Performance of two nacelle-mounted ice detectors: A case study

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Background

- Amount of wind power in cold climate and icy conditions is increasing
- Ice on the blades causes
  - Safety risk
  - Power losses
- Ice on the turbine blades is sensed by
  - nacelle mounted detectors

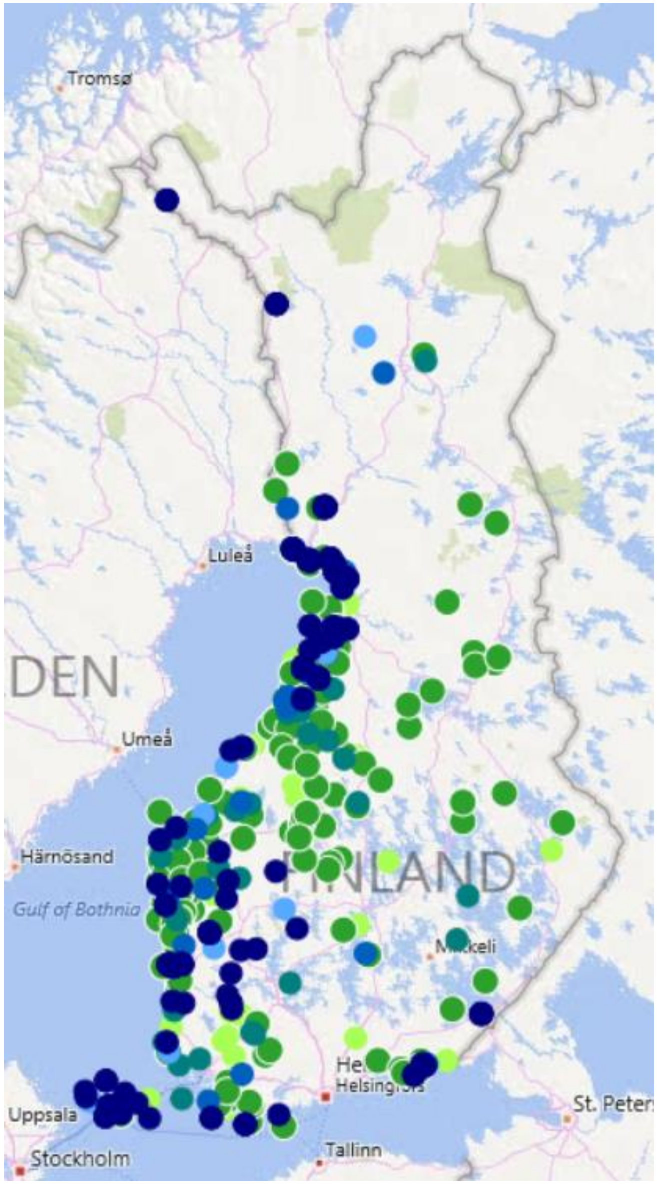
    + Easy to install on existing turbine

    + Low investment costs

    - Sense ice on nacelle, not on blades.
  - blade mounted sensors

    + Sense ice on blades themselves

    - More reliable results of the performance would be required



Picture: http://www.tuulivoimayhdistys.fi/hankelista

Scope

- The scope of the study is to investigate
  - What type of ice and how often occurs in Muukko wind farm?
  - In which weather conditions does ice occur?
  - Performance of two nacelle mounted ice detectors

- The study is part of a research project *'Wind power in cold climate and complex terrain*' carrying out by
  - Lappeenranta university of technology
  - Alstom Renevables España S.L
  - TuuliMuukko and
  - TuuliSaimaa

Scope

WP		Sub. WP	Title
1.	WP1. WIND FARM DATA ACQUISITION	1	Wind farm data acquisition
2.	WP2. POWER & OPERATIONAL PERFORMANCE ANALYSIS AND OPTIMIZATION	2.1	Power performance in cold climates
		2.2	Operational performance in cold climates
		2.3	Evaluation of WTG loads and dynamics due to ice accretion
		2.4	Analysis turbine control for cold climate
3.	WP3. ICING SENSORS AND ICE DETECTION	3.1	State of the art
		3.2	Performance analysis of ice detection sensors

Sensors and measurements (1/2)

- Ice detector, Sensor A
  - Freezing rain sensor
  - Ice detection is based on change of resonant frequency of vibrating probe
- Ice detector, Sensor B
  - In-cloud icing sensor
  - Ice detection is based on ultrasonic principle.
- Both sensors have heating switched on at the time of alarm
- Web camera mounted on nacelle and shooting blades

Sensors and measurements (2/2)

Other measurements used in the study

- Weather data of nearby Lidar
- Weather data from FMI
- SCADA data of the turbine

- Measurement period 18.10.2014 – 15.4.2015 (6 months)

Ice types found by web camera (1/2)

- Rime ice on leading edge found in 20 days

Ice types found by web camera (2/2)

- Snow-type of ice on the blades in 47 days
- In total, some type of ice (may be several types) found in 59 days

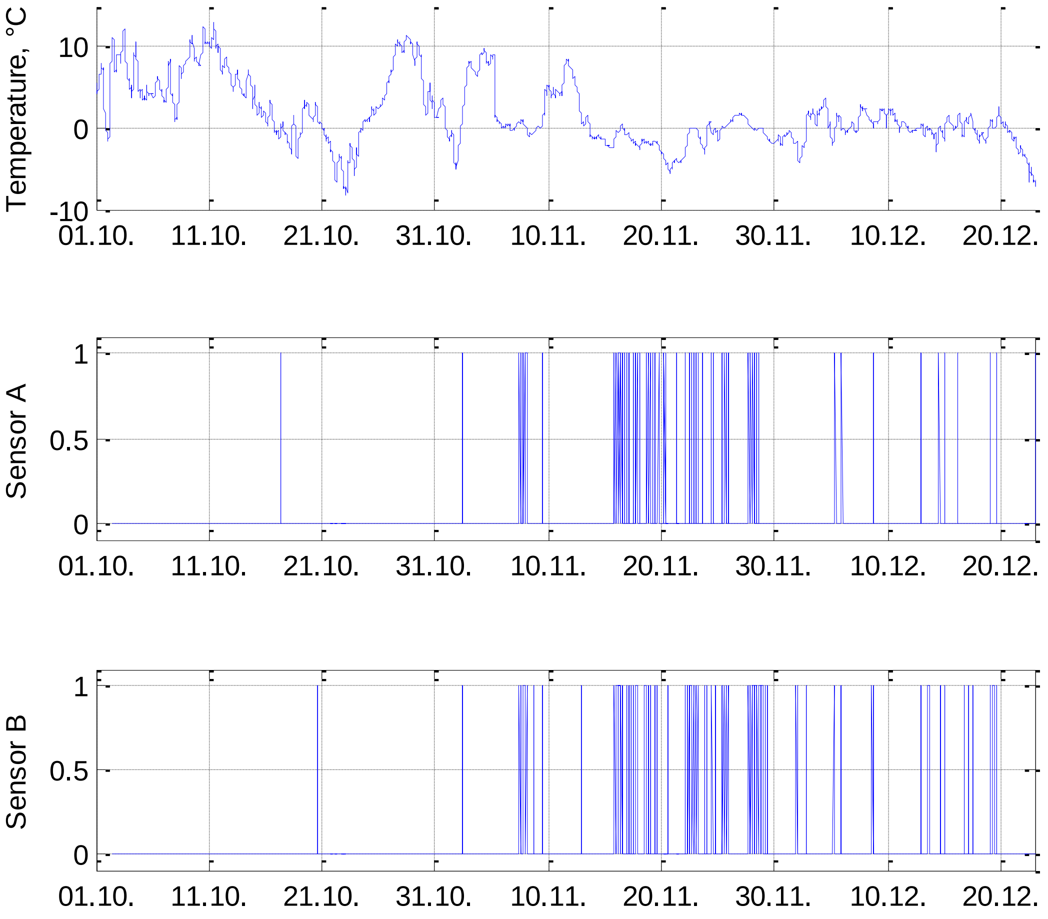
Challenges in detecting ice using web camera

- Camera far from the blade
  - ⇒ Not possible to see glaze or other thin formation of ice
- Poor visibility during dark, fog and heavy precipitation
- Camera with motion detector does not take pictures when turbine is standing

⇒ Most probably there has been
  - ice more often than in 59 days
  - also glaze

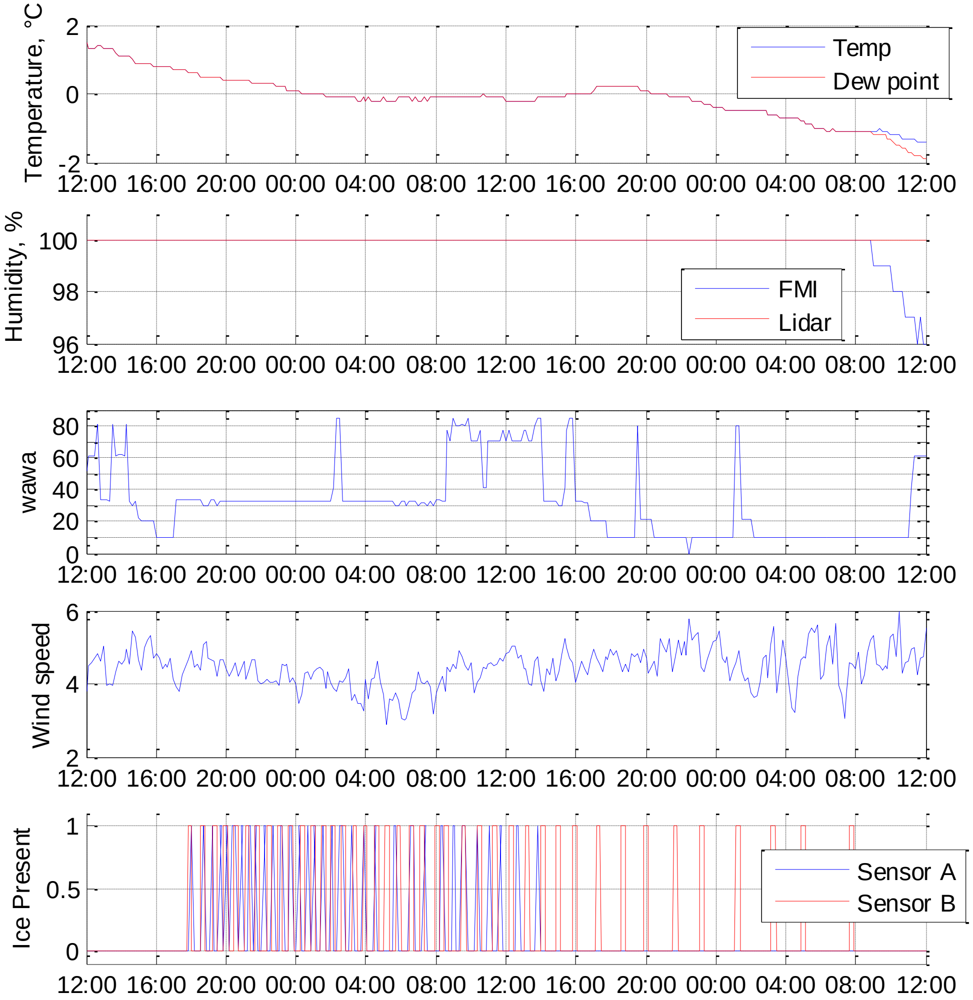
Alarms of ice detectors

- 76 alarms in total
- Overall duration of alarms 264 hours
- Each alarm over 1 hour was analyzed
  - Weather conditions
  - Ice seen by camera?
- Performance of ice detectors
  - Did ice detectors detect when there occurred ice?
  - False alarms?
  - Missing alarms?



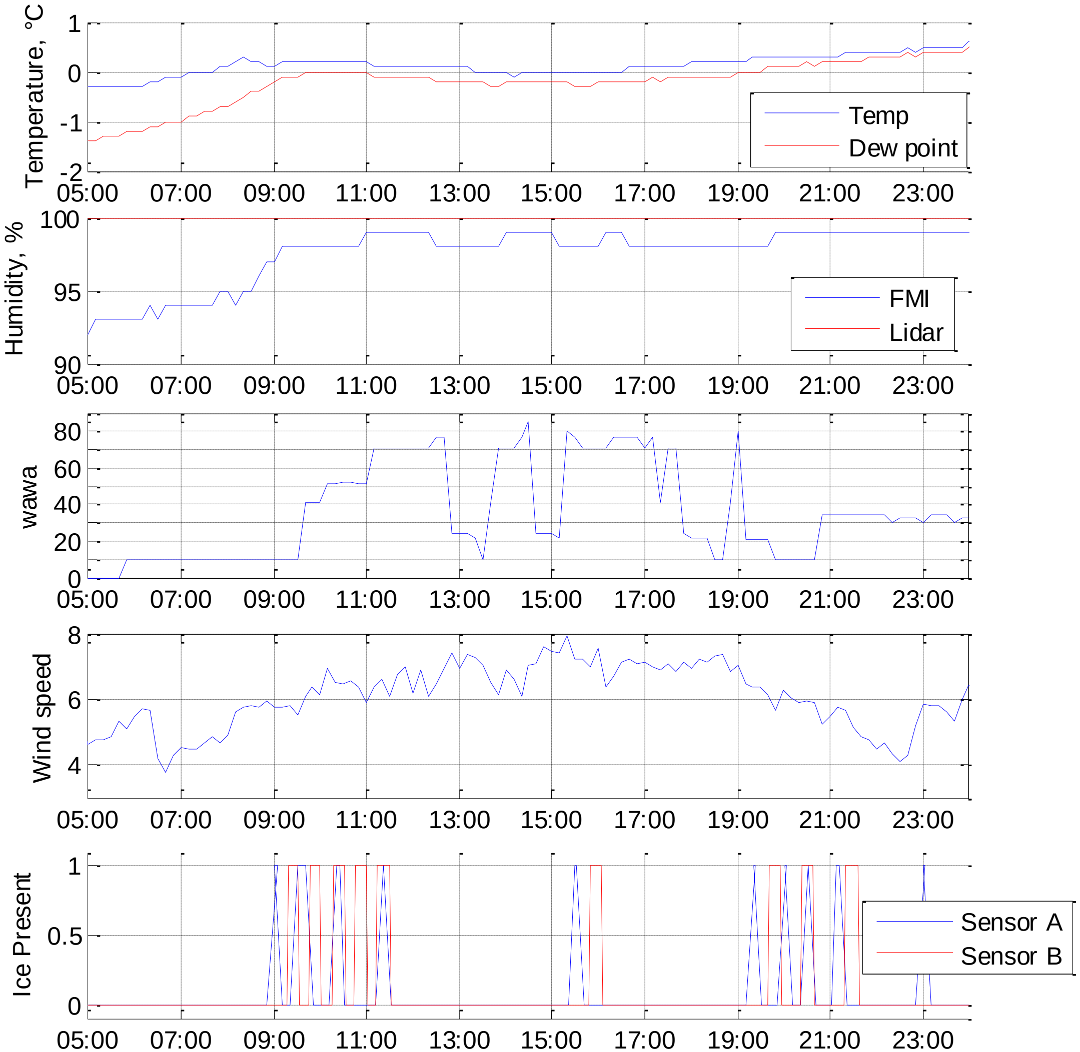
In-cloud icing causing rime ice

- In-cloud icing occurred especially on November 2014
- In total, 13 in-cloud icing cases were found
- Rime ice accreted according to the camera



Precipitation causing icing

- 24 cases where precipitation near zero degrees caused icing
- Several types of ice accreted: rime, snow-type
- Different types of precipitation; drizzle, rain, snow, no clear evidence of freezing rain
- In 4 cases, most probably wet snow



Performance of ice detectors

- All the ice occurrences seen by web camera were detected by both ice sensors or at least one of them.
  - Sensor **A detected 95%** (72/76) of icing cases
  - Sensor **B detected 97%** (74/76) of icing cases
- In many cases, sensor A gave alarm before sensor B
  - Reason probably **higher threshold value** of sensor A
- However, during **in-cloud icing**, sensor B often gave alarm before sensor A
  - Reason most probably that **in-cloud icing sensor B** is better capable of sensing in-cloud icing
- Additionally, sensor B was faster or only detecting sensor in 4 possible **wet snow** cases.
- Both sensors also gave some ”false alarms” and no ice was found with camera.
  - May have been accreted glaze or other thin layer of ice not visible by camera

Conclusions

- Both nacelle mounted sensors A and B performed very good.
- All the proven ice occurrences were detected by the sensors.
- No power loss caused by icing was observed by the first alarm.

- In future, in order to ensure proper threshold value for the ice alarm, the performance of nacelle mounted sensors should be analyzed together with blade mounted sensor and power loss of turbine

Thanks to the project partners:

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