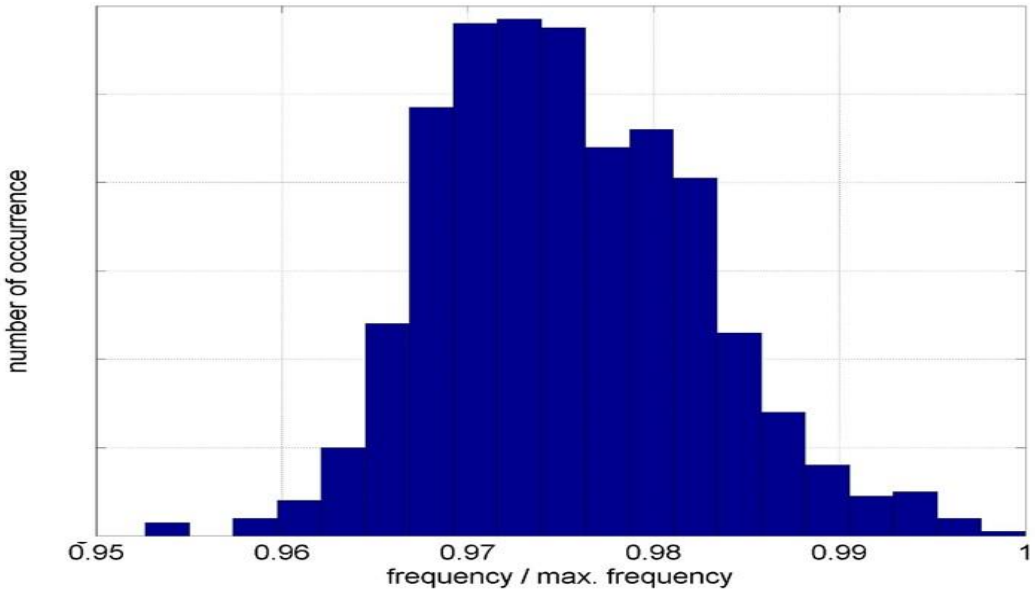
- According to DNV: Maximum ice thickness of 1.5 – 2.0 cm for worst case ice distribution (only on outer third of leading edge, with ice density of 0.9 g/cm^3)
- Test campaigns with OEMs: Measurements with extra masses of lead put on the leading edge
- **Result**: Correlation between additional mass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



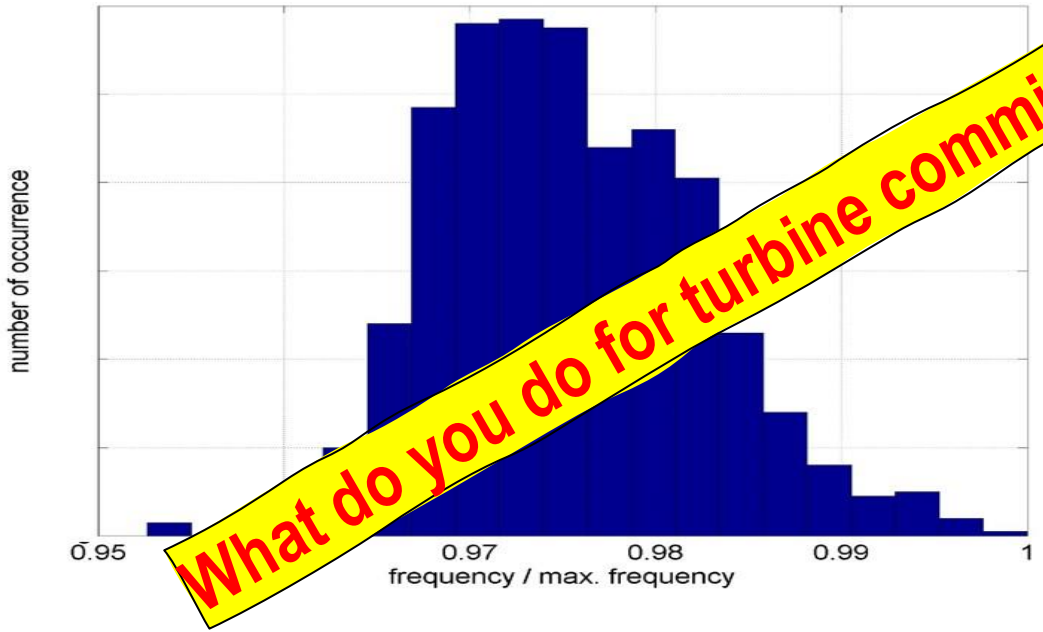
- evaluation of > 300 blades of same type
- variation of blade mass and stiffness
- variation of blades natural vibration of +- 2 %

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)

Calibration: Scattering of natural vibrations due to prod… tolerances

- evalu… 300 blades of same type
- … blade mass and stiffness
- …tion of blades natural vibration of +- 2 %



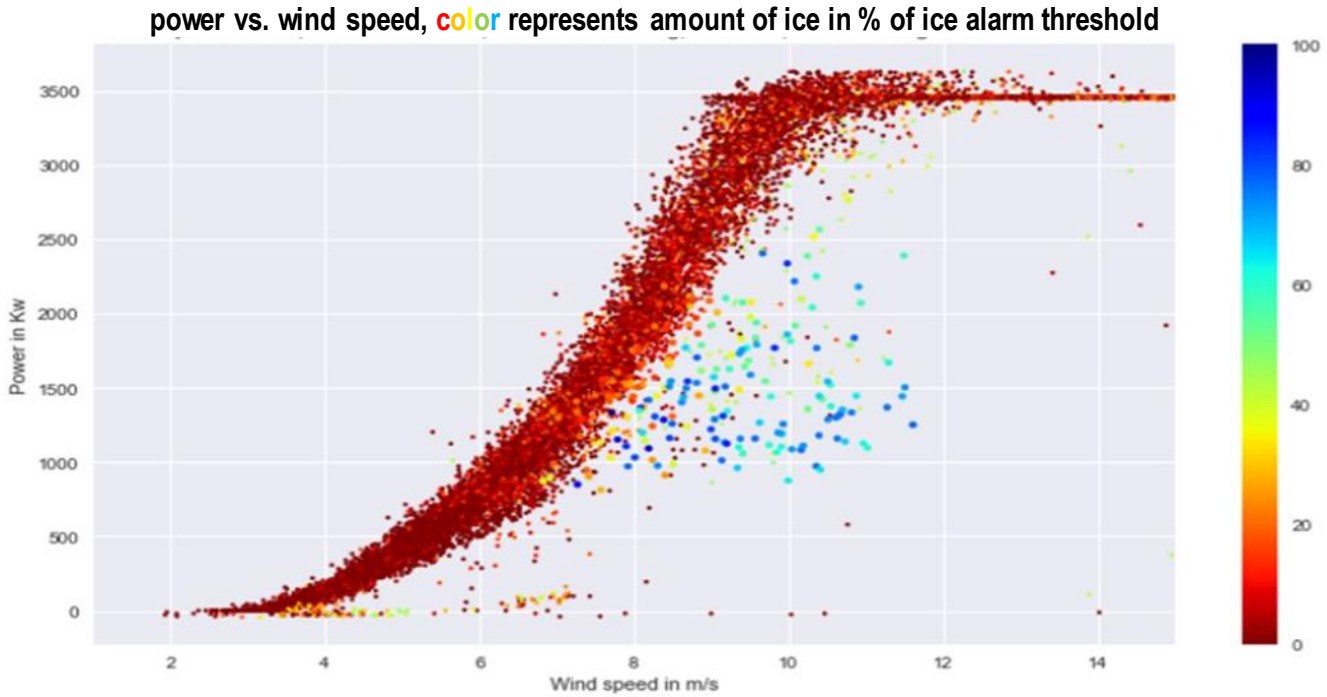
What do you do for turbine commissioning in winter season?

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)

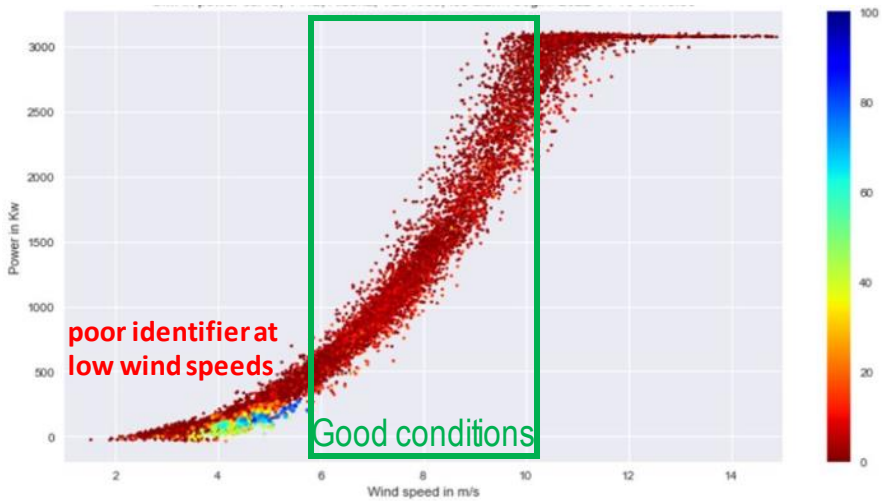
2. Choose calibration data based on power curve deviation

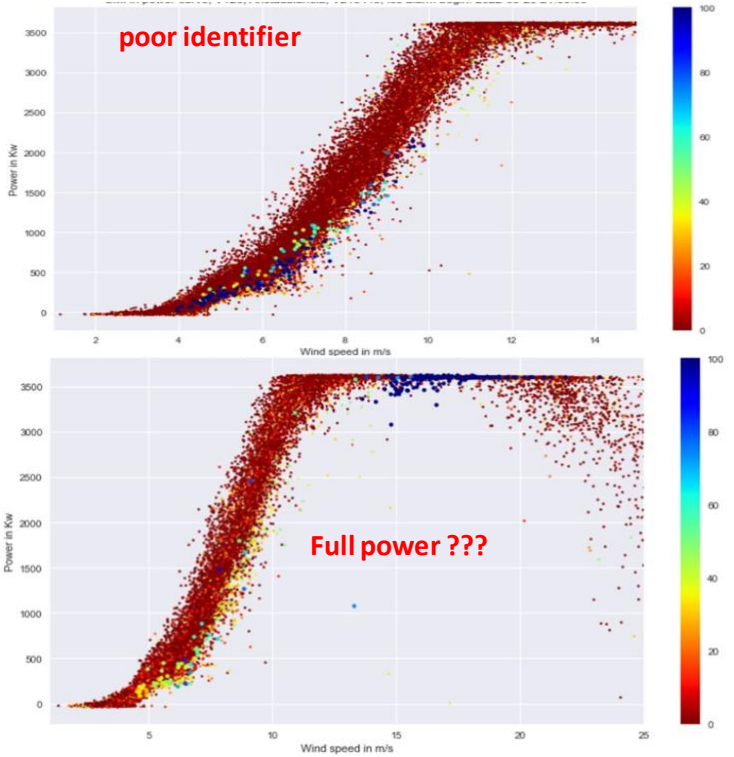
Principles of the approach



2. Limitations to the power curve based calibration

power vs. wind speed, color represents amount of ice in % of ice alarm threshold





X **For ice detection**: Does not work in all operating conditions

✓ **For calibration**: good conditions are sufficient!

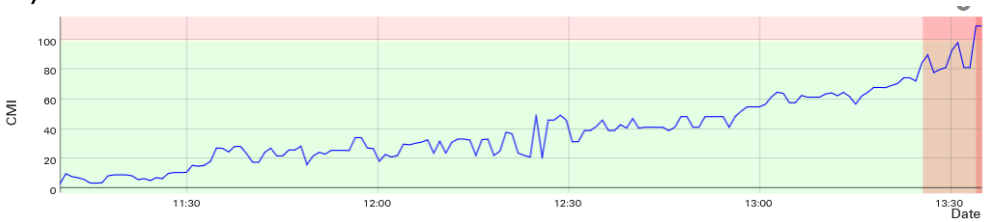
Solution based on icing event experience

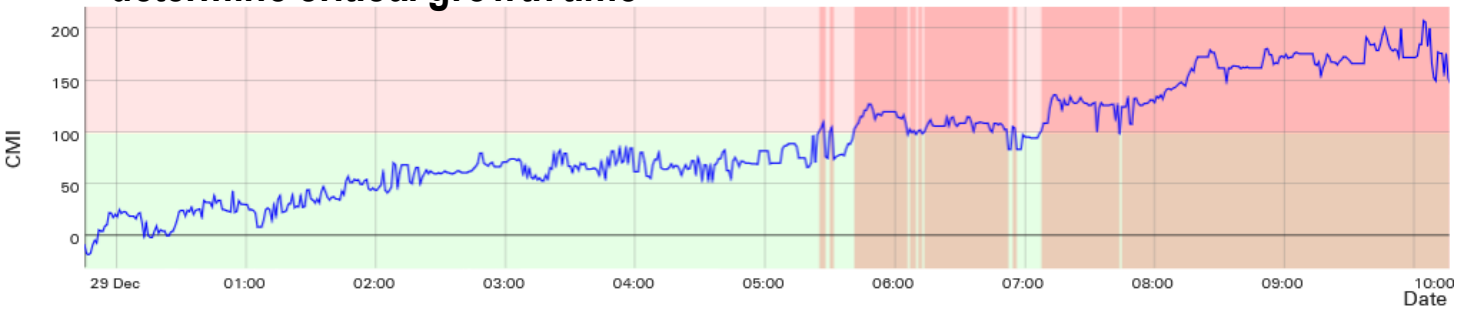
More than

- 100 Turbine & blade types (D 54 – 220m)
- 30 Countries
- 5900 turbines (16 GW)
- 23.000 Machine Years
- 50.000 Icing events

Different Icing conditions (snow, rime)

-> determine critical growth time



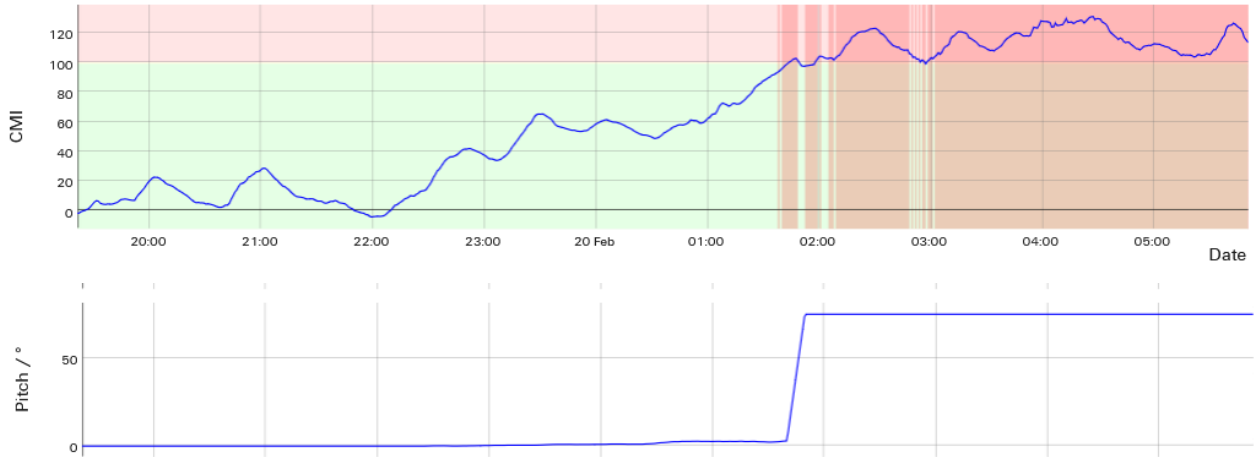


Weidmüller

Standstill calibration

When turbine is free of ice and in operation, initial icing is considered neglectable:

1. Turbine calibrated during operation
2. Turbine stops
3. Use next X minutes for calibration in standstill



Summary

- Usage of natural vibrations for ice detection
- How to cope with the influence of productional tolerances? Automatic & individual **calibration**
- Vestas Ice Detector (VID) and turbine controller share power curve data
- Automatic calibration possible throughout the year
- Also works in turbine standstill

Contact

Weidmüller Monitoring Systems GmbH

Name Dr.-Ing. Daniel Brenner
Position Head of Monitoring

Else-Sander-Straße 8
01099 Dresden, Germany

Phone +49 351 213 916 67

Email Daniel.Brenner@weidmueller.com
Web www.bladecontrol.de

Name Kirsten Larson
Position Senior Sales Manager

Phone +49 351 213 916 63

Email kirsten.larson@weidmueller.com


Connections are Our Expertise.
We Look Forward to Sharing Ideas with You.
Let´s connect!