Ice detection guidelines for wind energy applications

Winterwind
INTERNATIONAL WIND ENERGY CONFERENCE

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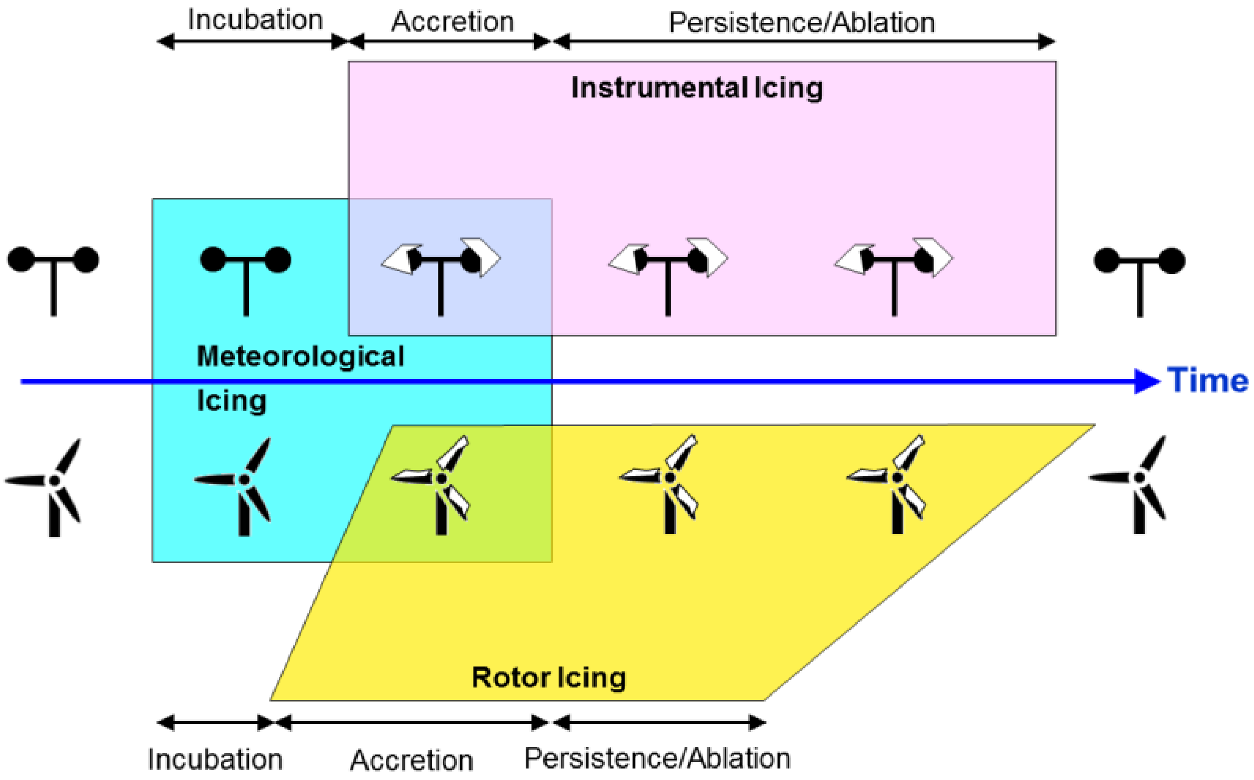
April 21, 2022

Background and objectives

- Variety of ice detection methods and applications in cold climate wind energy
- Propose a classification of available methods to pave the way for the optimization and standardization of ice detection technology
- Define which methods are best suited for a given application
- Propose standardized metrics for ice detection performance evaluation
- Review of certification process
- Discuss main risks and challenges associated with ice detection for wind energy applications

Standardized definitions



NEW

- During meteorological icing, the **ice accretion rate** expresses the **intensity** of an icing event in mm/h, kg/h or kg/(m*h).
- During instrumental or rotor icing the **maximum accumulation** of ice expresses the **severity** of an icing event in mm or kg.

Categorization

Considering the variety of available methods and measuring principles, two main categories can be defined based on the location of the ice measurement:

- Ice detectors placed on met masts and wind turbine nacelles to measure instrumental icing; or
- Ice detectors placed on – or inside – rotor blades to measure rotor icing.

Wind turbine nacelle or met mast

Icing type	Icing detection signal	Measuring principle
Meteorological icing	Discrete (True or false)	• Infrared reflection + heating • Atmospheric conditions (T, RH, visibility, etc.) • Vibrating wire or probe + heating
	Continuous intensity (in mm/h, kg/h or kg/m·h)	• Load cell attached to a rotating cylinder • IP cameras coupled with image analysis • Heat transfer rate on a probe • Change of impedance + heating
Instrumental icing	Discrete (True or false)	• Double anemometry • Infrared reflection
	Continuous severity (in mm, kg or kg/m)	• Load cell attached to a rotating cylinder • IP cameras coupled with image analysis • Heat transfer rate on a probe • Change of impedance

Wind turbine rotor

Icing type	Icing detection signal	Measuring principle
Meteorological icing	Discrete (True/false or categories)	• IP cameras coupled with image analysis • Change of impedance
	Continuous intensity (in mm/h, kg/h or kg/m·h)	• Change in blade eigenfrequencies
Rotor icing	Discrete (True/false or categories)	• Power curve + Pitch curve • IP cameras coupled with image analysis • Change of impedance
	Continuous severity (in kg or kg/m)	• Change in blade eigenfrequencies

Ice detection applications

The following ice detection applications are listed in the report

- Control of ice protection systems
- Evaluation of performance losses associated with icing
- Ice fall and ice throw risks mitigation
- Wind turbine control in icing and prevention of structural damage
- Research and validation (forecast input data)
- Resource assessment (planning phase)

Details in Appendix 1

Example of recommandations for anti-icing IPS control

Ice detectors for anti-icing IPS's should reliably detect both:

- Icing of low severity for the activation of anti-icing actions; and
- Icing of medium severity for the activation of de-icing actions.

For this application an ice detection method for anti-icing IPS must:

- Have high sensitivity, i.e. high accuracy at low icing severity, for the activation of anti-icing actions;
- Have high accuracy at medium icing severity for the activation of de-icing actions;
- Be easily integrated in the turbine control; and
- Be equipped with self-monitoring capability.

A highly sensitive rotor icing detector or a meteorological icing detector augmented with a discrete or continuous rotor icing detection method are recommended for this application.

Performance evaluation

Discussion of considerations for lab and field testing

Proposition of 12 repeatable and measureable KPIs that can be used in lab or field testing, such as :

- Response time: Time from start of icing conditions to positive detection (for a given set of controlled icing conditions or reference)
- Sensitivity: Minimum icing level that can be detected reliably considering background noise
- Resolution: For continuous methods, the amount of icing required to observe a change in the signal that is significantly higher than the background noise
- Etc.

Certification

In some jurisdictions and for some applications, the ice detection methods must be certified. A typical application often requiring certification is the mitigation of the ice throw hazard. Currently, ice detectors for this application are certified by DNV.

The certification ensures that:

- The ice detector meets the defined safety standard (e.g. the ice sensor system is able to detect whether ice on the blades and other components of the turbine is present or not, to enable an automatic restart of the wind turbine)
- The ice detector can be integrated into the turbine control in a reliable manner

Risks

When integrating ice detection in a wind energy project, some risks must be adressed:

- Commercial risk: What is the impact of a faulty or unavailable ice detection method on revenue (e.g. energy production) and compliance?
- Redundancy: Is there an alternative ice detection method if the preferred one becomes unavailable?
- Communication protocol: Is the ice detection signal compatible with the wind turbine controller? Since there is no standard for integrating third-party component signals to wind turbines, the controller may not be able to read the ice detection signal.
- Performance of the ice detection method: Is sufficient information available to understand in which conditions the ice detection method will provide an ice detection signal?
- Safety: None of the commercial ice detection systems is approved under the scope of the European Union Machinery Directive as a system with performance level D (Probability of Dangerous Failure per Hour between 10^{-7} and 10^{-6})

Key takeaways

Task 19 Ice detection guidelines for wind energy applications is an industry reference aimed at accelerating the standardization of ice detection methods by:

- Proposing a standardized classification of ice detection methods used in the wind energy industry
- Facilitating the selection of the most suited ice detection method for a given application
- Defining technical requirements for those applications
- Defining measureable and repeatable performance metrics for ice detection performance application
- Encouraging the industry to address the risks related to the usage of ice detection on wind farms

Full report

The full report will be available soon on the Task 19 website:

https://iea-wind.org/task19/t19-publications/

Appendix 1 : Ice detection method selection based on wind energy application

Application	Important metric	Required sensitivity	Additional considerations	Recommended ice detection method
Activation of a de-icing system	Presence of a given level of rotor icing	Low	Easy to integrate in turbine control Equipped with self-monitoring capability	Discrete or continuous rotor icing (power curve)
Activation of an anti-icing system	Early stage of rotor or meteorological icing for activation of anti-icing Presence of a given level of rotor icing for activation of de-icing	High accuracy at low and medium icing intensity	Easy to integrate in turbine control Equipped with self-monitoring capability	Highly sensitive rotor icing or Meteorological icing + discrete rotor icing
Post-construction evaluation of production losses associated with icing	Instrumental or rotor icing periods	Low	Cover all wind turbines of a given site Limited costs	Discrete instrumental or rotor icing (power curve)

Appendix 1 : Ice detection method selection based on wind energy application

Application	Important metric	Required sensitivity	Additional considerations	Recommended ice detection method
Ice fall and ice throw mitigation – Temperature-based	Temperature below a given threshold	High	N/A	Thermometer. Application recommended only for sites with scarce icing events and milder temperatures
Ice fall and ice throw mitigation – Active warning signs	Presence of icing risks on site	Medium	Communication link to active warning signs on site Equipped with self-monitoring capability	Meteorological, instrumental or rotor ice detection method
Ice fall and ice throw mitigation – Icing detection + visual inspection	For shutdown: meteorological, instrumental or rotor icing periods For restart: visual inspection in person or by video	High	Certification required Easy to integrate in turbine control Equipped with self-monitoring capability	Meteorological, instrumental or rotor ice detection method AND Visual inspection
Ice fall and ice throw mitigation – Automated	For shutdown: rotor icing periods For restart: demonstration that there is no more risk of ice fall or ice throw	Medium	Certification required Easy to integrate in turbine control Equipped with self-monitoring capability	Impedance- or eigenfrequency-based rotor icing detection

Appendix 1 : Ice detection method selection based on wind energy application

Application	Important metric	Required sensitivity	Additional considerations	Recommended ice detection method
Wind turbine control in icing and prevention of structural damage	Severe instrumental or rotor icing periods	Medium	Easy to integrate in turbine control Equipped with self-monitoring capability	Continuous instrumental or rotor icing
Research	Ice accretion rate and icing severity	High		Continuous meteorological, instrumental or rotor icing
Resource assessment	Meteorological or instrumental icing periods; Instrumental icing severity	Low	Variation of icing across large wind farms and terrain elevation	Discrete meteorological or instrumental icing on a met mast
Forecast or long-term icing model validation data	Ice accretion rate and icing severity	High		Continuous meteorological, instrumental or rotor icing

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