



> Nordex Anti-Icing System on N131

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- 1 Anti-Icing System - Features
- 2 Development of N131 with AIS
- 3 Validation of design and functionality
- 4 Field experience and yield improvement



Key features of the Nordex Anti-Icing System (AIS)

Availability:

- N117 Delta
- N131 Delta

Heating element:

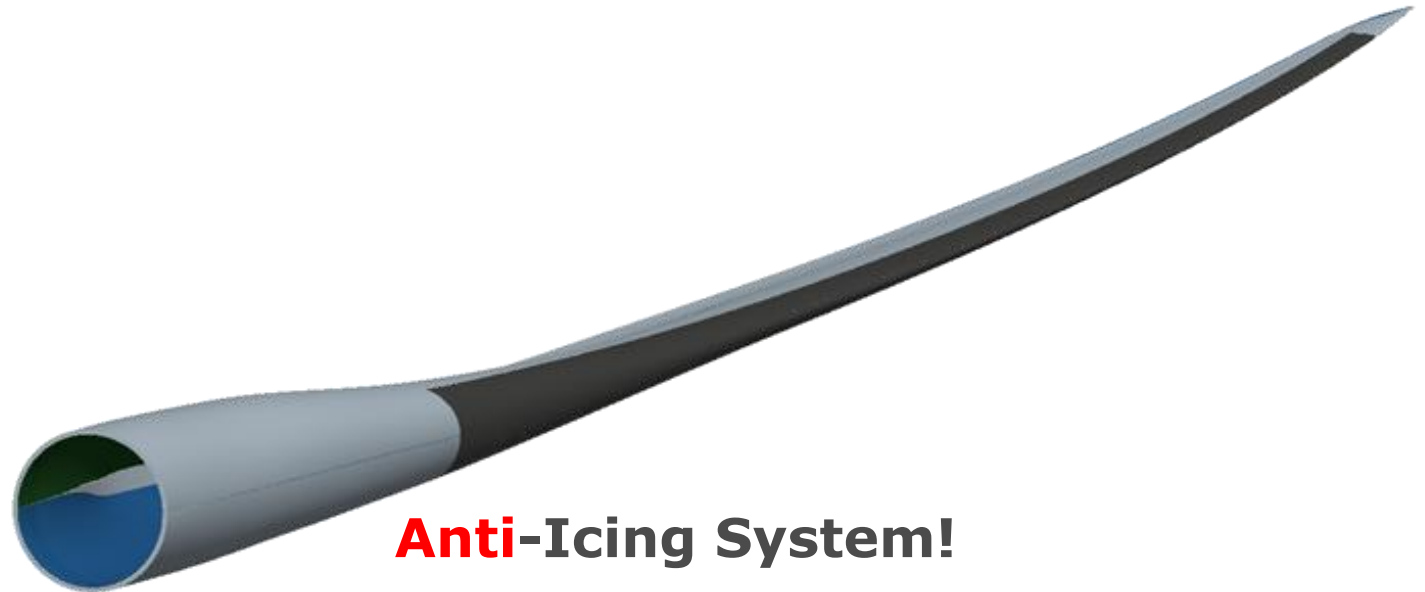
- Electrical resistance heater
- Carbon fiber reinforced plastics
- Aerodynamically relevant surfaces

Operation:

- Down to -20°C, even in severe icing
- Fully operational during turbine operation

Power consumption:

- Minimized by heating the surface rather than the blade structure
- Minimized by intelligent algorithm to switch off, low power or high power

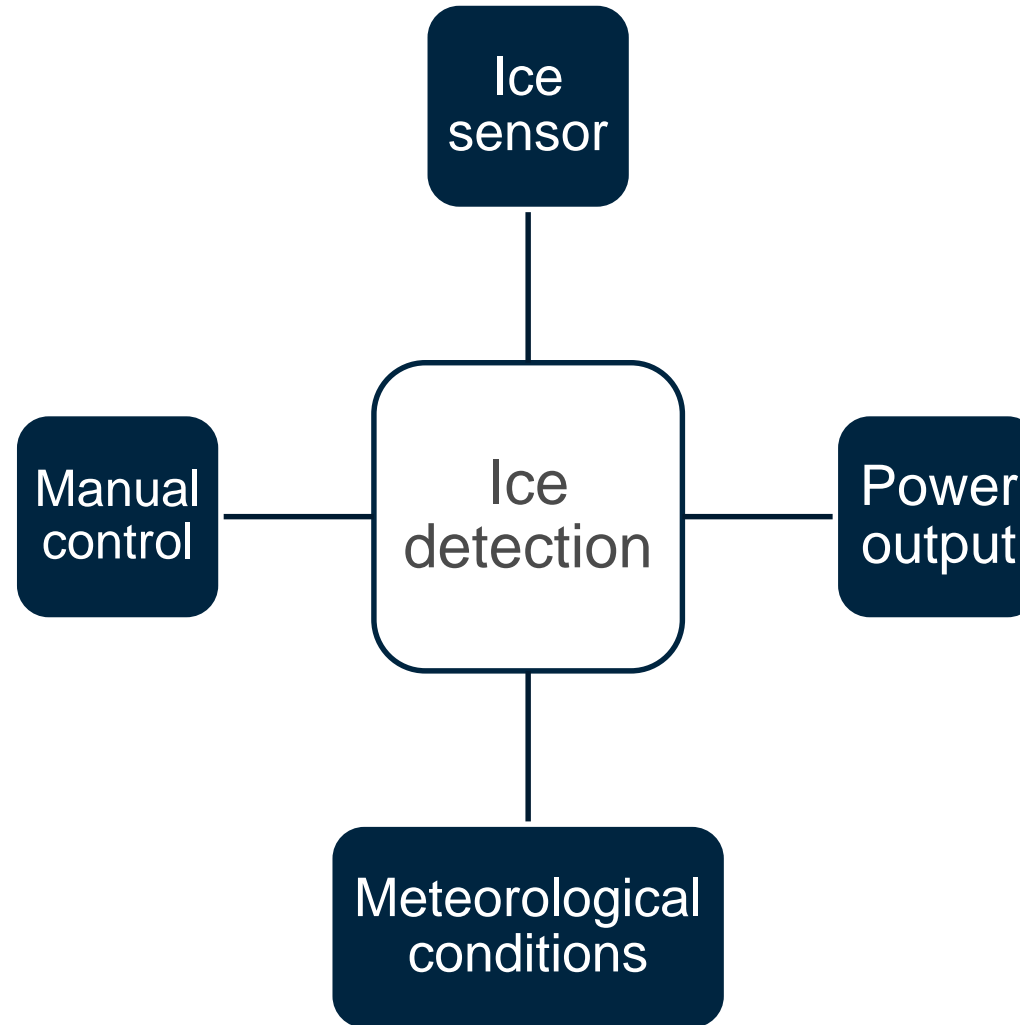


Anti-Icing System!

Fights the ice before it accumulates on the blade!

Reliable detection of icing conditions is vital for a good Anti-Icing System

Multi sensor approach:



Nordex has long experience in developing Anti-Icing Systems

2010: 3 x N100/2500-CCV-AIS with pilot Anti-Icing Systems

2011: 14 x N100/2500-CCV-AIS

2012: 32 x N100/2500-CCV-AIS

2013: 1 x N117/3000-CCV-AIS

30 x N100/2500-CCV-AIS

2014: 9 x N100/2500-CCV-AIS

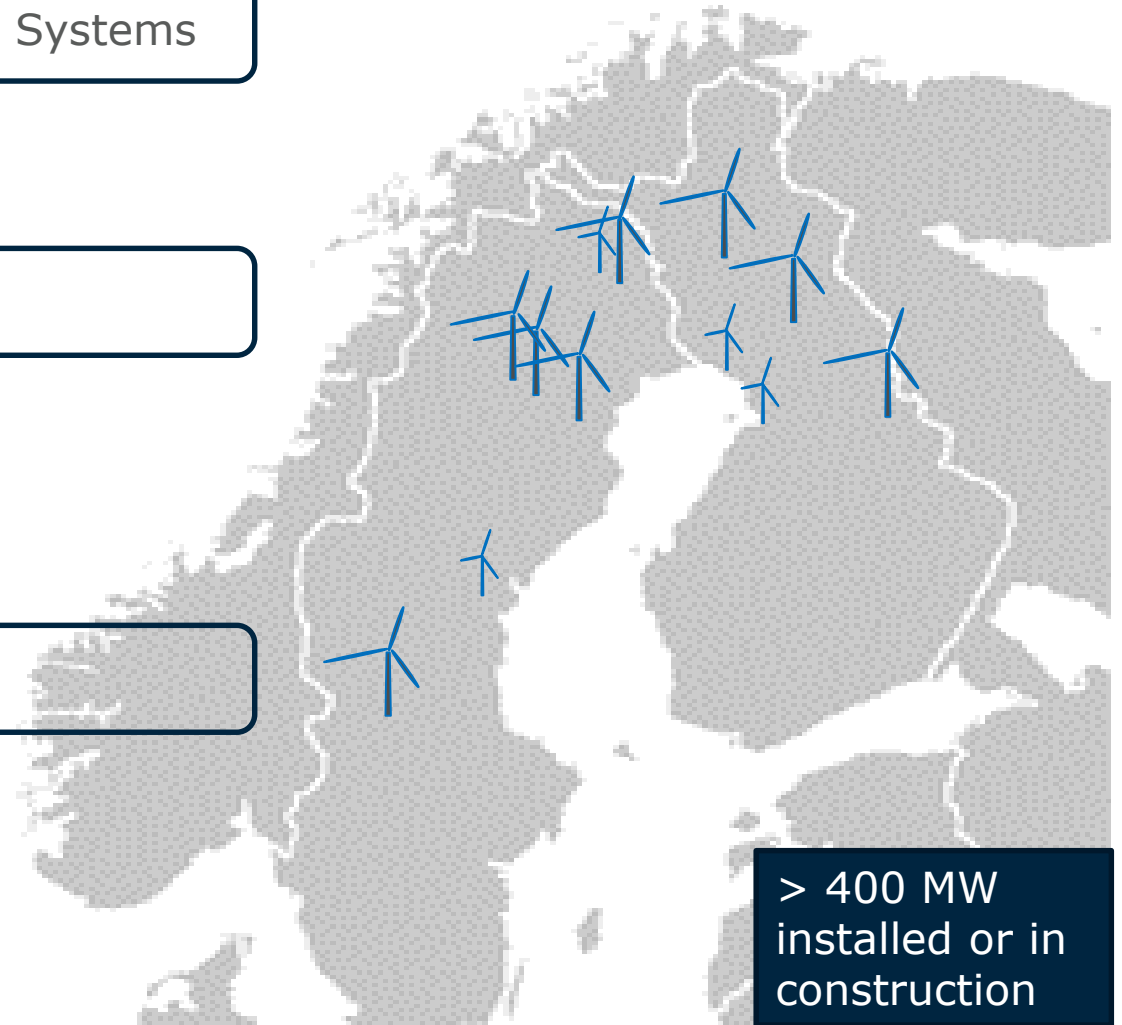
34 x N117/3000-CCV-AIS

2015: 2 x N131/3000-CCV-AIS

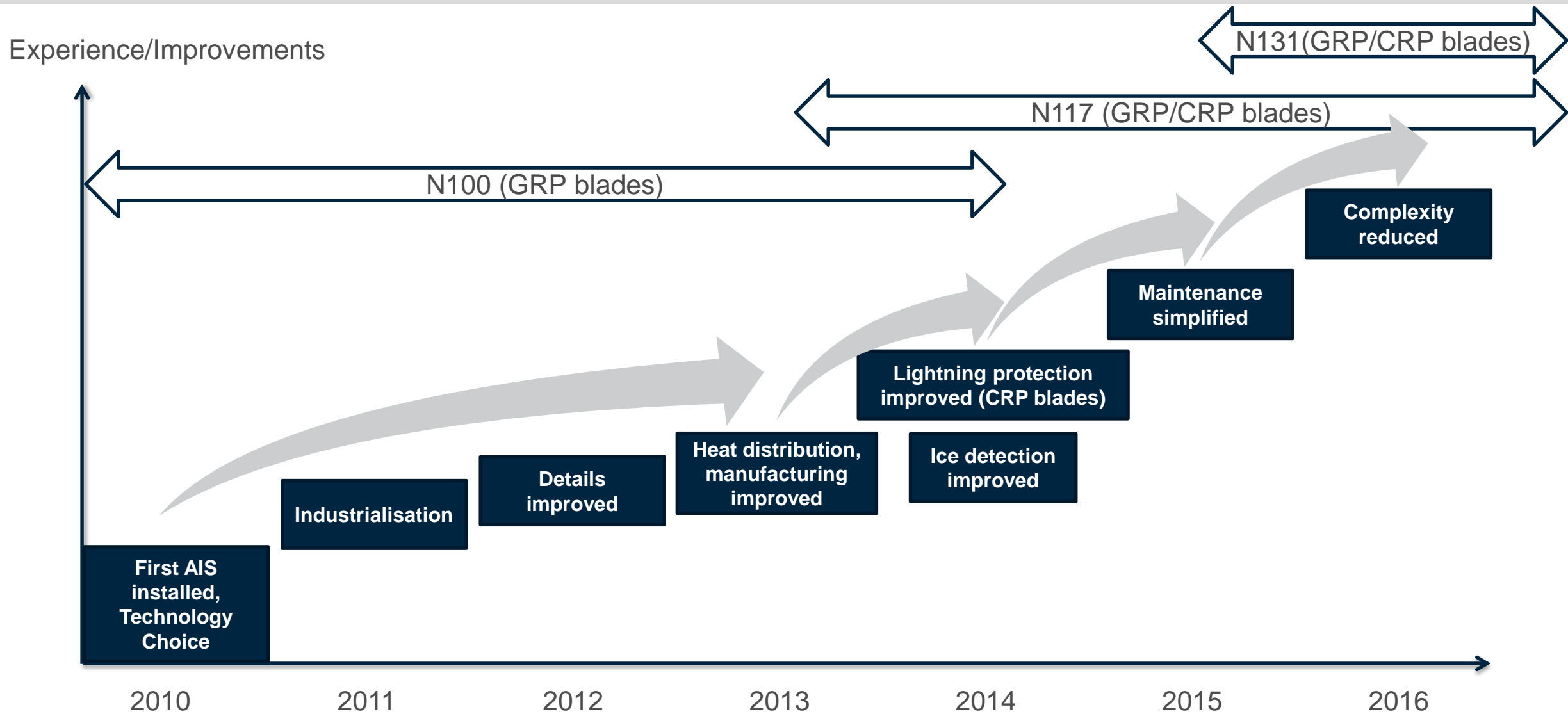
17 x N117/3000-CCV-AIS

2016: 13 x N131/3000-CCV-AIS

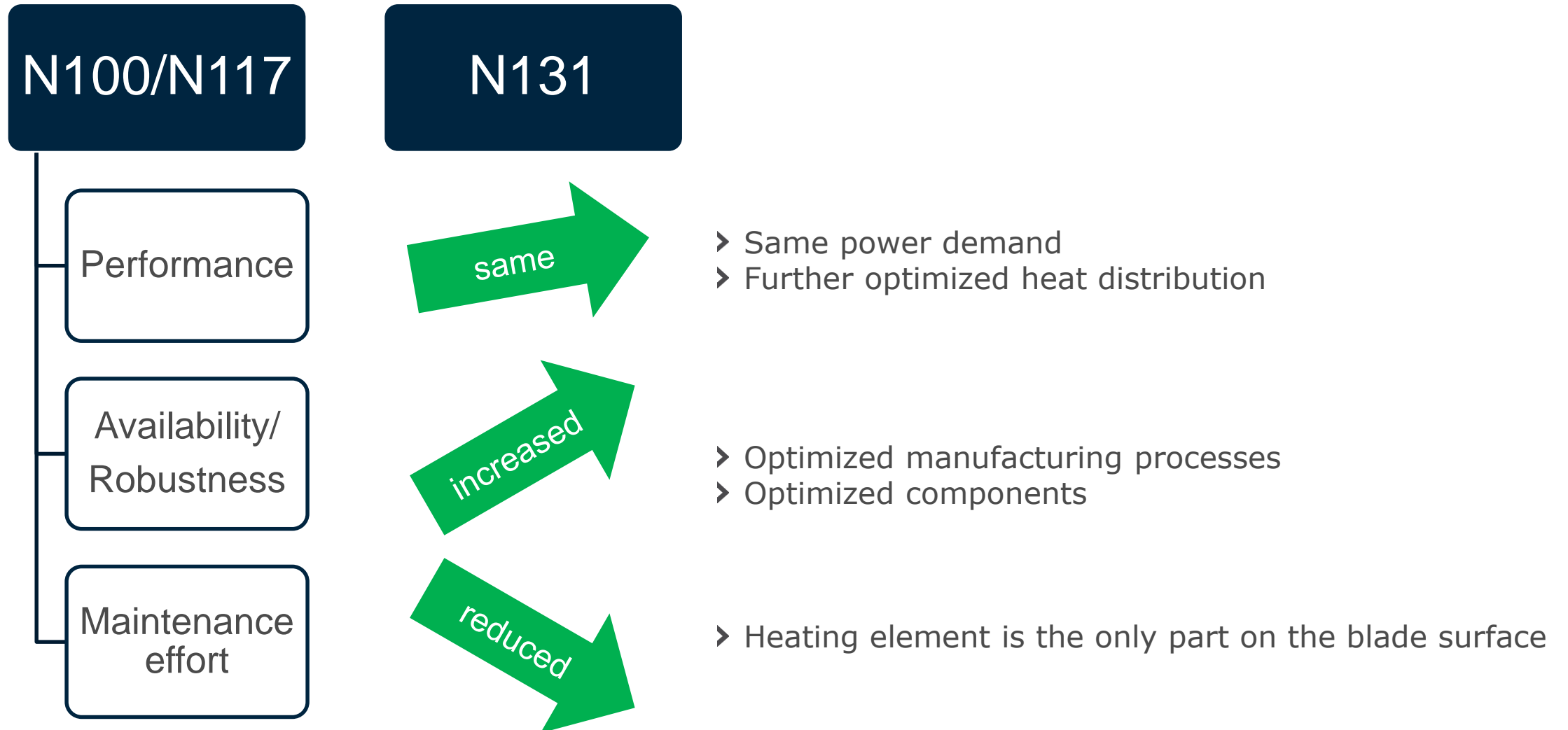
2017: 17 x N131/3000-CCV-AIS (in construction)



Continuous improvement by learnings and innovations



> Design goals for N131 AIS



Validation – Structural design

NR65.5 blade is fully tested in static and dynamic tests applying all additional loads for the AIS

- Dynamic flapwise: 2.5 million cycles ✓
- Dynamic edgewise: 7.5 million cycles ✓
- Static ✓
- Heating element ✓

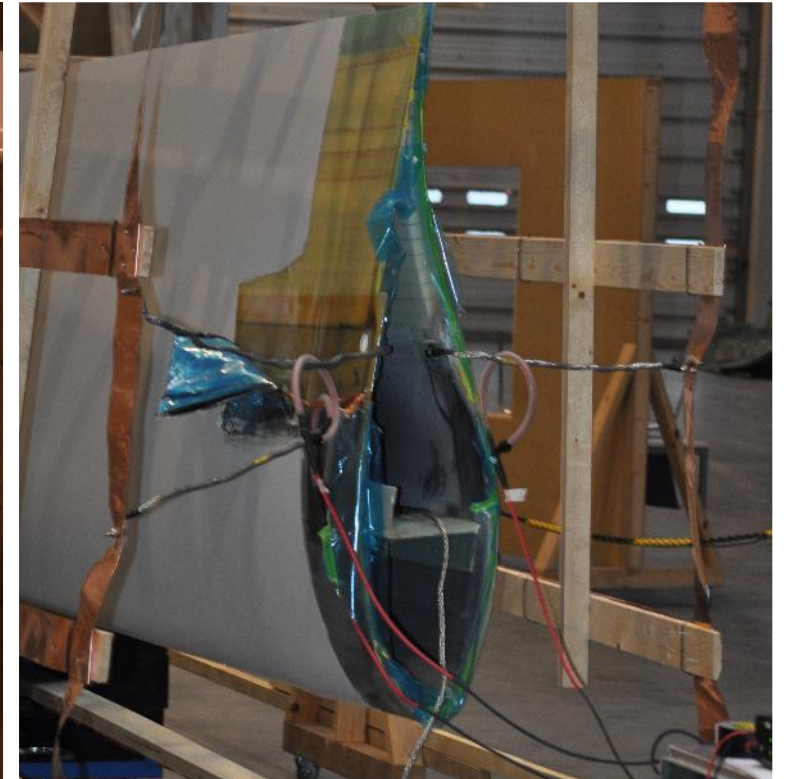
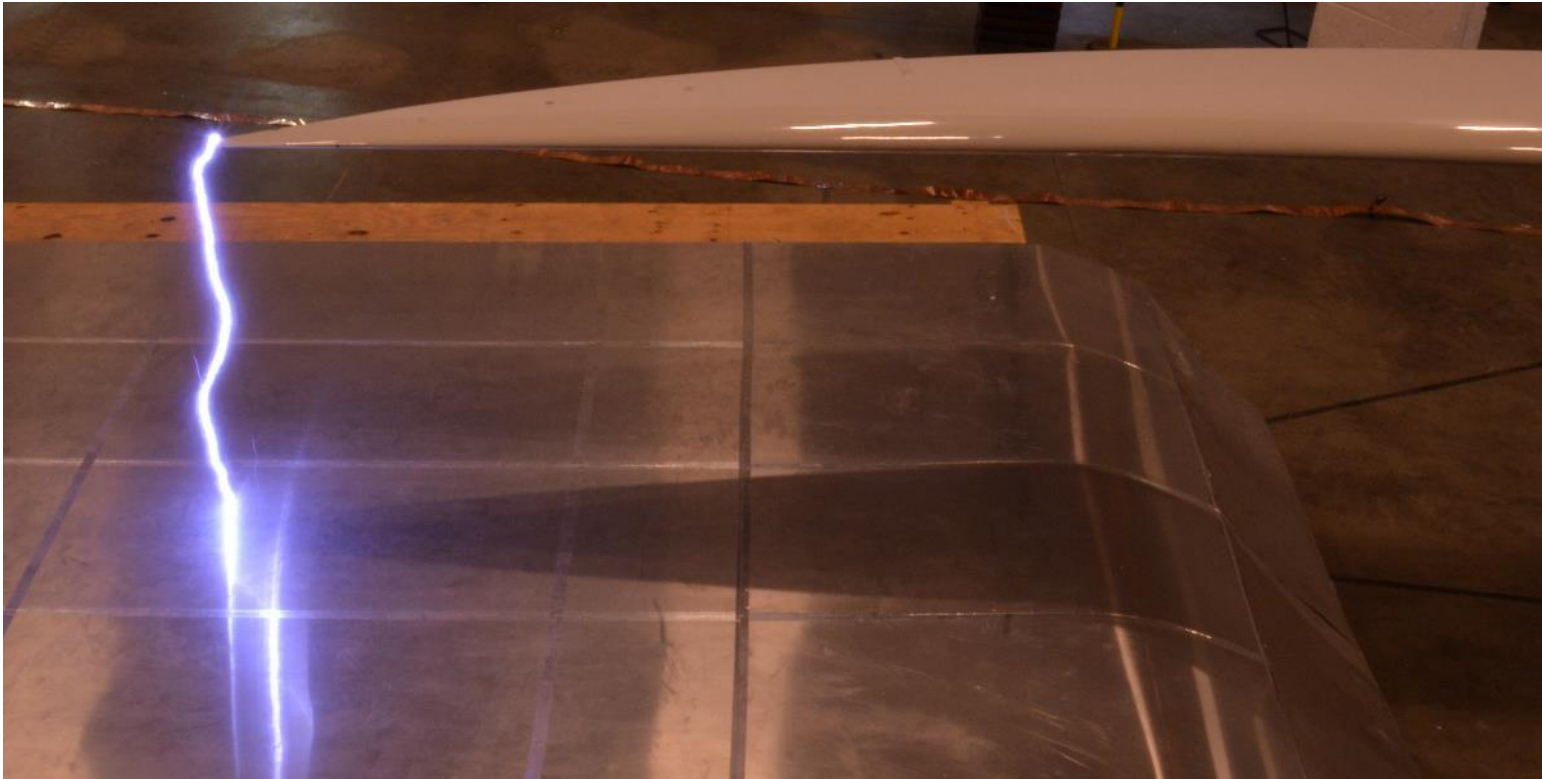


> Validation – Lightning protection system

NR65.5 lightning protection system is fully tested by third party

- Initial leader attachment test ✓
- High current coupon tests ✓

- Current distribution test ✓

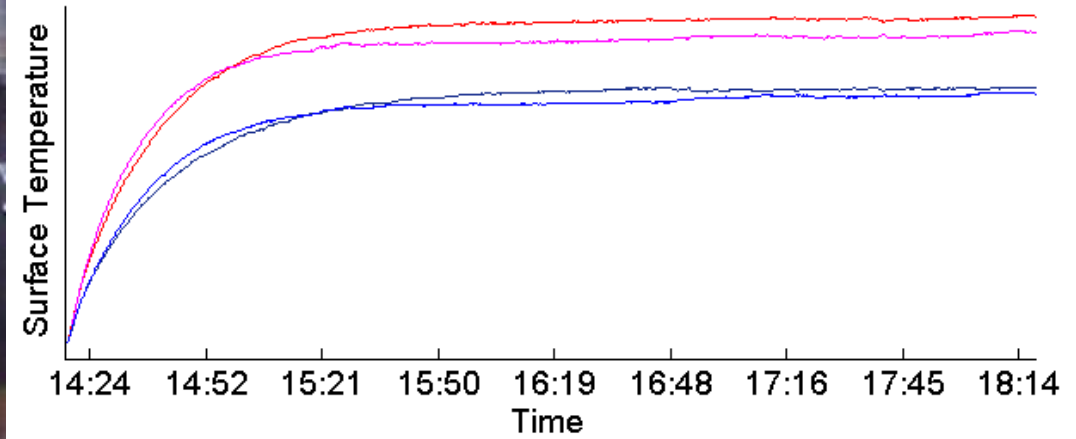
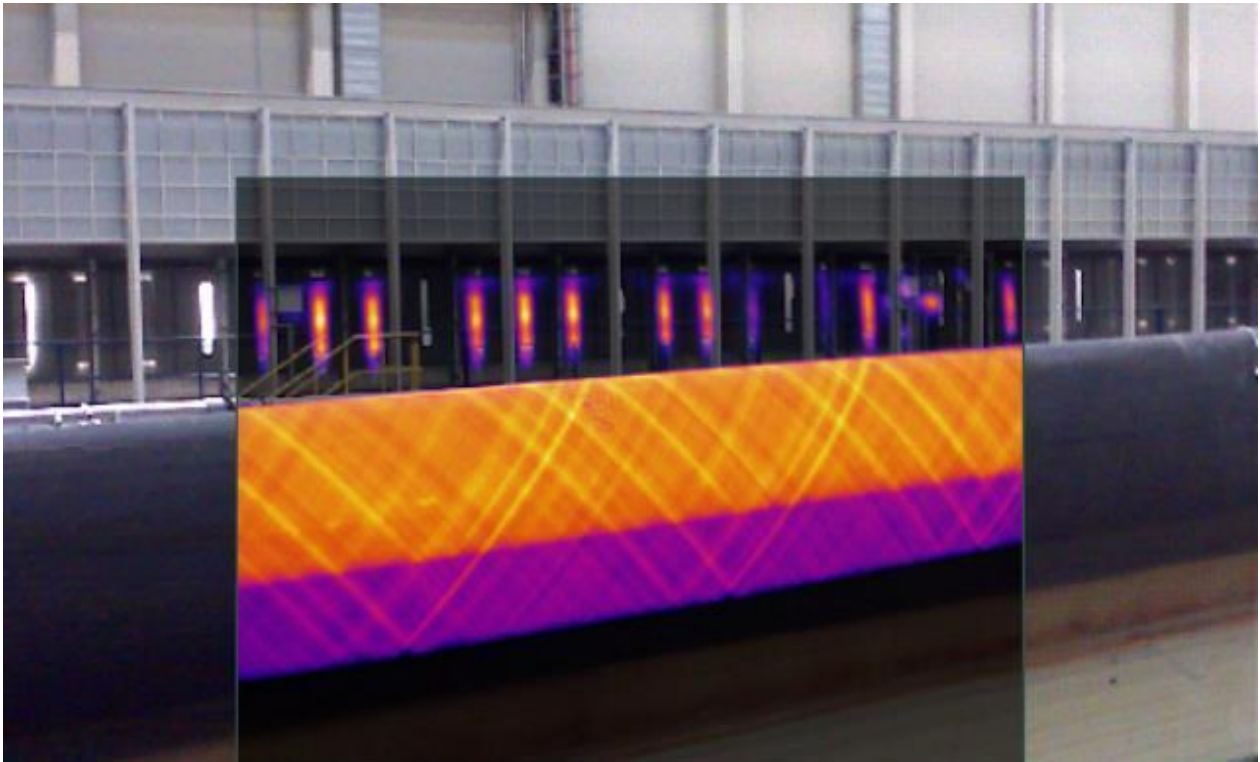


Validation – Anti-Icing System (AIS)

Every single blade of NR65.5 Anti-Icing System is fully tested inhouse

- Resistance and insulation test ✓
- Heating cycles ✓
- Final acceptance test ✓
- Inspection for Hot Spots ✓
- Overheat protection test ✓
- Long time heating test ✓

Prototypes only



Field validation – NR65.5 Anti-Icing System (AIS)

Specially equipped prototype turbines in Finland



- Cameras on blades
- Ice thickness measurement device
- Additional ice detectors

Observation of:

- icing periods
- severity of icing

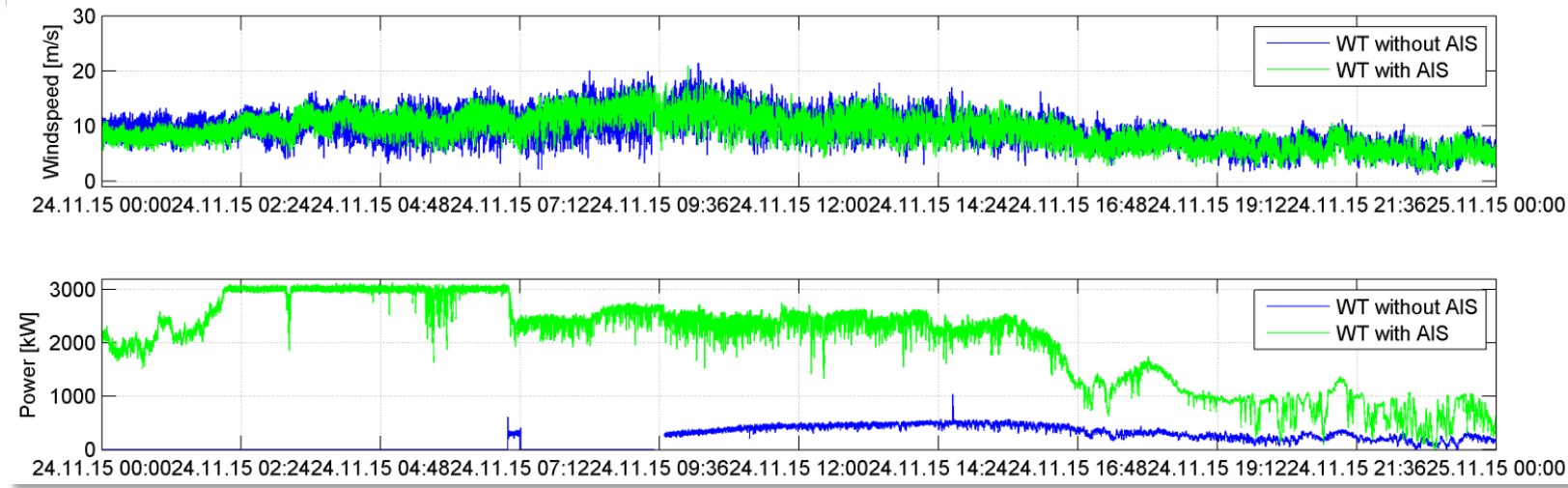
Known problem:

- Visibility is very bad during icing

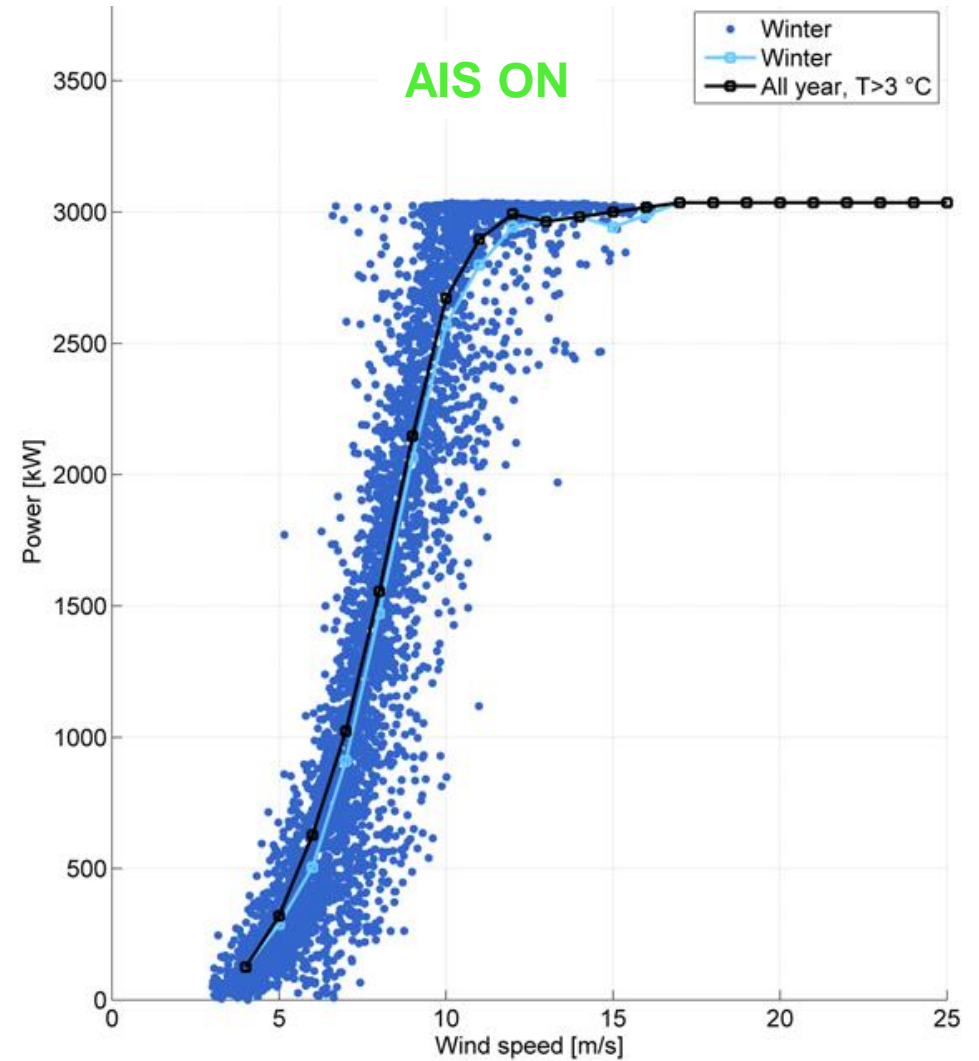
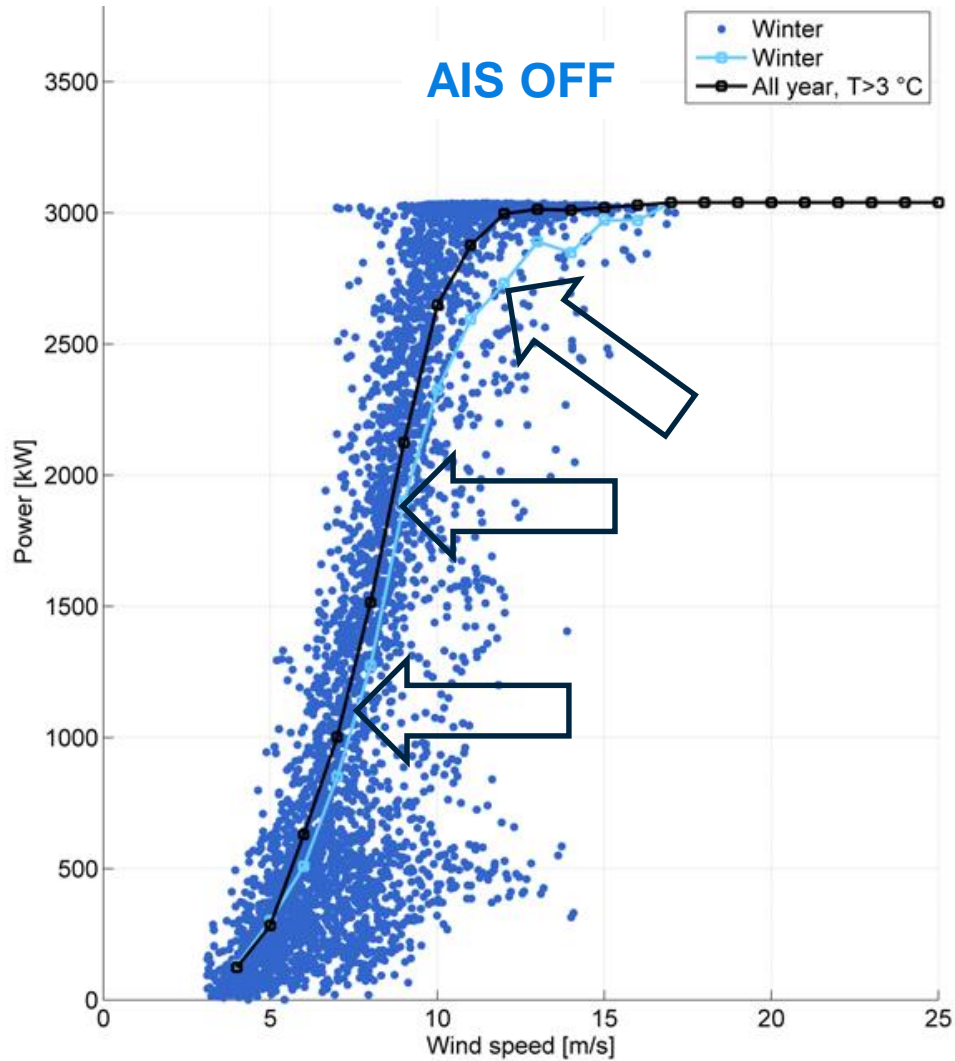
Field validation – Example of production gain in Lapland



- Winter 2015/2016
- N117, Sweden



Power curves reflect the yield improvement due to Anti-Icing System (AIS)



Field validation – De-Icing



Nordex Anti-Icing System (AIS) can also do De-Icing

- AIS switched off intentionally
- Turbine stopped due to icing
- Very fast De-Icing of the leading edge (\approx 20 min.)
- Turbine back in operation

Conditions:

- Winter 2015/2016
- N117, Sweden
- Temperature: -8 °C
- Wind speed: 6 m/s

Summary

NORDEX Anti-Icing System ...

- ... is based on proven technology
- ... has a long track record
- ... is subject to continuous improvement and innovation
- ... guarantees large yield improvement in icing conditions

NORDEX Anti-Icing System for N131 ...

- ... is fully certified and tested
- ... has maximized robustness and minimized maintenance effort



**> Thanks for
your attention**

> Together on the same course

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