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

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

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

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

Icing event with over 250 kg ice per blade
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
De-icing systems

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
Noise problems

Tonality – excited by drive train

Resonance: kinematic excitation meets 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

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Noise problems

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

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

Source: windpowerengineering.com
Vibration problem

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

Amplitude is ten times too high!

Reduction of the vibration via controller adaption

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

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

After correction by manufacturer

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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
1\(^{st}\) 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 and 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