NORDEX

ANTI-ICING SYSTEM ON N131 TURBINES DEVELOPMENT AND VALIDATION

Winterwind
2016
Åre, Sweden

Track Record and Experience
NORDEX Cold Climate Turbines and Anti-Icing System

- Nordex has more than 16 years experience on cold climate sites
- First stall turbines were installed at Inner Mongolia/China
- In 2002 the first multi megawatt platform turbines were installed at Havøygavlen Windpark/Norway (100 km south of the North Cape)
- In 2007 Nordex introduced the CCV option for the multi megawatt platform
- Since 2007 the majority of CCV turbines were installed in the USA and Northern Europe

Today

> 1500 MW of CCV turbines in operation

> 400MW of turbines with AIS in operation or installation

Track Record and Experience
NORDEX Cold Climate Turbines **AND** Anti-Icing System

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

2011: **16 x** N100/2500-CCV-AIS

2012: **30 x** N100/2500-CCV-AIS

2013: **30 x** N100/2500-CCV-AIS

1 x N117/3000-CCV-AIS

2014: **24 x** N117/3000-CCV-AIS

1 x N117/3000-CCV-AIS

9 x N117/3000-CCV-AIS

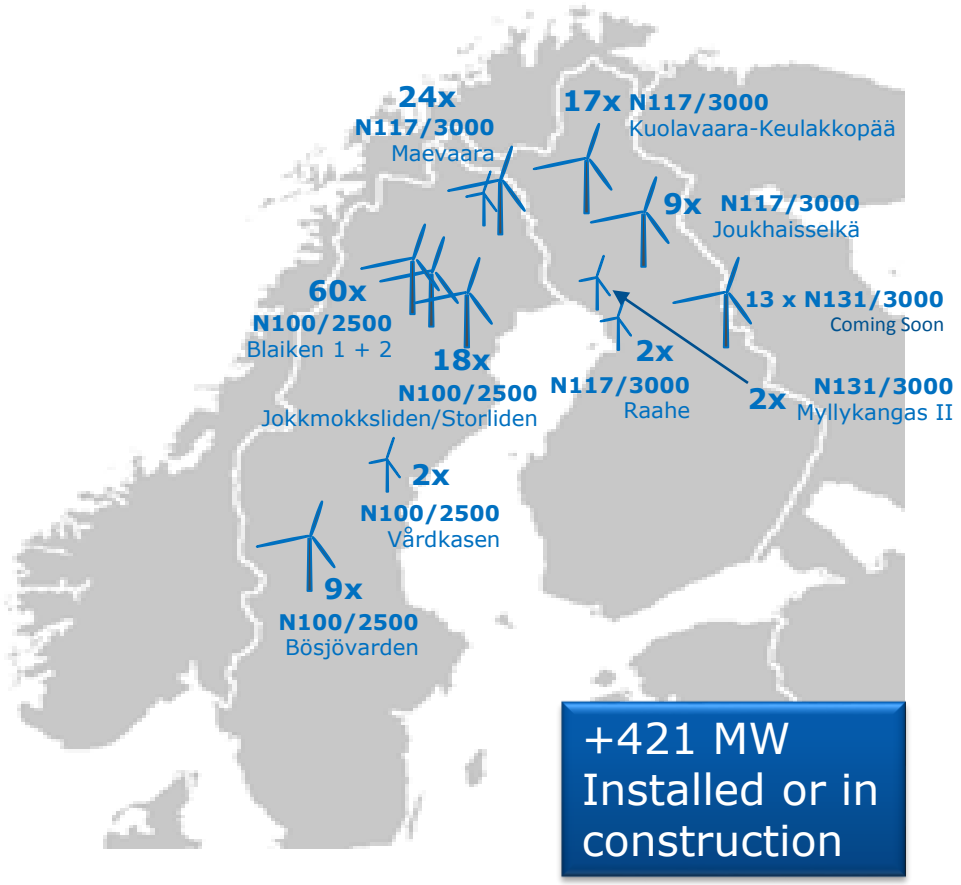
9 x N100/2500-CCV-AIS

2015, under construction:

17 x N117/3000-CCV-AIS

2 x N131/3000-CCV-AIS

2016: **13 x** N131/3000-CCV-AIS



Nordex Anti-Icing System

IEC2a → N117/3000

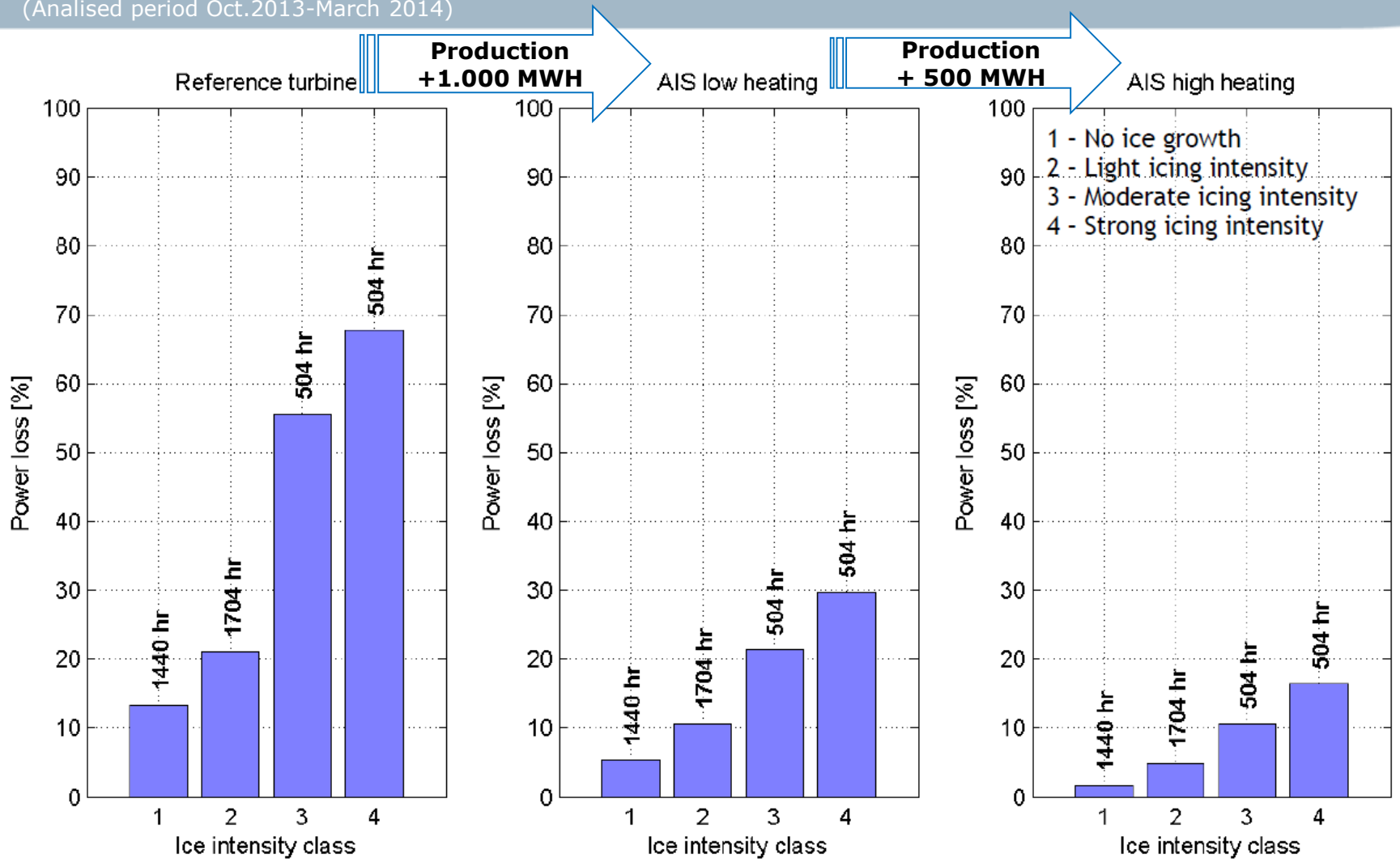
IEC3a → N131/3000

- Anti-Icing System = System fights ice formation with heat during operation
- System to heat the aerodynamically relevant parts of the blade
- Electrical resistance heating mat
- Resilient solution integrated into the blade structure
- Available for key Nordex Delta turbines suitable for Northern European Sites

Track Record and Experience

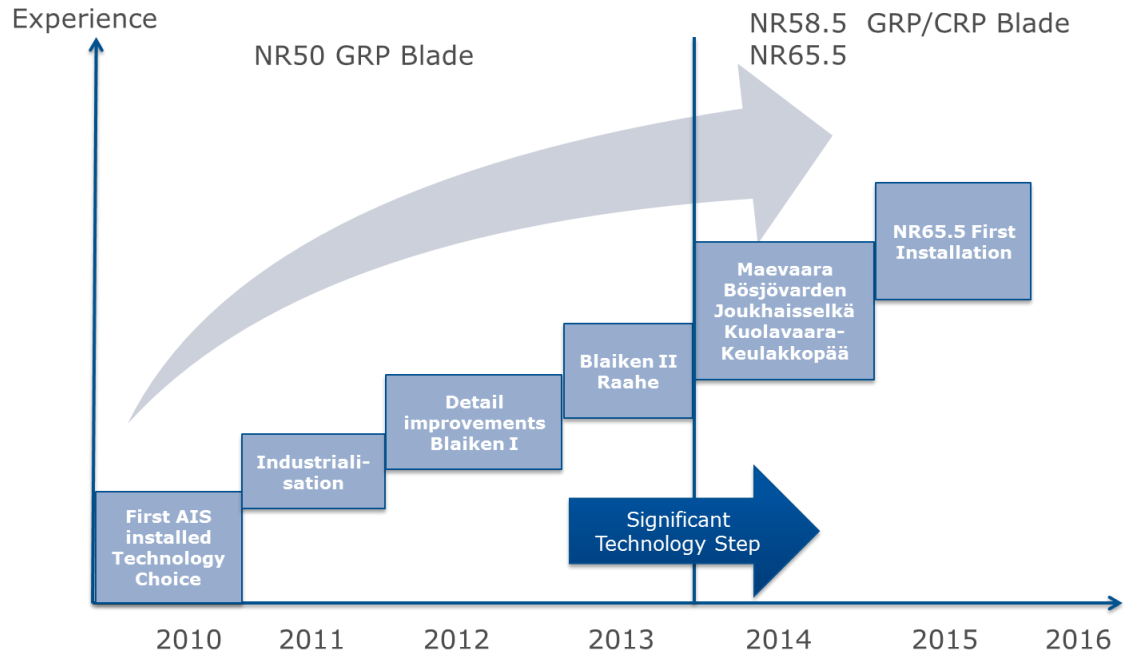
Case Study: Performance in Different **Ice Intensity** Classes

(Analised period Oct.2013-March 2014)



Production loss in 4 ice intensity classes for reference turbine (left), AIS with low heating (middle), and AIS with high heating (right). The number of hours with icing in the different classes is also shown.

Anti Icing on N131 Turbines



Nordex AIS on N131 Turbines

- Improved Operation
  - Improved control & monitoring algorithms
  - Reduced amount of sensors
  - Improved icing prediction
  - Lowered consumption
- Improved Service/Maintenance
  - Easy access, fully integrated
  - Robust Heating Concept
  - Improved Repair Concept

IEC 61400-1/22 – Including Anti-icing

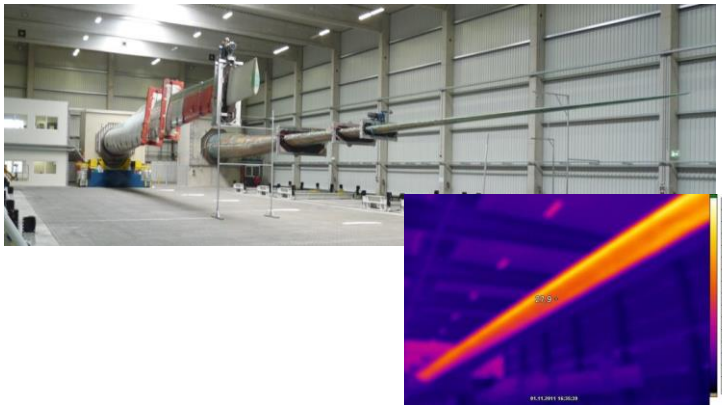
Design Verification- full scale testing
Fatigue and Lightning Protection Test

- **IEC 61400-24 class I** ✓

Lightning protection tests have been performed and successfully passed

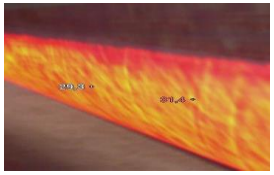
- **IEC 61400-23** ✓

Static & Dynamic Tests performed on full scale AIS blade

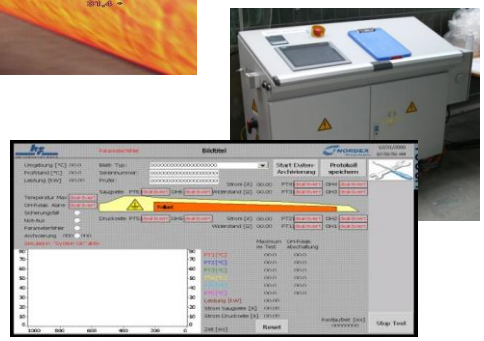


- Edgewise: 5 Mio. | Flap wise: 2.5 Mio Cycles
- Fatigue testing during heating
- Continuous resistance measurement | Heating cycles

- **Full blade testing during production** ✓
  - Resistances and electrical connection checks
  - Visual inspections



- **Full system test after system assembly** ✓
  - Automatic test bench | Hot spot detection | Overheating test
  - Final functional test after completion



Nordex Anti-Icing
Summing up

- Design verified by **full scale and component testing**
- **Proven technology** with **confirmed track record**
- **Reduction of icing** on blades with Anti-Icing Option
- Significant **production gain** due to Anti-Icing Option

Nordex provides turbines with an efficient and proven Anti-Icing System

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