Weidmüller

Experience with De-icing systems, noise and vibrations evoked by ice accretion

Dr. Daniel Brenner, Daniel.Brenner@Weidmueller.com

Skellefteå, Winterwind conference, 08th Feb 2017

content

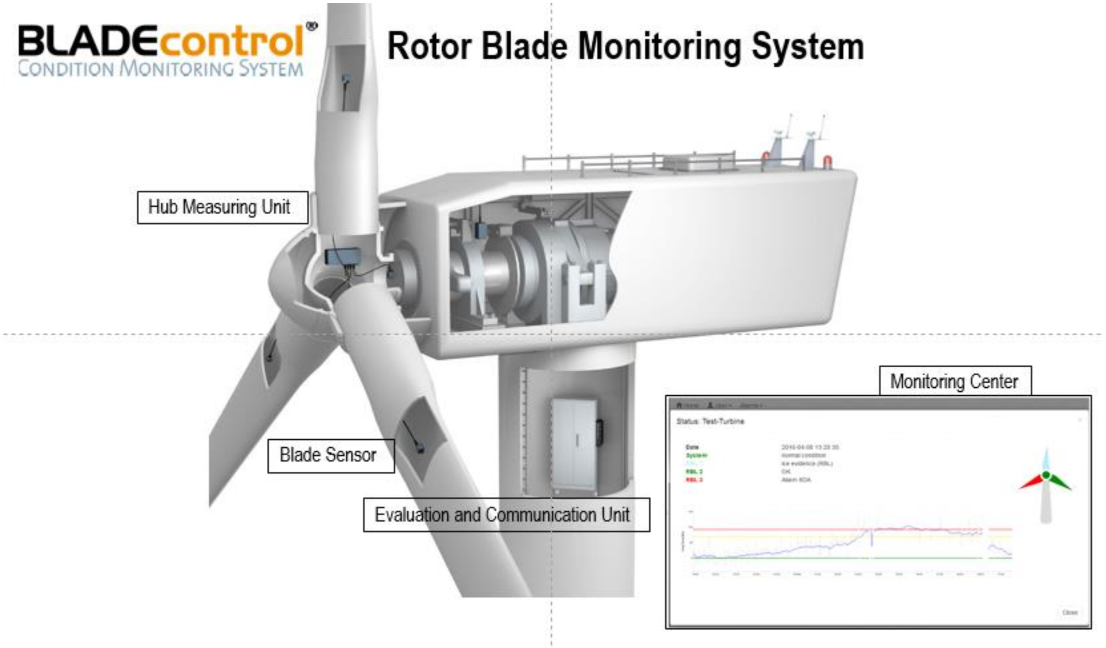
Weidmüller

- Where does the experience come from?
- De-icing systems
- Noise
- Vibrations

Weidmüller

BLADEcontrol®
CONDITION MONITORING SYSTEM

System facts summary

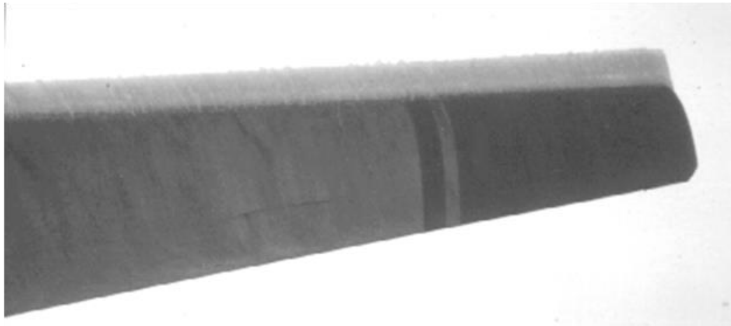


- **Turbines in Monitoring: >1,500***
- **Sold Systems, in total: >2,000***
- **Monitoring background**
  - Over 4,000* machine years of monitoring experience
- **Market distribution**
  - System of choice of all major OEMs and large operators
  - Covering a wide variety of turbine and blade types, on- and offshore
- **BLADEcontrol is the pioneer in rotor blade monitoring**
  - Ice detector first certified in 2008
  - Damage detection first certified in 2013

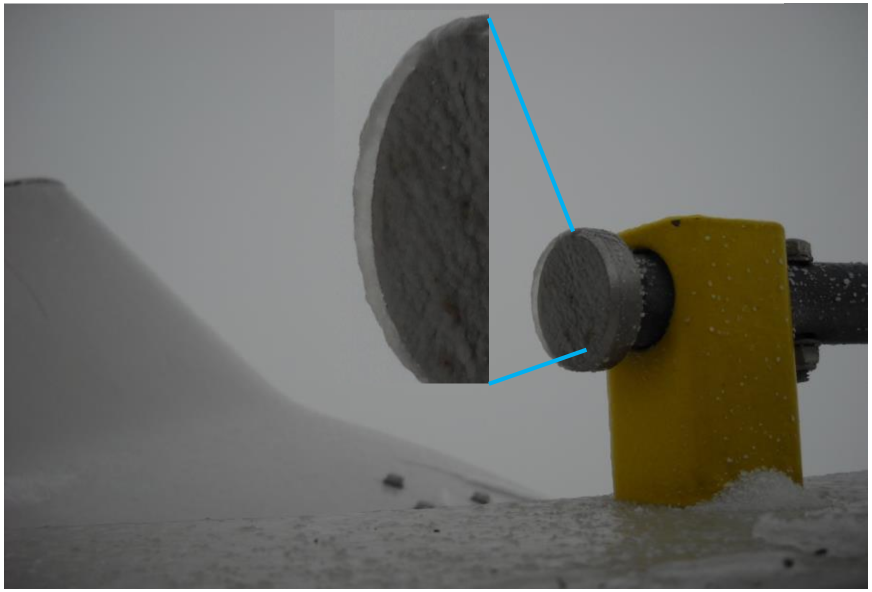
* as of February 1st, 2017

Icing conditions on blades

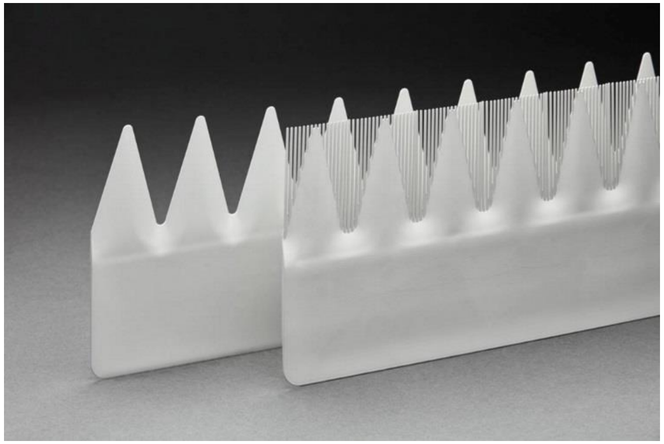
Icing only on leading edge



Ice rain on whole turbine and blade



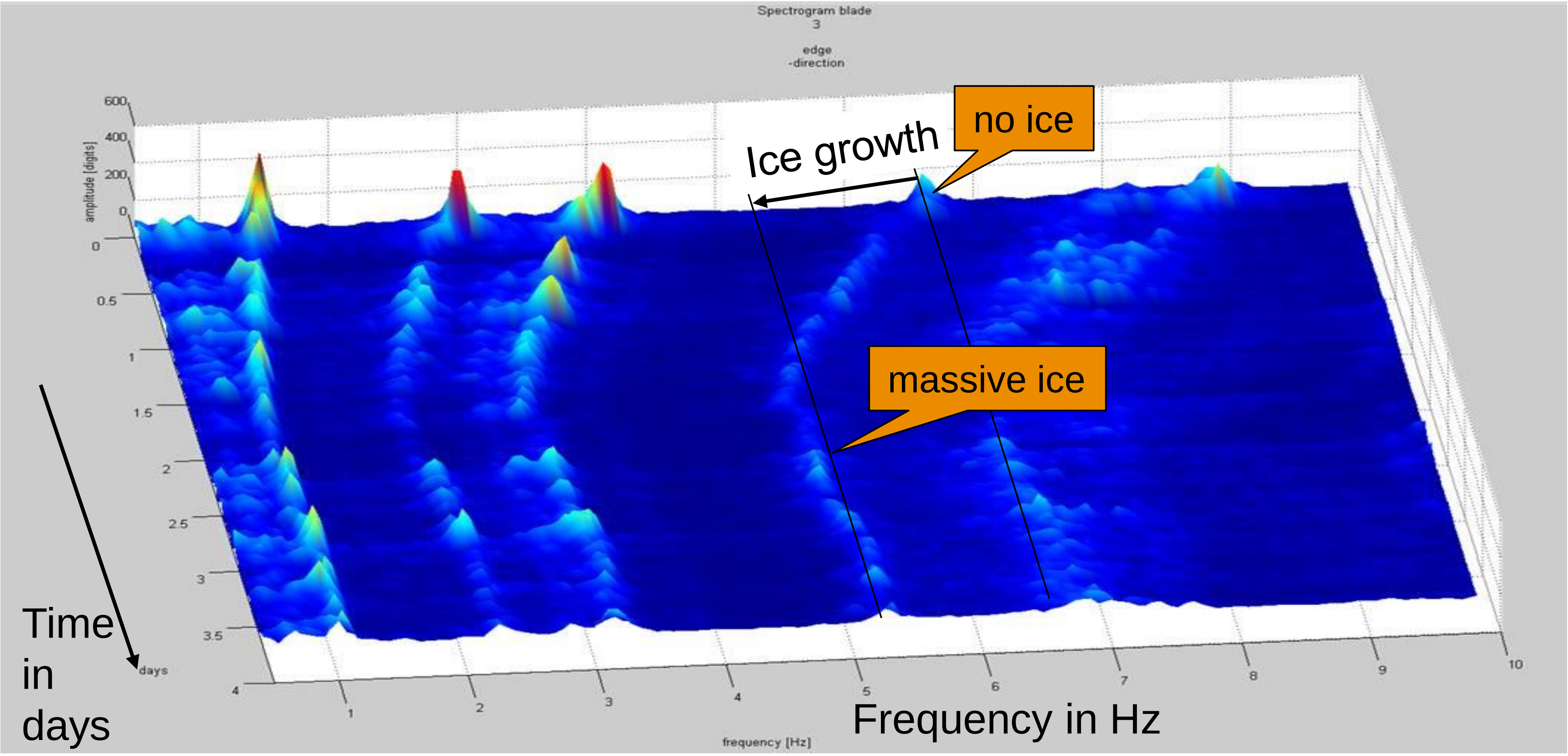
Trailing edge icing esp. at serrations



Source: windpowerengineering.com

Effect of icing on natural vibration

Weidmüller

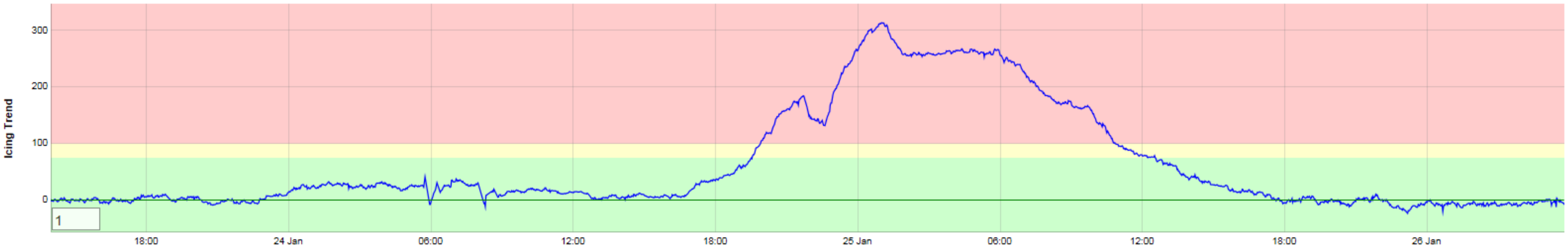


Icing event with over 250 kg ice per blade

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

Effect of icing on natural vibration

Visualization of ice accretion over time



ice accretion plotted as blue line:

- Icing trend proportional to amount of ice
- Green area means „free of ice“
- Yellow – warning
- Red area – heavy ice accretion -> usually turbine stop necessary

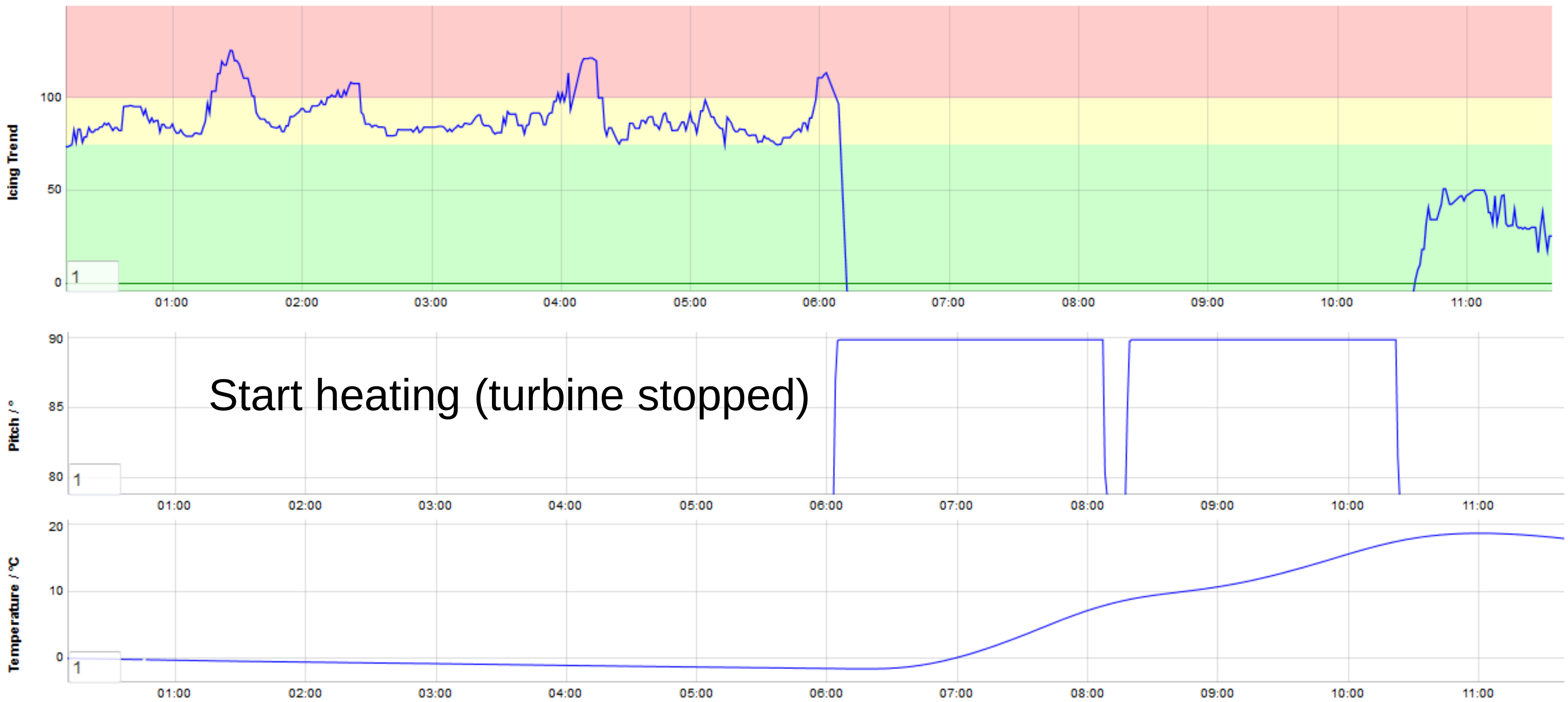
Weidmüller

Hot air fan

6 turbines with De-icing equipped with BLADEcontrol

Icing duration this season: 140 hours per turbine

Heating events this season: > 20 per turbine



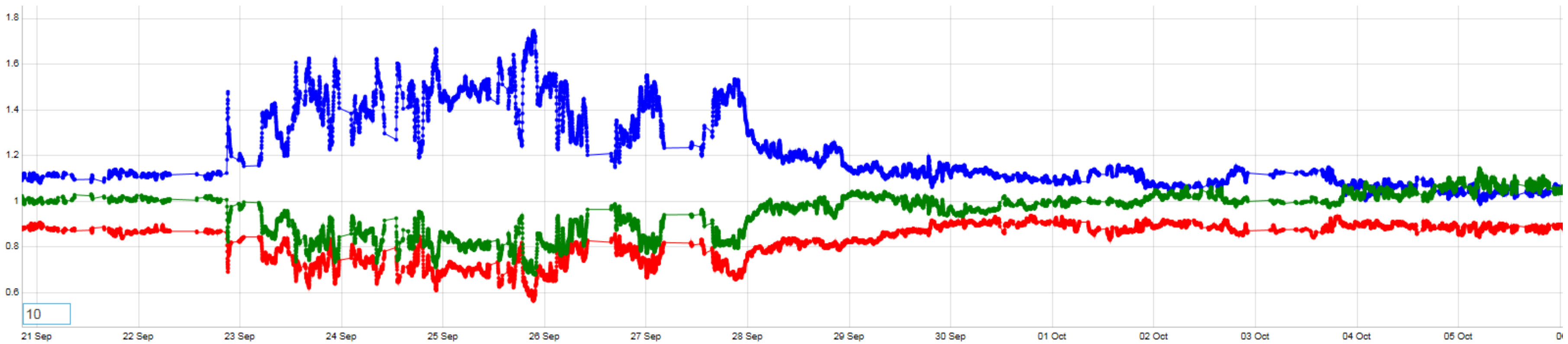
conclusion: Hot air fan is a robust system / technique, capable of de-icing

De-icing systems

De-icing system: heating mat on leading edge of the outer 2 third of the blade

Recalibration of BLADEcontrol after De-icing system installation necessary

Heating mat separated partly and was deinstalled before winter season

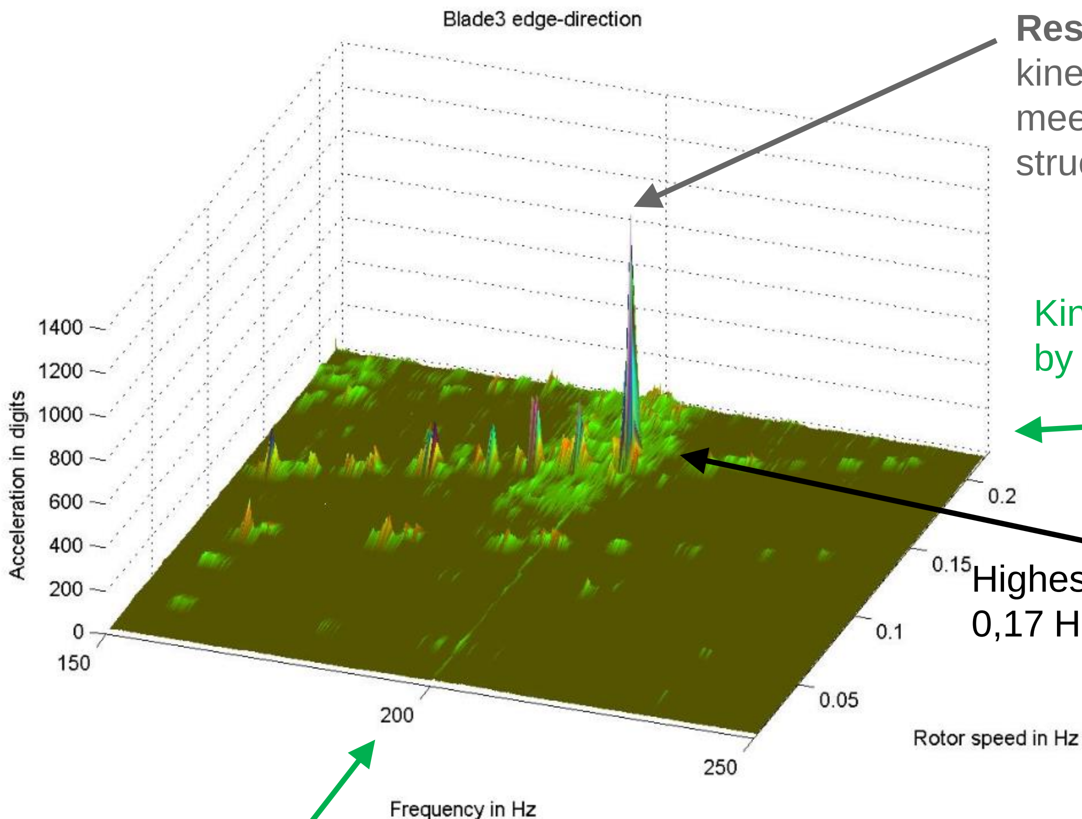


BLADEcontrol damage detection indicator revealed defect at heating mat at blade 2 (blue)

conclusion: Proof of reliability for systems with heating mat on leading edge necessary

Weidmüller

Tonality – excited by drive train



Resonance:
kinematic excitation
meets
structural vibration

Kinematic excitation
by gearbox

Highest amplitude at
0,17 Hz (10 rpm)

Structural vibration

Noise reduced mode
Lower rotor speed for
lower blade tip speed,
but **maximum torque**
for high power output

For this Turbine
Decreasing noise
strategy led to Tonality
-> increased noise

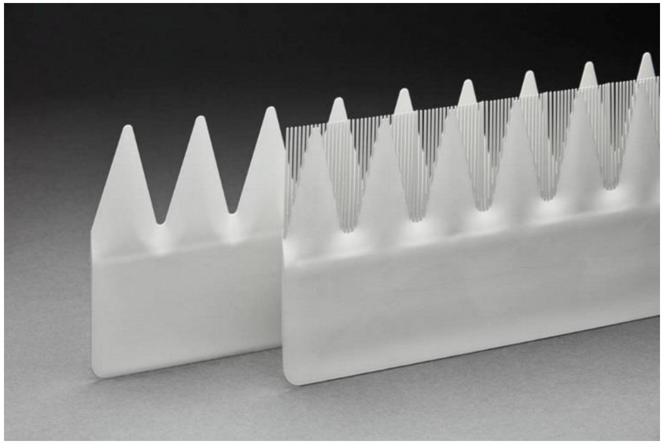
Complaints by residents:
sounds like a starting helicopter

Influence of icing: Reduction of vibration frequency shifts the tonality problem to a different rotor speed

Icing at trailing edge especially at serrations

Complaints by residents near windfarms about whistling sound

Investigation by technicians on the turbine: very thin icing between teeth of serrations

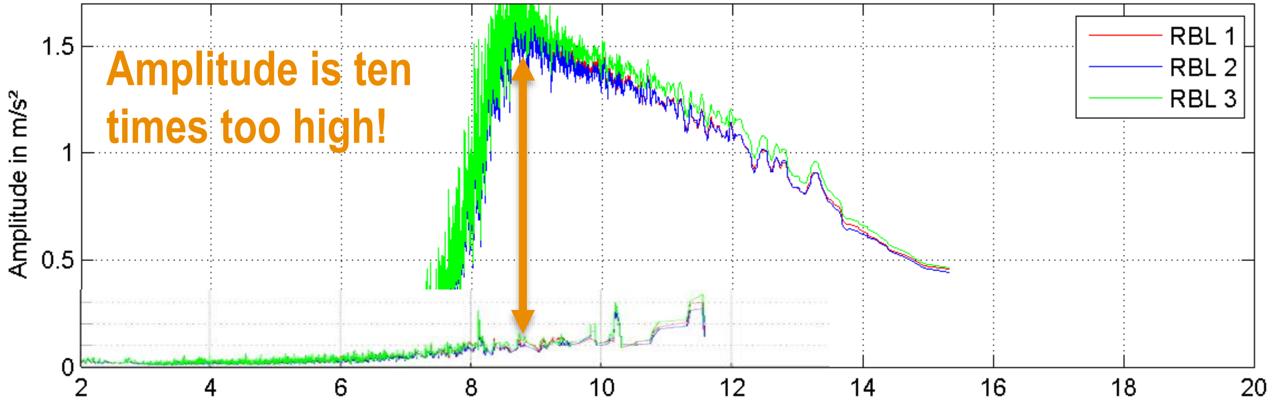


Source: windpowerengineering.com

<u>For this Incident</u>
Decreasing noise strategy led to whistling sound -> increased noise

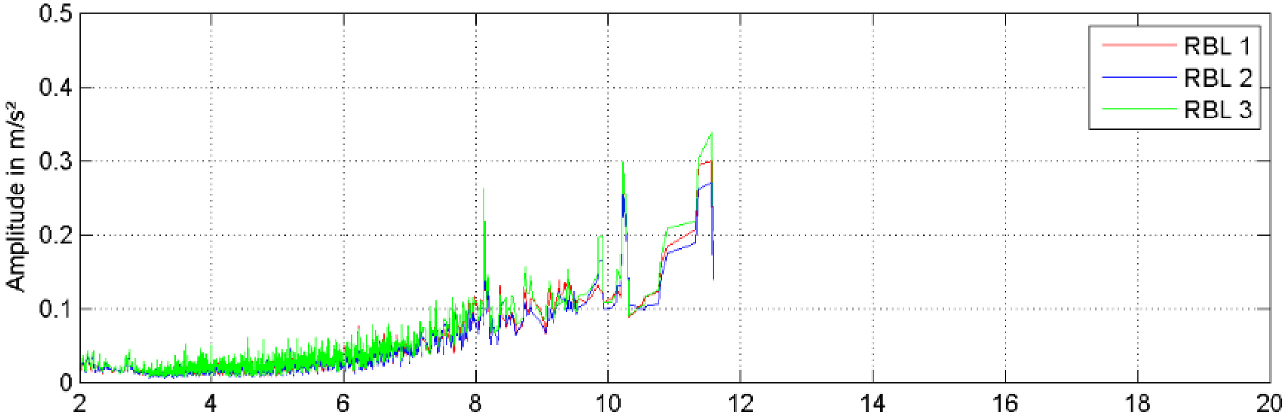
Weidmüller

Detection of increased Drive Train Torsion



Amplitude of the drive train torsion vibration measured on the blades plotted over wind speed

Noticable measurement triggers information for manufacturer

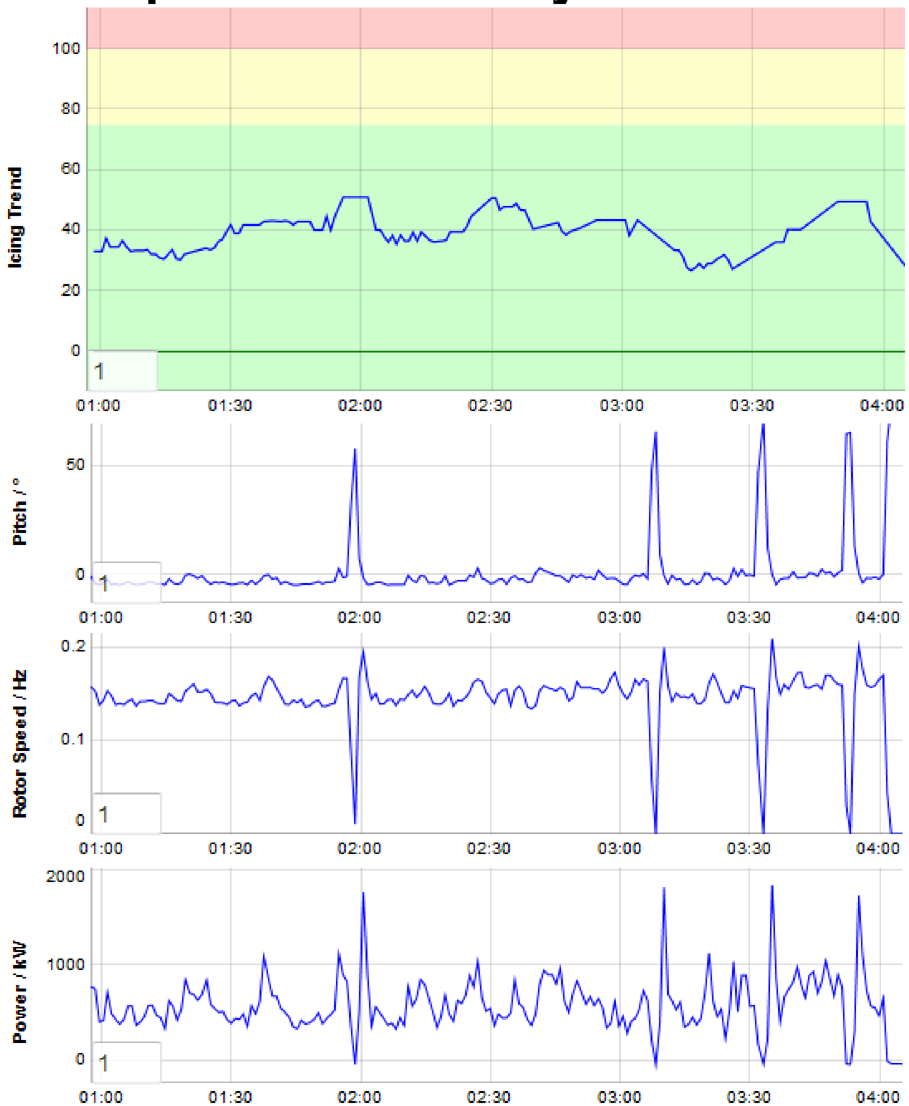


After correction by manufacturer

Reduction of the vibration via controller adaption

Influence of icing:
Reduction of vibration may not be adjusted by open-loop controller

Example: Small aerodynamic imbalance excites tower vibration



Only little icing, below 50 % of alarm value

Acceleration sensor in nacelle triggers turbine stop

Hybrid tower

height: 140m

1st natural tower vibration: 0.15 Hz

Rotor speed : 0.15 Hz (9 rpm)

Rotor speed = natural tower vibration
+ small imbalance
-> RESONANCE

Summary

- De-icing solutions differ in maturity
- Noise by thin ice between serrations difficult to detect an de-ice
- Natural Vibration frequency changes due to ice accretion -> may lead to resonance
- Aerodynamic imbalance + rotor running with tower vibration frequency causes emergency stops