Ice detector research results from wind turbine field tests and from icing wind tunnel tests

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Labkotec
INDUTRADE GROUP

Contents of the presentation

History of the blade-mounted ice detector 1994

First ever blade-mounted Ice detector was delivered by Labko Oy (nowadays Labkotec Oy) to Finland, Pyhätunturi, 1994.

→ Start blade heating

Figure BF. The first blade mounted ice detector delivered by Labko Oy. Pyhätunturi test station 1994.

Status of the blade-mounted ice detectors

- Labkotec is developing new generation ice detection system
- Ice sensors are mounted on the turbine blades
- Direct ice accumulation measurement and ice detection from the blades
- Radio communication between the sensors and the control unit.

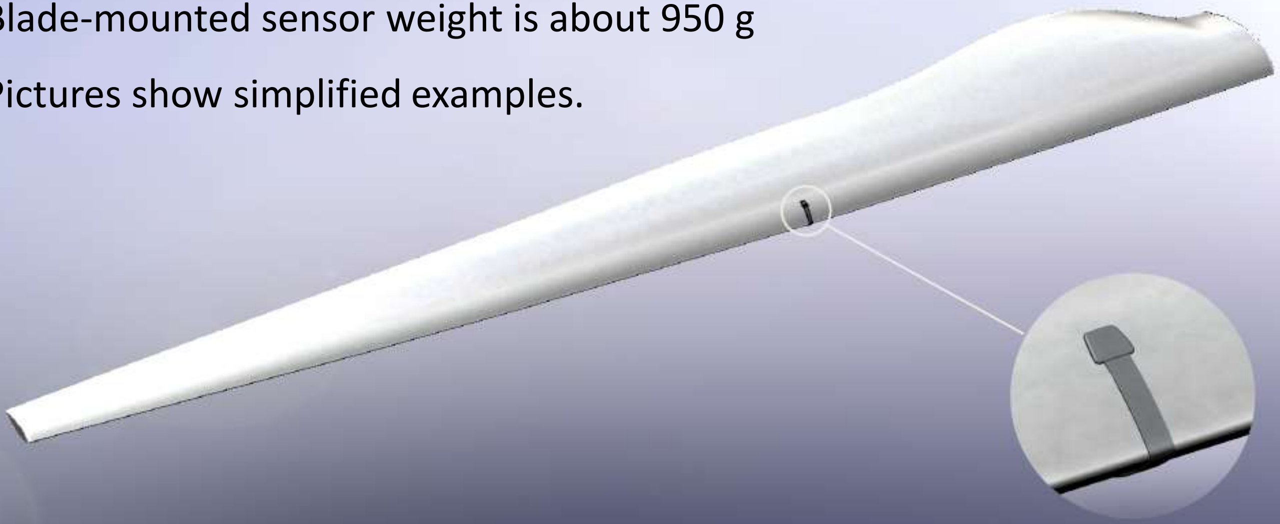
Blade-mounted ice detector system

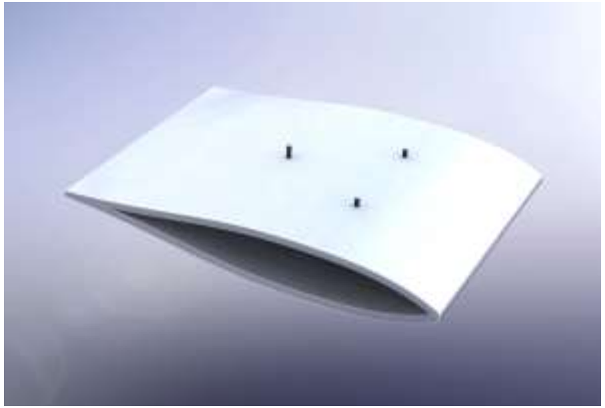
Symbols explanations

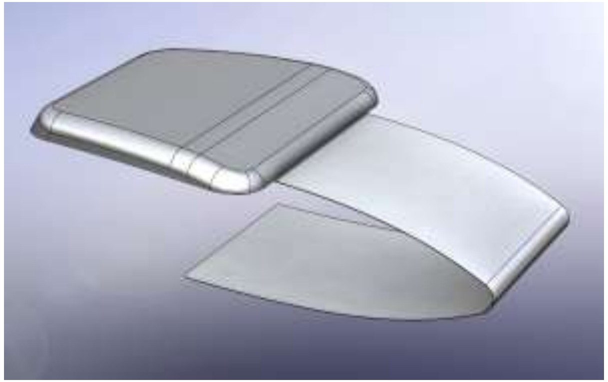
- ● 1 to 9 pcs blade-mounted ice sensors including radio transmitter
- LID/ISD nacelle-mounted sensor
- Control unit and radio receiver inside the nacelle

Blade-mounted ice detector specification

- Dimensions. Box for electronics is about 22 x 230 x 270 mm. Flexible sensor strip is about 1 x 165 x 550 mm.
- Blade-mounted sensor weight is about 950 g
- Pictures show simplified examples.







Blade-mounted ice detector installation example

Preparation

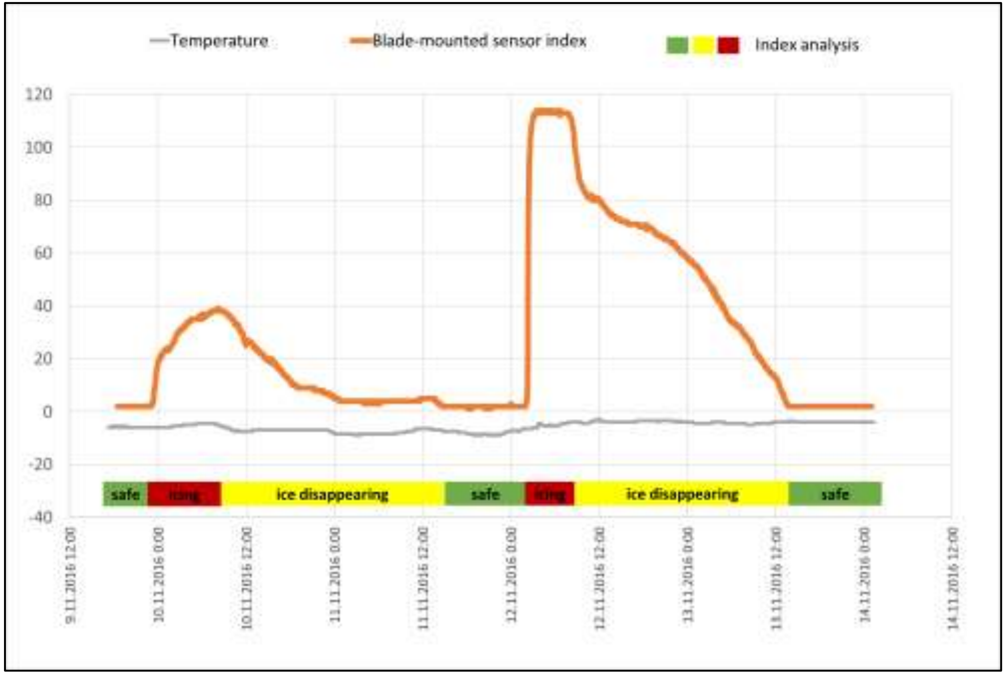
- Metallic inserts are embedded on the blade surface before installation.

Installation

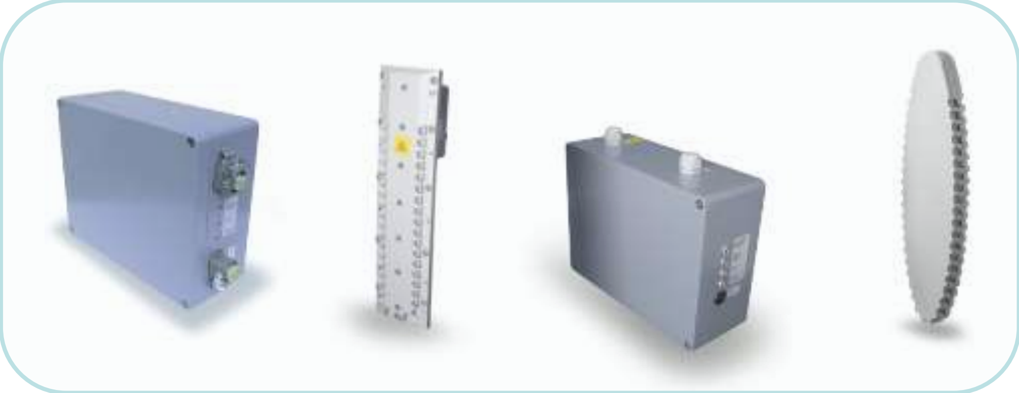
- Box for electronics by metallic inserts.
- Flexible sensor strip by adhesive.

Analysis of the blade-mounted ice detectors

- Ice index (orange line) shows how ice accumulates or disappears on the sensor.
- Index analysis (traffic lights) shows what’s happening on the blade, e.g.:
  - Safe
  - Icing
  - Ice disappearing
  - Wet
- Data on the right is actual data from a 3 MW turbine.



History of the nacelle-mounted ice detectors



	LID-3210C **Control Unit and Ice Sensor**	**LID-3210D** **Control Unit with** – Ice Alarm LED – Test button	**LID/IS** **Ice Sensor** – Sensitivity improved		**LID-3300IP Control Unit** – Web server (remote access) **LID/ISD Ice Sensor** – Sensitivity further improved **LID-3300IP Type 2** (2018 ->)
1994 ->	2002..2008	1Q/2008...2014	4Q/2008..2014		1Q/2010 ->

Component Certificate

CC-GL-013A-2014 **GL Renewables Certification (GL RC)**

Normative references:
GL Rules and guidelines – IV Industrial Services-Part 1 "Guideline for the the Certification of Wind Turbines", edition 2010.

Ice Detector LID-3300IP has been assessed by GL Renewables Certification (GL RC), concerning the Design, the "Implementation of the design requirements in Production and Erection" IPE, the prototype Testing and manufacturer´s quality system.

The GL certificate is valid for Ice Detectors with Software version of v1.30 and newer.

LID-3300IP

GL certificate:

- ”Safe to use in wind turbine”
- ”Detects in-cloud and freezing rain ice”.

Certificate

Certificate no. CU 72131267 01

License Holder:
Labkotec Oy
Myllyhaantie 6
FI-33960 Pirkkala
Finland

Manufacturing Plant:
Jotel Oy
Ilkontie 1
36241 Kangasala
Finland

Test report no.: USA-AF 31282519 001
Client Reference: Jarkko Latonen
Tested to: UL 61010-1:2004 R10.08
IEC 61010-2-010:2003
CAN/CSA-C22.2 NO. 61010-1-04+GI1 (R2009)
CAN/CSA-C22.2 NO. 61010-2-010-04 (R2009)

Certified Product: Ice Detector for Wind Turbines

Model Designation: 1) Control Unit: LID-3300IP
2) Ice Sensor Unit: LID/ISD Ice Sensor

Rated Voltage: 1) AC 230V, 50/60Hz (Load: AC 230V)
2) AC 230V

Rated Power: 1) 7VA (Load: 350W)
2) 350W

Protection Class: I
Ingress Protection: IP65
Special Remarks: To be installed with an AC 230V wind turbine power system only.

Appendix: 1, 1-5

Licensed Test mark:

Date of Issue (day/mo/yr) 26/04/2013

LID-3300IP

UL/CSA certificate:

- ”Safe to use in wind turbine”
- Now selling also in the USA and Canada.

NEW! LID-3300IP Type 2 (available 1H/2018)

Functional safety:

- Functional safety level has been further improved from PLb to PLd
- According to the standard ISO 13849-1.

Compatibility:

- Fully compatible with current LID-3300IP; same features, interfaces and look and feel.

System interfaces:

- Power
- Signal
- Heating
- RS-232
- Analog outputs
- Relay outputs
- Ethernet RJ-45
- Optical fibre.

Interface upgrades:

- Improved transient voltage protection
- RS-232 and analog outputs isolated
- Safety relay outputs with feedback
- Easy access connectors.

Ice alarm test:

- Ice sensor starts sending low signal levels, which simulate a real icing condition
- Therefore, the whole chain of safety functions will be tested.

LID-3300IP Type 2 Functional safety

- Development on nacelle-mounted ice detector LID-3300IP Type 2 has been focusing on functional safety aspects.

- Improved safety aspects include, for example, safety relays where relay position is constantly monitored and a separate safety processor is applied to double check information inside the ice detector. Also more advanced diagnostics is included.

- Functional safety analysis has been carried out according to the standard ISO 13849-1. LID-3300IP base release has PL value b and LID-3300IP Type 2 has higher PL value d.

Ice detection performance tests: “Pre-certification of LID-3300IP Type 2”

The LID-3300IP Type 2 Ice Detector was tested at the VTT Icing Wind Tunnel (IWT) in the following conditions:

- typical in-cloud icing
- severe in-cloud icing
- freezing rain

Ice accretion simulations were done for NREL 5 MW reference wind turbine blade section number 9 (51,04 m – 54,46 m). The length of the reference turbine blade was 61.5 meter. (Report VTT-CR-06350-17).

LID-3300IP Type 2 Pre-certification

Typical icing conditions

Table 1. *Summarization of Icing Wind Tunnel (IWT) test results and TURBICE™ simulation results (ice mass [kg/m] section no. 9 and ice thickness [mm]) in typical icing conditions. /1, 4/*

Icing Wind Tunnel Tests Standard Icing Condition 8540798 05 19 17	Average Time [mm:ss]	Average deviation [mm:ss]	Ice Mass [kg/m] Section no. 9 (50,7 m – 54,8 m)	Ice Thickness [mm]
Amplitude 99 %	09:29	00:20	0,08	1
Amplitude 90 %	10:24	00:58		
Amplitude 80 %	10:46	00:55	0,09	1
Amplitude 70 %	12:12	00:20		
Amplitude 60 %	12:24	00:18	0,10	1
Amplitude 50 %	14:30	00:58		
Amplitude 40 %	15:56	00:39	0,13	2
Amplitude 30 %	16:51	01:05		
Amplitude 20 %	19:54	00:58	0,17	2

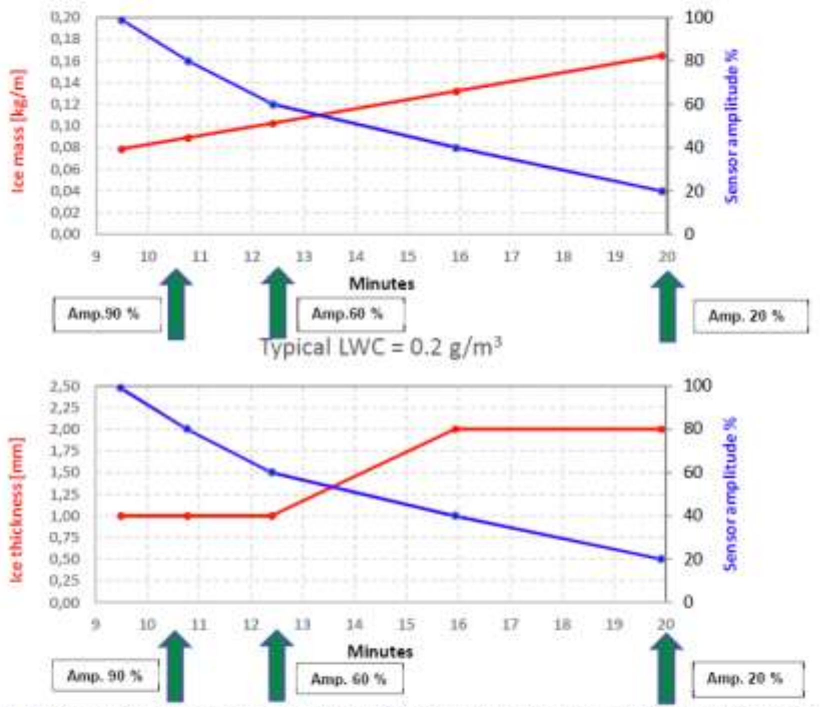


Figure 2. Illustration of TURBICE™ simulation results (ice mass [kg/m] & ice thickness [mm]) in typical icing conditions. /4/ *At the icing alarm moment (~ 12,5 min - amplitude value 60 %) the simulated ice thickness was 1 mm and the simulated ice mass was 0,1 kg/m in the blade section no. 9. In the secondary Y-axis sensor amplitude value is presented as a function of time /1, 4/.*

LID-3300IP Type 2 Pre-certification

Severe icing conditions

Table 2. Summarized VTT Icing Wind Tunnel test results and TURBICE™ ice accretion simulations in severe icing conditions. /1, 4/

Icing Wind Tunnel Tests Standard Icing Condition 8540798 05 19 17	Average Time[mm:ss]	Average deviation[mm:ss]	Ice Mass [kg/m] Section no. 9 (50,7 m – 54,8 m)	Ice Thickness [mm]
Amplitude 99 %	05:57	00:09	0,11	1
Amplitude 90 %	05:59	00:09		
Amplitude 80 %	06:20	00:09	0,11	1
Amplitude 70 %	06:45	00:31		
Amplitude 60 %	07:06	00:20	0,12	2
Amplitude 50 %	07:48	00:58		
Amplitude 40 %	08:42	00:34	0,15	2
Amplitude 30 %	08:56	00:38		
Amplitude 20 %	09:23	00:44	0,17	2

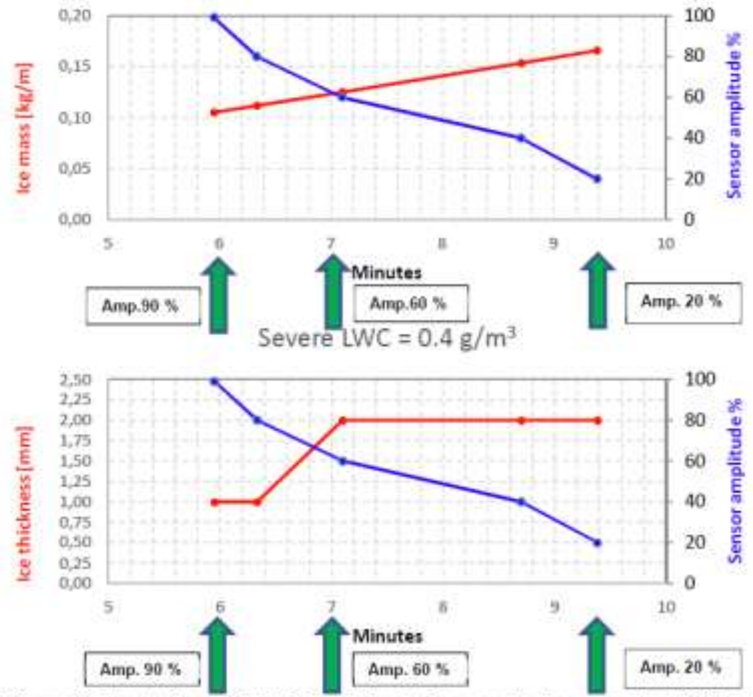


Figure 3. Illustration of TURBICE™ simulation results (ice mass [kg/m] & ice thickness [mm]) in typical icing conditions. /4/ At the icing alarm moment (~ 7,0 min - amplitude value 60 %) the simulated ice mass was 0,12 kg/m and simulated ice thickness was 2 mm in the blade section no. 9. In the secondary Y-axis sensor amplitude value is presented as a function of time /1, 4/.

Melting and ablation tests in the VTT Icing Wind Tunnel (IWT)

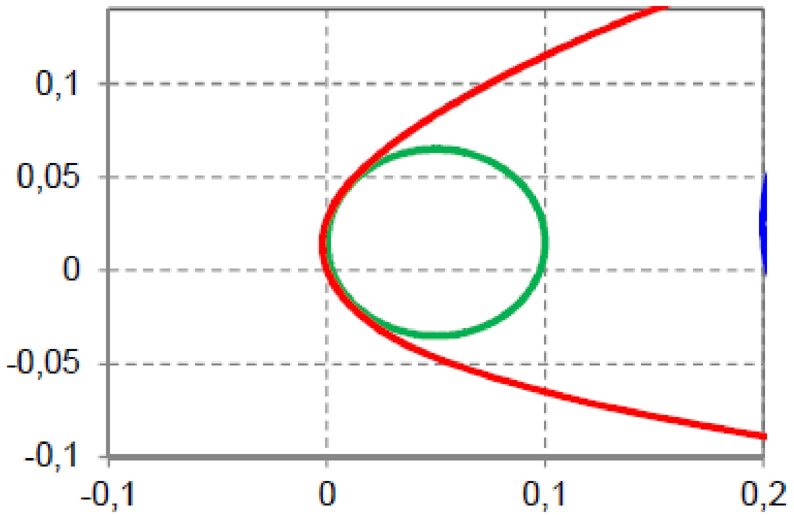
- The goal of these Icing Wind Tunnel tests was to estimate the time it takes for ice to melt and/or ablate from the diameter of 100 mm aluminium cylinder and reference blade profile. (Report VTT-CR-00542-18).

- The tests were part of the Pre-Certification of LID-3300IP Type 2 Ice Detector For Wind Energy Applications. (Report VTT-CR-06350-17).

Melting and ablation tests in the VTT Icing Wind Tunnel (IWT)

- The diameter of 100 mm aluminium test cylinder represents the leading edge curvature of reference NREL 5 MW of the wind turbine blade section close to the tip.

- Ice accretion temperature ~ -5 C
- Temperature ramping ~ -5…+3 C
- Rise of temperature ~ 2,8 C / hour
- Melting and ablation test temperature ~ +3 C.



Test Results

Test No.	Cylinder No.	Specimen	Ice Thickness [mm]	Ice Removal [Yes/No/Partly]	Ice Removal & Test time [hh:mm]
Test IV	I	⌀ 100 mm	13	Yes	5:20
Test IV	II	⌀ 100 mm	13	Yes	5:44
Test IV		Profile	13	Yes	9:12

NEW! Protection package surge SG for LID-3300IP

- A factory installed option for LID-3300 Ice Detectors
- Protects the Ice Detector against lightning and over-voltage
- Tested in high voltage laboratory by Phoenix Contact GmbH.

Summary

- Labkotec is a pioneer and market leader in wind turbine ice detection.
- New innovations include (among others):
  - Overvoltage protection package for LID-3300IP
  - Modbus over TCP/IP for LID-3300IP
  - Complete ice warning systems for wind farms
  - LID-3300IP Type 2 (available during 1H/2018)
  - Blade ice detector (available for customer pilots during 2018)
- Performance and high quality of ice detectors is ensured by continuous and intensive testing in icing wind tunnel, met masts and wind turbines.