Anti-Icing System on Nordex wind turbines - lightning protection and operating experience

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Winterwind 2015
03.-04.02.2015

NORDEX
We've got the power.

AGENDA

1. Nordex AIS Track Record
2. Overview of heating systems
3. Lightning Protection
   - Lightning Characteristics
   - Requirements from the Standards
   - Determination of Current Distribution and Voltages
   - High Voltage Tests
   - High Current Tests
4. Operating Experience
5. Summary

NORDEX ANTI-ICING SYSTEM – TRACK RECORD

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

2011: **16 x** N100/2500

2012: **30 x** N100/2500

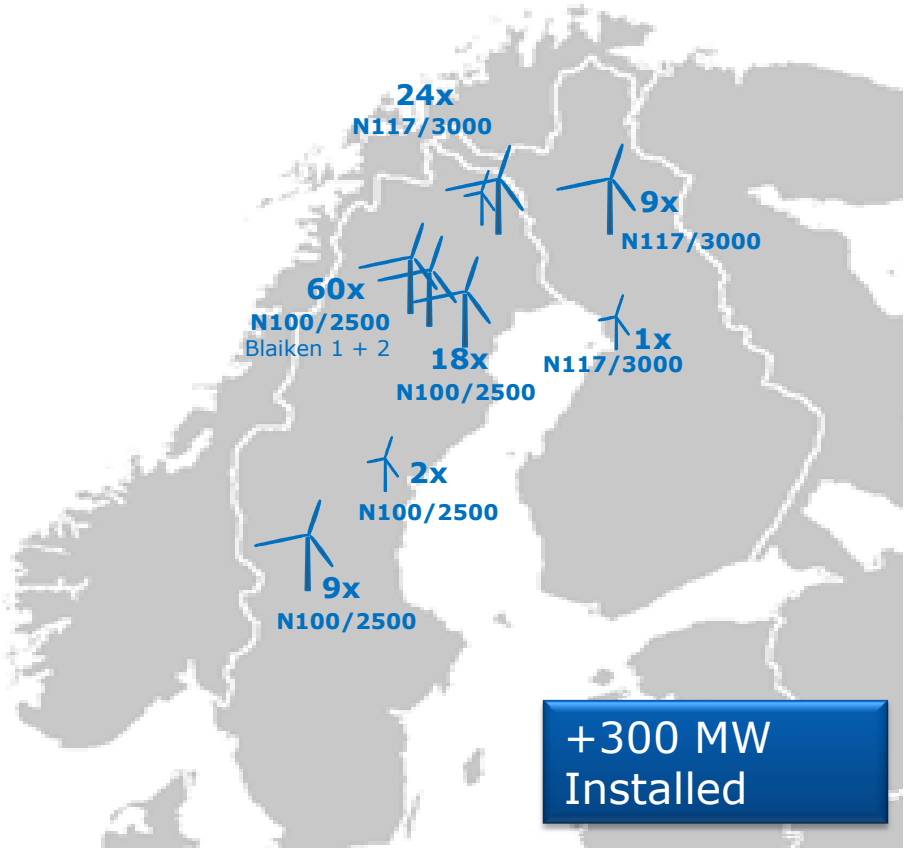
2013: **30 x** N100/2500

1 x N117/3000

2014: **24 x** N117/3000

9 x N117/3000

9 x N100/2500



De-Icing and Anti-Icing systems in the market

Many Systems have been tested on a prototype level

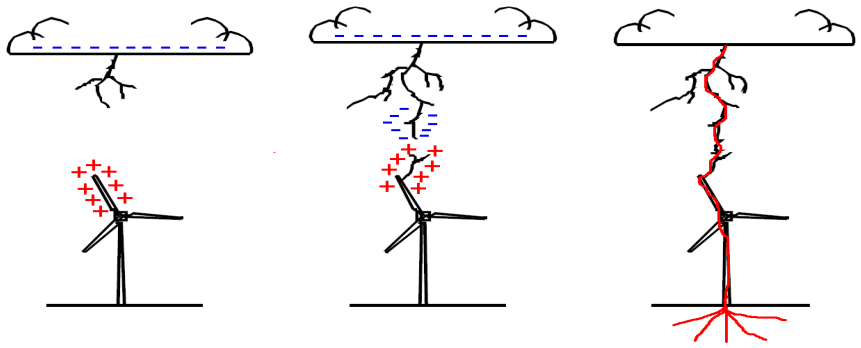
- Hydrophobic coating ⇨ low efficiency of available coatings
- Black paint ⇨ only efficient on sunny days
- Microwave ⇨ In prototype phase (Re-Turn, Norway)

Two major technologies in the market

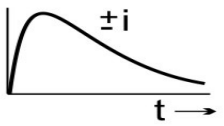
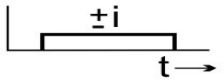
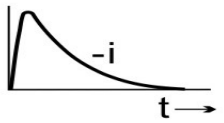
	Heating mat	Hot-air
Method	Ice prevention (Anti-Icing)	Ice removal (De-Icing)
Reaction time	fast	slow
Energy consumption	low	high
Lightning protection	solution available	No special solution required

CHARACTERISTICS OF LIGHTNING FLASHES

- Lightnings are discharges between cloud and ground
- 90% of all flashes are negative cloud to ground-flashes



A lightning flash has typically several discharges

	Maximum values of lightning parameters - LPL I (IEC 61400-24)	Typical wave shape
First stroke	Peak Current: 200 kA	
Long duration stroke	Charge: 200 C	
Subsequent stroke	Average steepness: 200 kA/µs	

Challenges for design and verification of the Anti-Icing-LPS

1. *Electrical heating mat connected to turbine power supply*
2. *Additional conductive components (IEC 61400-24: chapter 8.2.4.3)*

Conductive components:

- Down conductor
- Pressure / suction side spar caps
- Electrical heating mats
- Power supply cables
- Sensors and sensor cables

Standard glass blade

Standard carbon blade

Carbon blade with electrical heating mat

Incr. number of conductive comp.

Requirements from the standard

- All components have to conduct their shares of lightning current
- A flashover between conductive parts is not allowed

Considerations for Design

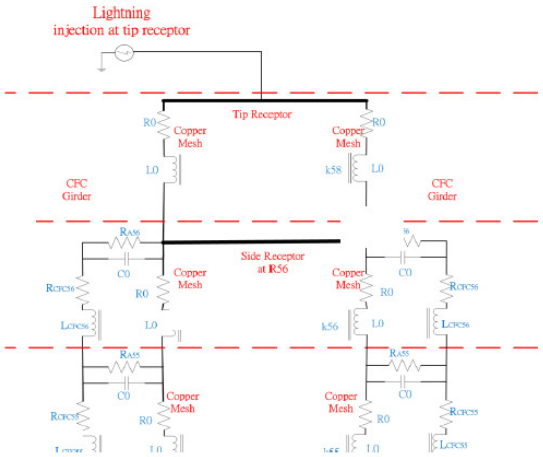
- Distribution of receptors
- Bonding/non-bonding of conductive components into LPS
- Electrical insulation of conductive components
- Integration into blade structural design
- Integration into manufacturing process
- Protection of the electrical system in the turbine

Current distribution and Voltages – Calculation and Tests

(1) Determine voltage distribution and currents in all conductive components

(2) Modify design until flashovers are eliminated ☑

FEM- and EMTP-analysis of sub-scale and full-scale blade



Resistance, inductance and capacitance have to be included in the FEM-analysis

Validation with testing

15m tip section – not scaled

High Voltage - Tests

➢Interception effectiveness of the air termination systems

➔ **initial leader attachment test**

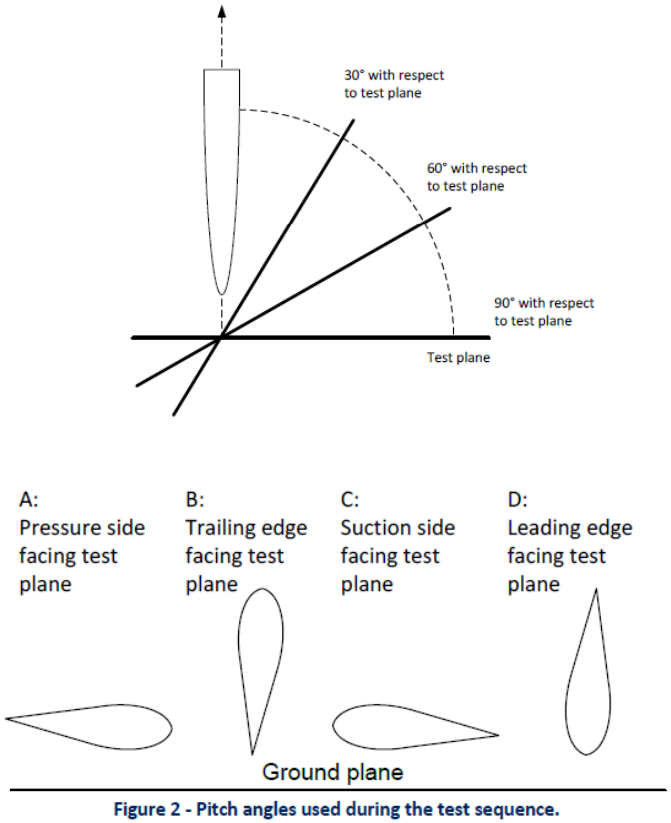


Figure 2 - Pitch angles used during the test sequence.

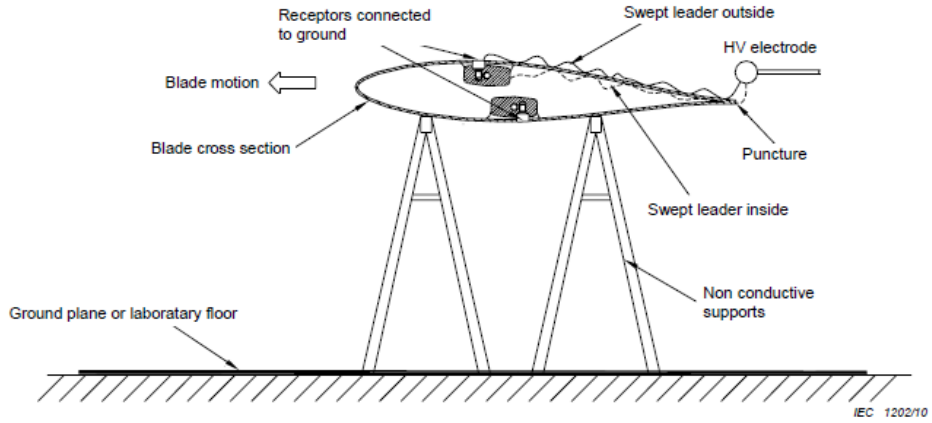
High Voltage - Tests

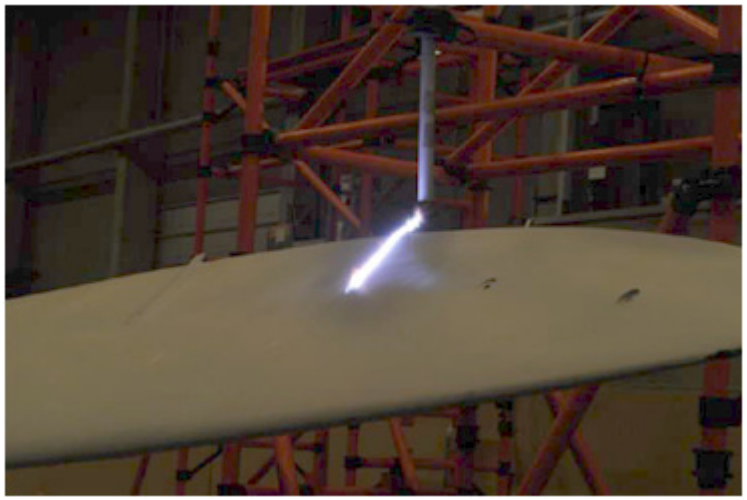
➢Verification of interception effectiveness of a rotating blade

➔ **Swept channel attachment test** ☑

Assessment of:

- possible puncture locations on non-conducting surfaces
- flashover paths over non-conducting surfaces
- the performance of protection devices, such as diverter strips



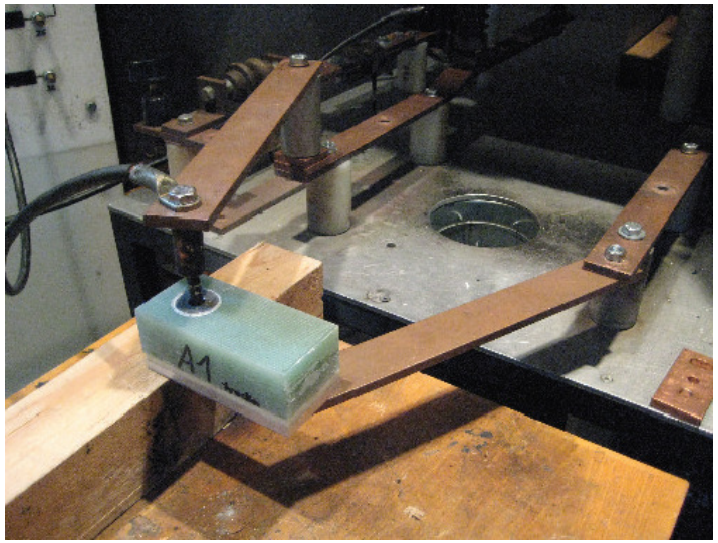


High Current - Tests

➔ **Arc entry test** ☑

Assessment of:

- arc attachment damage
- hot spot formation
- metal erosion at air termination systems



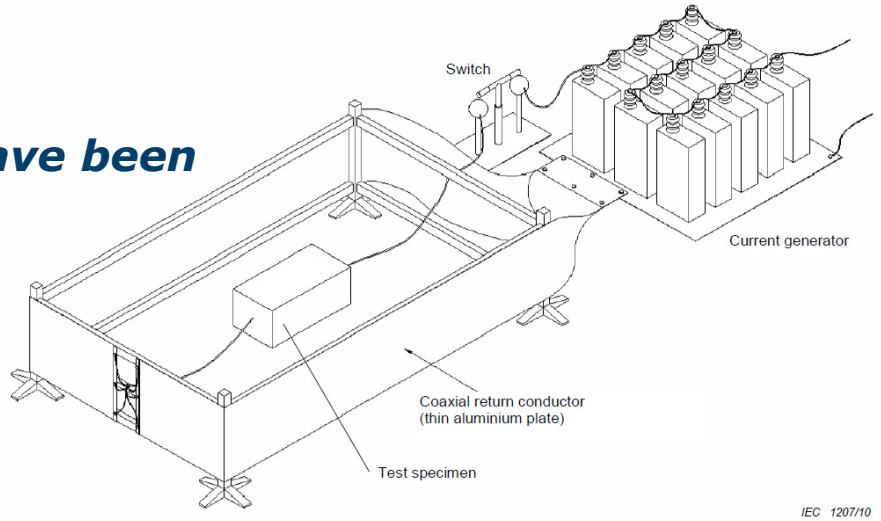
High Current - Tests

➔ **Conducted current test** ☑

Assessment of:

- lightning current conducting abilities
- temperature rises in conductors and connections
- arcing and sparking in connection components
- conducting adequacy of carbon fibre composite materials and interfaces

All relevant components have been tested succesfully !



Conclusion for Lightning Protection

- Current distribution in conductive components has been determined with tests and analysis

Flashovers are prevented

- High Voltage Tests
  - Initial leader attachment test
  - Swept channel attachment test

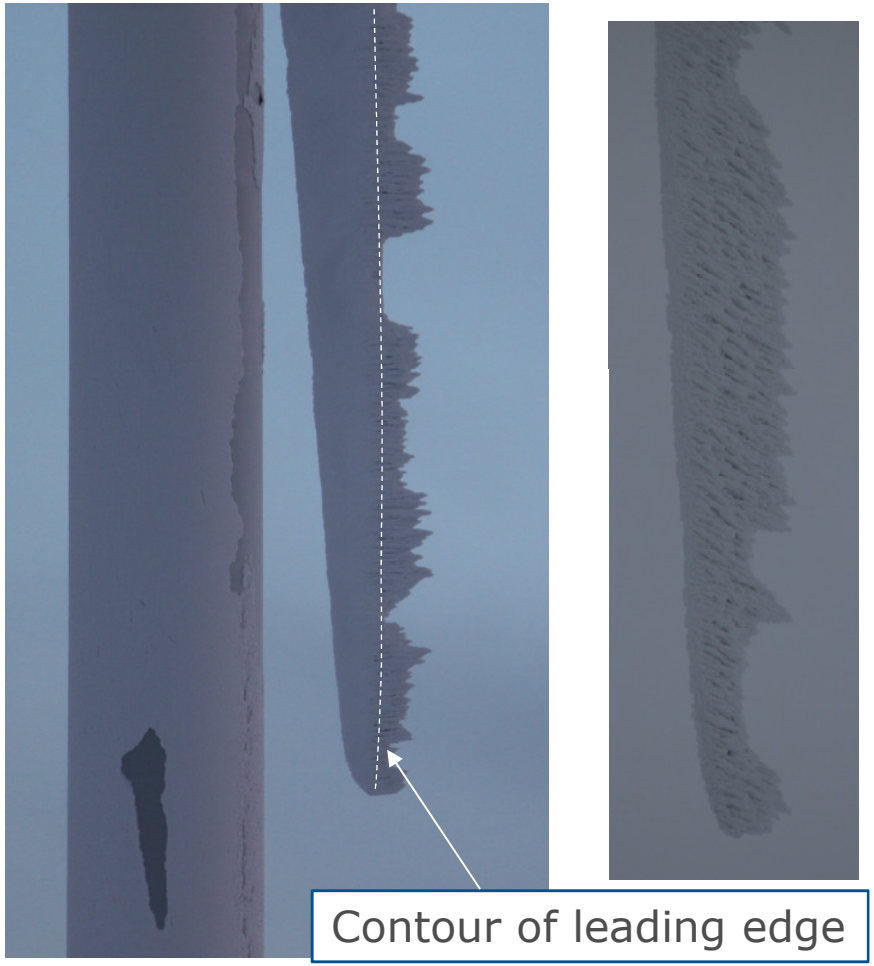
Lightning strikes are intercepted with installed receptors

- High Current Tests
  - Arc entry test
  - Conducted current test

Components can carry the lightning current

HEATING PERFORMANCE

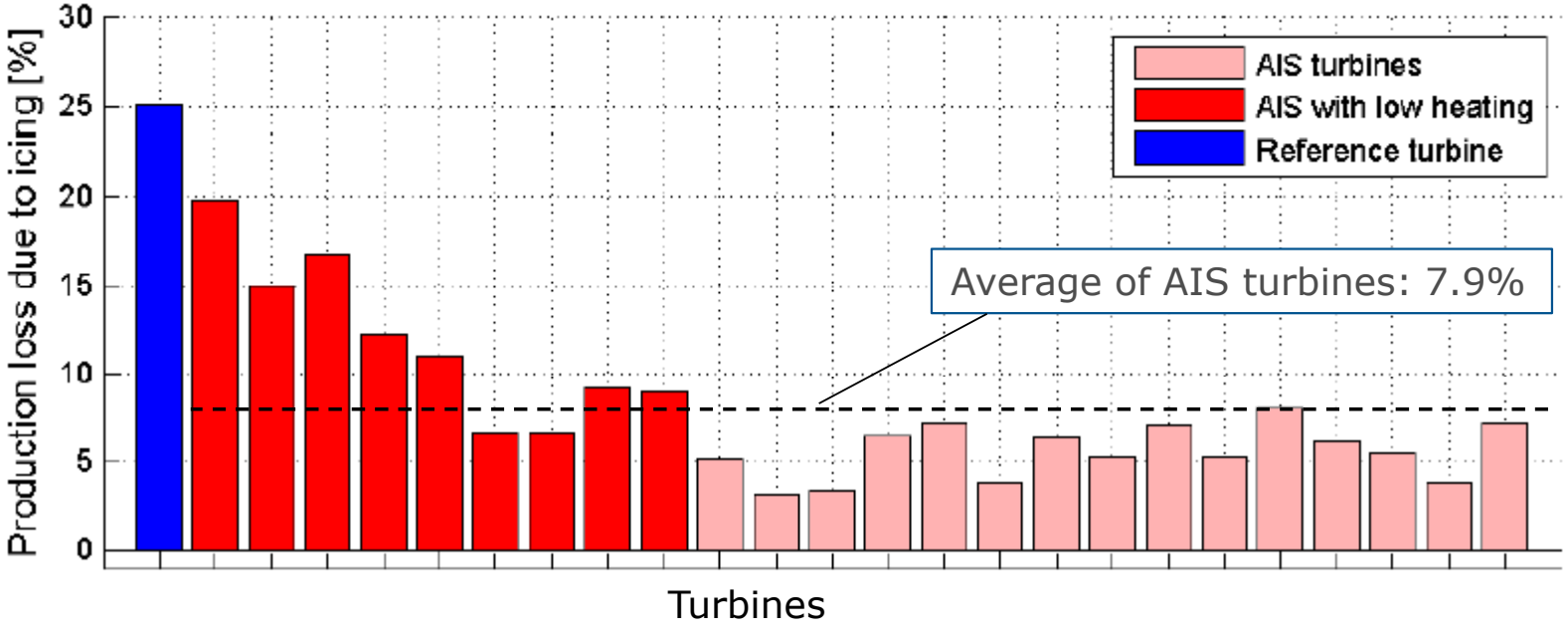
Turbine without heating



Effective blade heating system

Evaluation of N100 with AIS at Blaiken (Sweden)

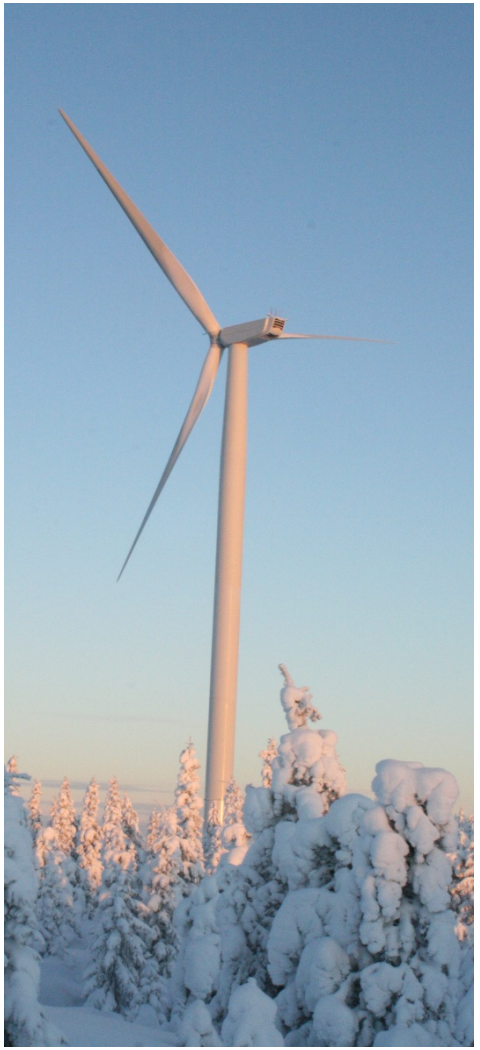
10.Oct. 2013 – 01.Apr.2014



Evaluation period: 10.10.13-01.04.14	Production loss icing	Energy consumption
Reference turbine	25.0 %	
AIS turbines (average)	7.9 %	1.7 %

SUMMARY

- Heating mat is integrated in blade structure
- Temperature distribution optimized for Anti-Icing
- LPS verified according to IEC 61400-24
- Efficient Anti-Icing system
  - Low energy consumption
  - Fast reaction time
  - Low icing losses



THANKS FOR YOUR ATTENTION

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