STATE OF THE ART AND BENEFIT OF DE-ICING AND ANTI ICING TECHNOLOGIES

For wind turbine operating in areas with icing condition

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SKELLEFTEÅ kraft

Agenda

- My background
- Why explore wind power in cold climate?
- Effects on wind turbines
- Icing
  - –Types
- Anti and de de-icing technology
  - –Passive
  - –Active
- Conclusion

My background

Ph.D Student Manufacturing Systems Engineering 1999-2004

MW-Innovation 2005-2010

Own independent consultant since April 2010 with a mission for Skellefteå Kraft AB (SKAB)

My mission for SKAB

Evaluation of existing de-icing technology/system in actual projects for their wind power exploration in cold climate.

Analyze report and provide SKAB with latest information about ongoing interesting project etc.

Update and supply SKAB latest technology level/stage about de-icing.

Why explore wind power in cold climate at high altitude?

Wind speed increase by 0,1 m/s per 100 m for the first 1000 m.

In areas with cold climate, available wind power is approximately 10% higher than other regions due to the increased air density at lower temperatures.

Icing on wind turbine blade

Significantly reduce the aerodynamic properties.

Mechanical failures due to increased load or unsymmetrical distribution of the ice.

Damages on bearings and gear boxes.

Safety risks

Damage on a roof (service building) from ice thrown.

Icing

Three types

- In cloud icing
- Precipitation
- Frost

In cloud icing

Most common, super cooled droplets hit a surface below 0° C freeze upon impact.

Soft rime, temp well below 0° thin ice with needles and flakes, low density and little adhesion

Hard rime, higher density, more difficult to remove

Glaze, the droplets not freeze upon impact, runs back, freezes later. Strong adhesion and density.

Rime ice

Most common type of in-cloud icing. Rime ice forms ice vanes on the windward side of the objects.

Leads to uneven loading by ice.

In-cloud icing depends on the dimensions of the object exposed, the wind speed, the liquid water content in the air, the drop size distribution and the air temperature.

Precipitation

• Can be snow or rain. The accreation rate can be higher than in-cloud, causes more damage

• Freezing rain, rain falls on a surface whose temp is below 0° C. It often occurs during inversion. Ice density and adhesion are high when this phenomenon occurs

• Wet snow, when the air temp is between 0 and -3° C. It sticks to the surface . Easy to remove at first, but can be difficult if it freezes on the surface.

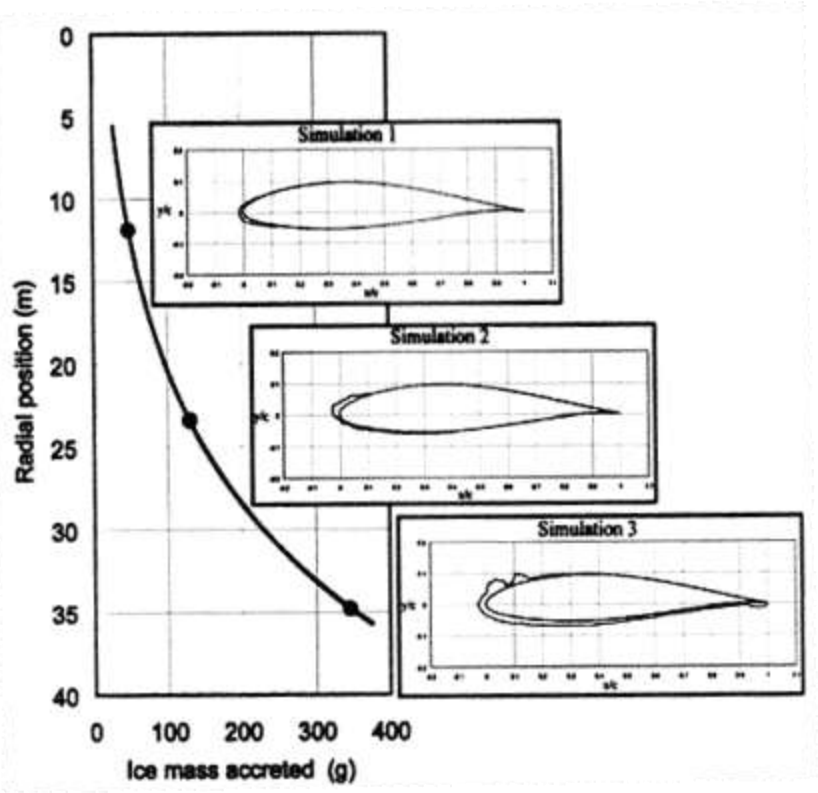
Frost

- Appears when water vapour solidifies directly on a cool surface.
- It often occurs during low wind speed.
- Frost adhesion can be strong.

Research

Quantity of captured water and ice increase with the relative air velocity

Researching work has shown that it is most important to de-ice the outer third of the blade.



Anti-Icing and De-Icing Technology

- Mechanical
- Passive
- Active

Mechanical

- De-icing with crane

Passive anti-icing system

- Black paint
- Special coating
- Chemicals
- Flexible blade/active pitching

Black paint

Advantage

• Cheap easy to apply

• Test in Yukon (Canada) showed immediate and noticeable improvement in performance

• Sufficient at sites where icing is slight, infrequent, icing periods followed by temperatures above 0° C or in areas with high winter solar intensity at lower altitudes.

Disadvantage

• Most of time not sufficient to prevent icing

• Sunny days blade temperature will be high and can affect the material properties.

• Allows blade heating only sunny days

Special coating

Ice-phobic coatings prevent ice from sticking to the surface (anti adherent property)

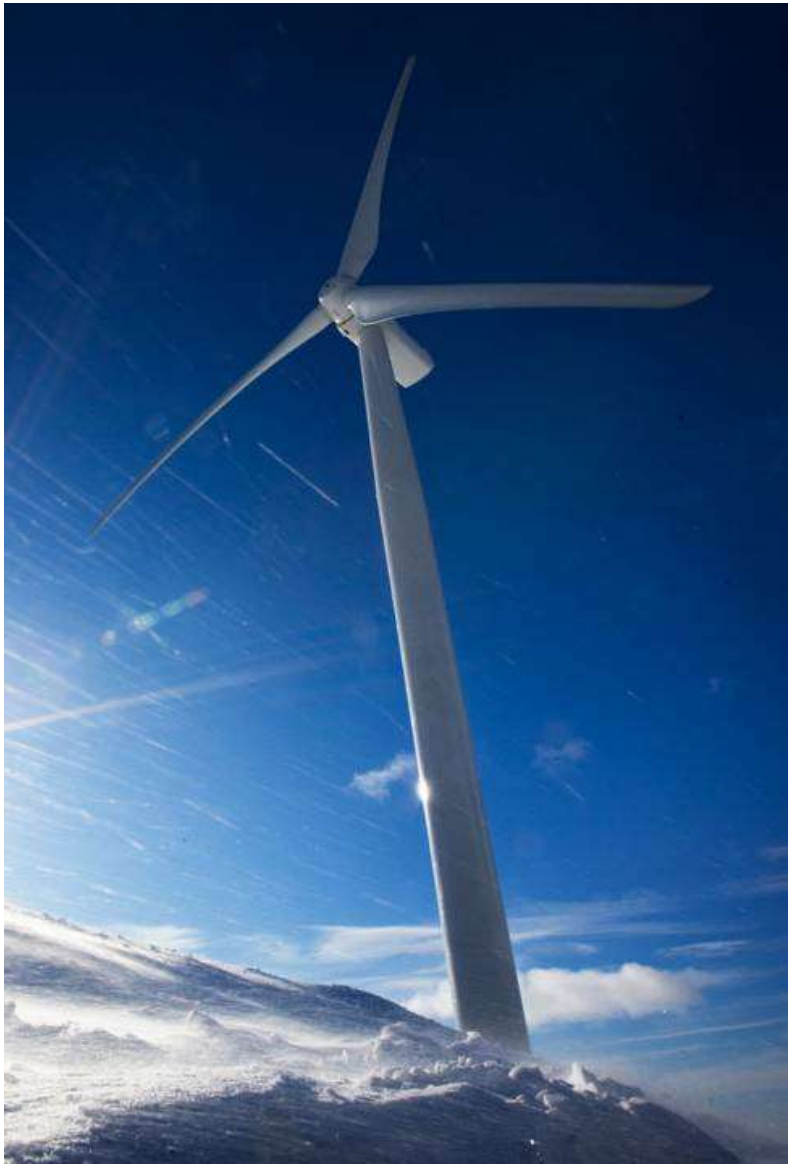
Super-hydrophobic coatings do not allow water to remain on the surface (repulsive features)

Reuced shear forces betwee the ice and the surface will also reduce sensitivity to dirt and bugs.

Special coating

Advantage

- Low cost
- No special lightning protection needed
- Easy blade maintenance, protects the whole surface
- Easy to apply



Special coating

Disadvantage

• Several materials tested but no good solution has been found.

• Icing occurred even on coated surfaces regardless of the temperature

• Materials degradation, coating becomes porous

• But a clean and smooth surface is preferable

Chemicals

Applied on blade surface, lower the freezing point. Common used during aircraft take-off.

Disadvantage

It is a pollutant, needs special application and maintenance.

Cannot remain on surface for a long time.

Passive de-icing system

Flexible blades, flexible enough to crack the ice loose.

Flexing is known to help shed the ice.

Not so much information published

Active pitching. Start/stop not scientificaly verified, may damage the turbine.

Active de-icing system

- Kelly Aerospace
- VTT (KAT)
- Enercon
- EcoTEMP
- Ice CODE/Goodrich
- Siemens
- Microwave

Kelly Aerospace

- Electro thermal system
- External installation peel and stick.
- Field or factory installation
- Advantage fast heating of surface
- Low energy consumption sectioned
- Flexible system design
- Easy to repair (Good weather)
- Lightning?

EcoTEMP

- Electro thermal system
- External installation peel and stick.
- Field or factory installation
- Advantage fast heating of surface
- Low energy consumption
- Sectioned
- Flexible system design
- Easy to repair (Good weather)
- Lightning?

VTT

- Electrothermal system
- Integrated carbon fiber below coating.
- High energy consumption
- Advantage, protected heaters
- Hard to repair
- Lightning?

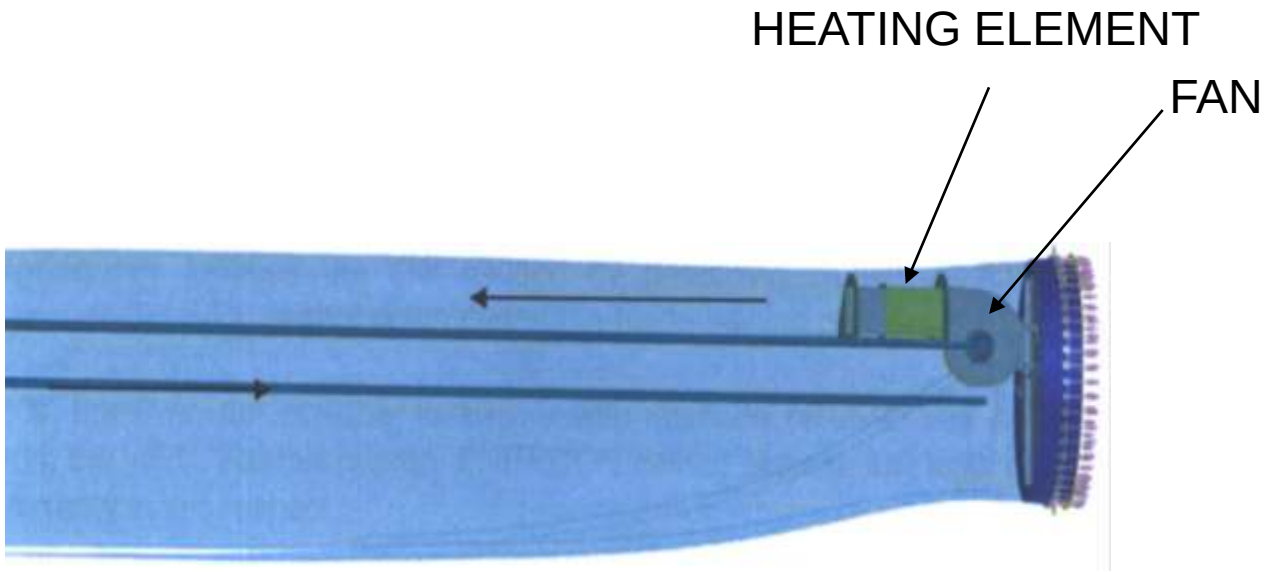
Lightning

- Challenge for electrothermal system?

Platform

- Installation
- Repair
- Service
- Inspection
- Maintenance

Enercon



Hot air system, air circulates inside the blade

Heats the laminate

Cheap

High energy consumption

Other de-icing system/technology

ICECODE

- PETD Pulse electro-thermal de-icer
- Electrically conductive paint
- Electrically conductive polymer films
- Metal films
- Sputtering technology

Goodrich has acquired exclusive rights to develop the technology for de-icing airplanes and windmill turbines.

Microwave

Tested by LM Glassfiber and Halmstad University.

- Low transmission distance
- Low absorption in composite
- Low absorption in glaze ice
- Positive results with applied surface absorbers
- Further research needed

Ongoing project in Sweden with support from the Swedish Energy Agency

- Skellefteå Kraft Uljabuouda
- Svevind Dragaliden/Gabrielsberget
- Dong Energy Storrun
- O2 Vindkompaniet Bliekevare, Braehus

Conclusion

Lightning can be a challenge

Most important to de-ice the outer third

Chemical de-icing is no solution

Clean and smooth/coated blade is preferable.

De-icing is necessary

Thank you for your attention

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On behalf of Skellefteå Kraft AB