Experience with Wind Turbines in Arctic Environment

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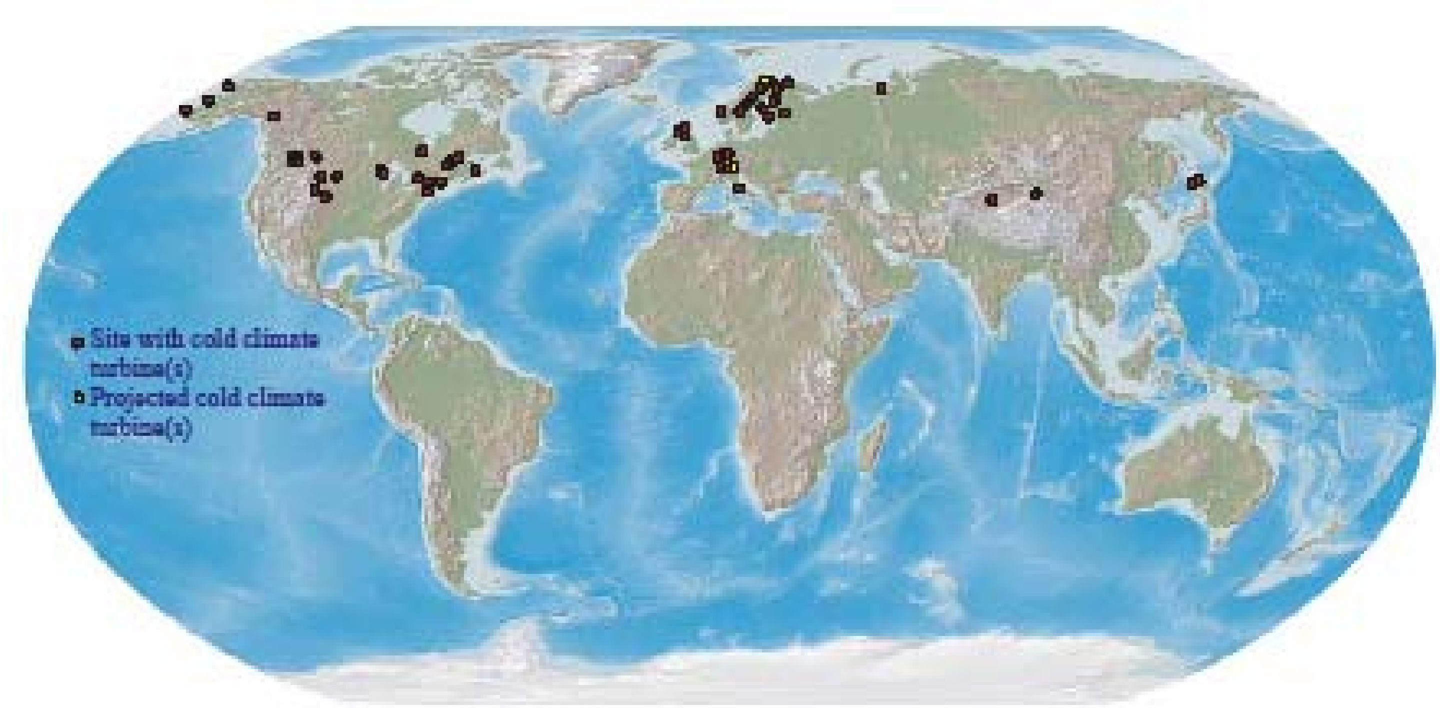
Annex: Wind Energy in Cold Climates



Operating wind turbines in cold climates from

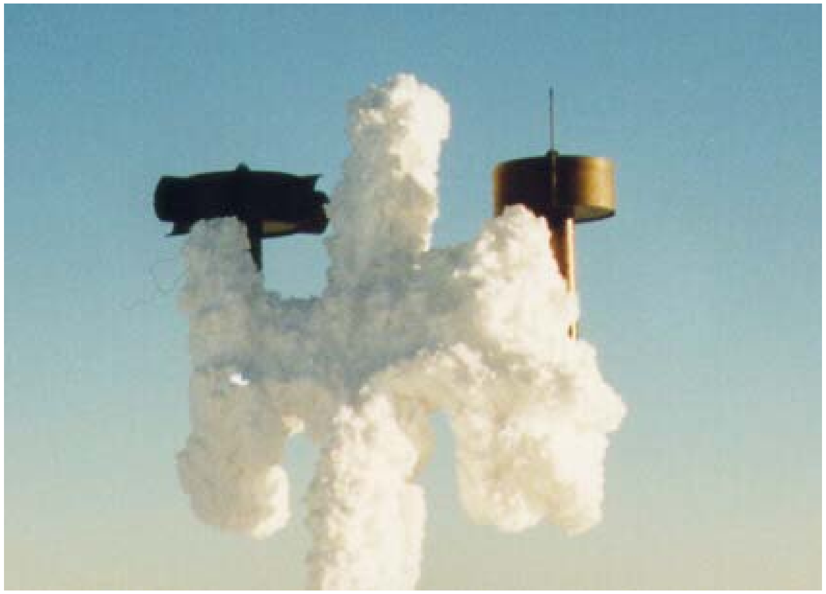
Laakso et al., State-of-the-art of wind energy in cold climates, IEA, 2003

Laakso et al., Wind Energy Projects in Cold Climates, IEA 2005

Laakso et al., 2003 is a report describing some of the experiences with these turbines and Laakso et al., 2005 is a report on what to consider for wind turbine projects in cold climates

can be downloaded from http://virtual.vtt.fi/virtual/arcticwind/

- Wind measurements (anemometers)
- Different icing
- Effect of ice on loads and power
- Effect on mechanical components (gearbox, yaw system, hydraulics)
- Solutions for cold climate
- Operational experience



Ice free anemometer, from

T.Laakso et al., State-of-the-art of wind energy in cold climates, IEA annex XIX, 2003

Ice or rime may underestimate wind speed up to 30 % and can affect stop in high wind speeds. Further it may prevent the wind turbine to start after a possible stop.

To heat the anemometer (appr. 1500 W) needed. Solar panels not sufficient and access to the grid needed.

Different ice mechanisms

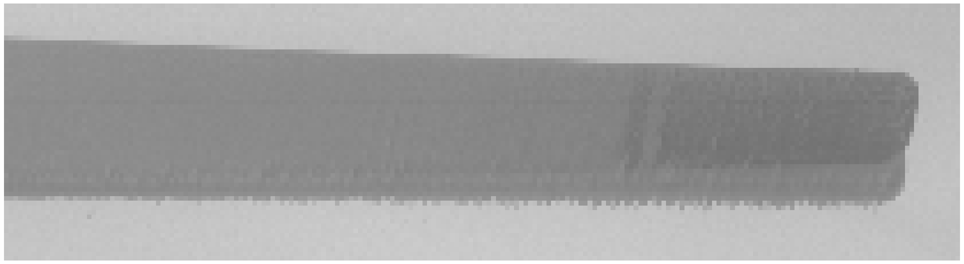
In-cloud icing when the cloud base lower than site elevation and temperature less than 0 degrees

Freezing precipitation occurs when raining and temperature less than 0 degrees. Typical associated with a warm front.

Frost – when the surface temperature drops below zero due to radiation or heat transfer

Wet snow/sleet is formed when the heat flux at lower elevations is high enough to melt the surface of dry snowflakes.

Different types of ice

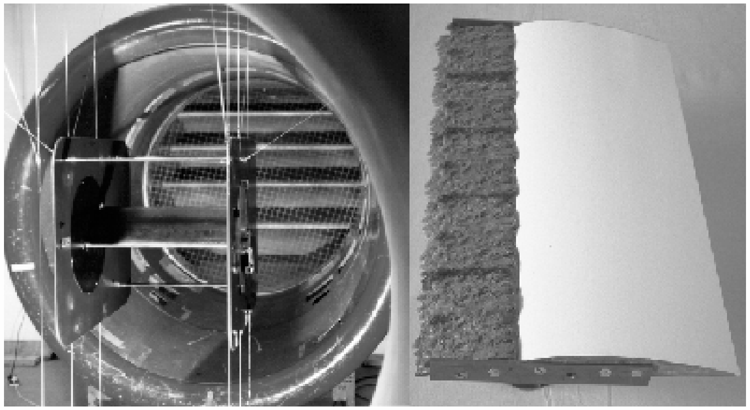


Rime ice on operating WT from

Tammelin B and Seifert H, Large Wind Turbines go into cold climate, EWEC 2001

Glace ice from

Hochart C, Wind Turbine Performance under Icing Conditions, Wind Energy, to be published 2008



Plastic model of rime ice from

Seifert H, A recipe to estimate aerodynamics and loads on iced rotor blades, Boreas IV, 1998

Glace ice is more adhesive/sticky and rime ice more brittle

The ice built-up depends on different parameter:

LWC liquid water content [g/m^3]
MVD mean droplet diameter [μm]
T absolute temperature [K]
p pressure [kPa]
V_{rel} relative velocity [m/s]
Airfoil geometry
t accretion time [s]

Ice accretion can be estimated with known parameters using various codes from aeronautical industry (LEWICE,TURBICE ETC.)

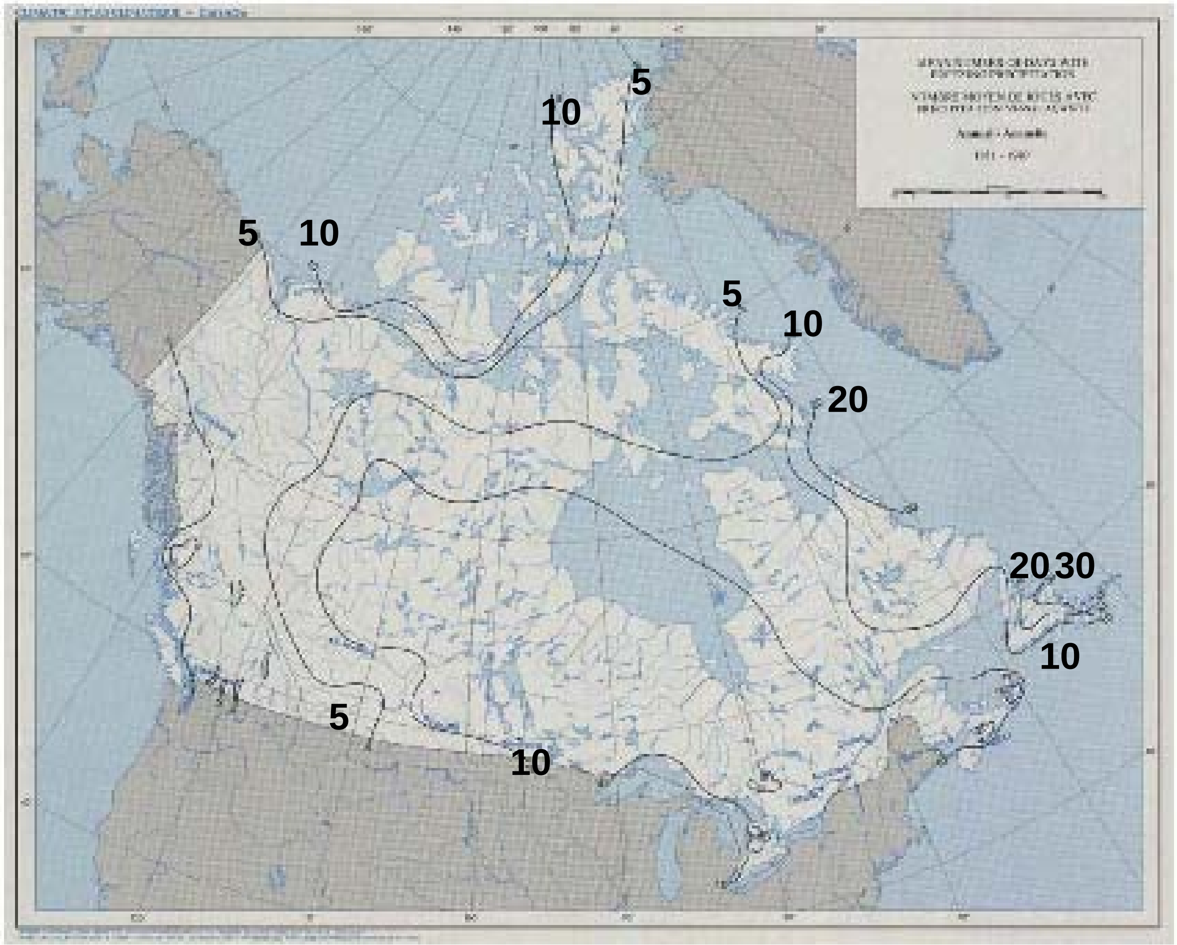


Figure 8. Mean number of days with freezing rain during one year in Canada between 1951-1980. Map from National Archives & Data Management Branch of the Meteorological Service of Canada.

De-icing system may be necessary for the blades

To overcome power loss

Safety reasons close to roads, settlements etc.

Systems

Heating (electrical or convective) or pneumatic systems exists

Thrown of ice pose a risk

www.tauernwind.com

Other issues

- Snow and freezing moisture in gearbox and yaw system must be avoided
- Nacelle must be sealed against drifting snow
- Control electronics should be heated against moisture and condensation
- Synthetic lubricants rated for cold temperatures must be used
- Most wind turbine manufacturers recommend to stop the turbines at temperatures below 30^{o}C

Operational experience

Icing causes loss in power production due to deterioration of aerodynamic profiles

Uneven ice shedding yields mass unbalances giving vibrations that either stops the wind turbine or give extra fatigue damage

Sensors affected:

Iced anemometer may not start even in strong winds

Iced vane can cause yaw misalignment leading to high fatigue loads

Operational experience continued

Use of wrong lubricants and greases have damaged bearings and gearboxes during low temperature operation

Insulation on electrical wires becomes brittle and may fall off leading to shortcuts.

Air density increase with decreasing temperatures ($p=\rho RT$). Stall regulated turbines have overproduced more than 20% and in Canada and Finland overheated generators have been reported.

Experience from Canada

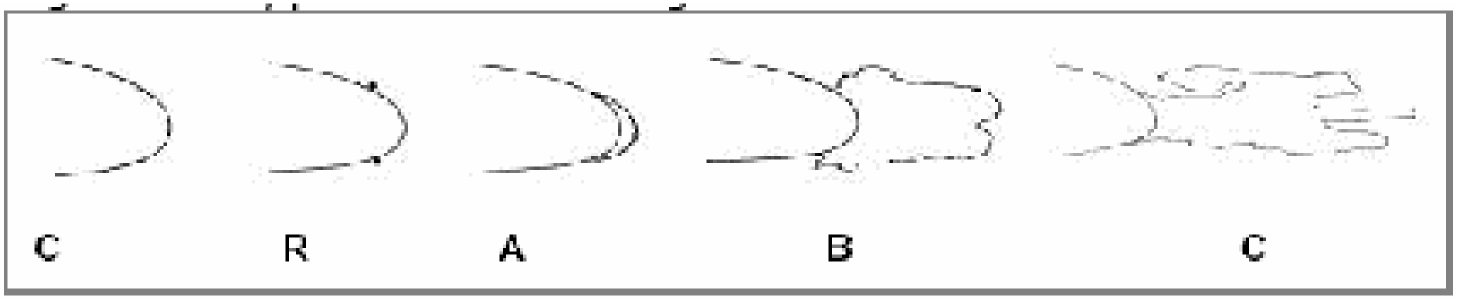
Yukon Energy identifies iceing the most important issue. Covering the blades with black, low adhesion type of paint have helped.

Low temperature steels, synthetic lubricants and heating systems for gearbox, generator and electrical cabinet worked well.

Another operator claims that overproduction at low temperatures for stall regulated wind turbines is the most significant issue. A 600kW machine in Ontario has reported to overheat the generator that tripped out.

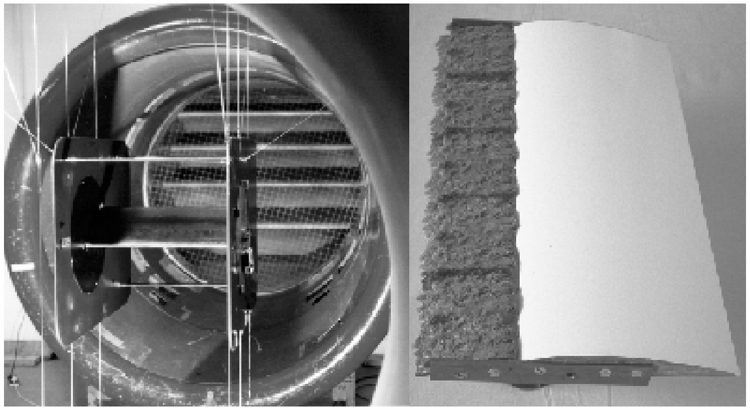
$$\left.\begin{array}{l} p = \rho_1 R T_1 \\ p = \rho_2 R T_2 \end{array}\right\} \Rightarrow \frac{\rho_2}{\rho_1} = \frac{T_1}{T_2} = \frac{273+15}{273-30} = 1.18$$

18 % higher density yields 18 % more power



Observed ice accretion from

Seifert H, A recipe to estimate aerodynamics and loads on iced rotor blades, Boreas IV, 1998

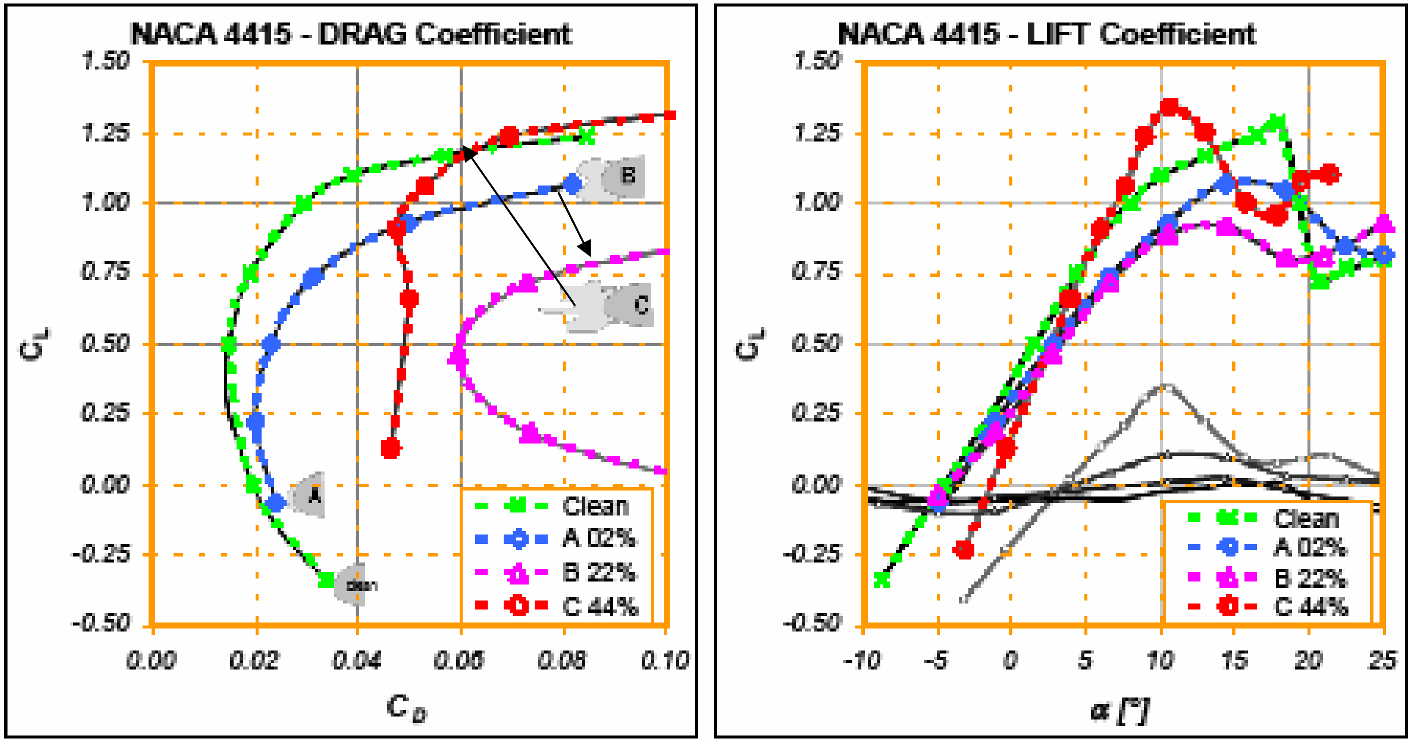


Plastic mould of observed ice

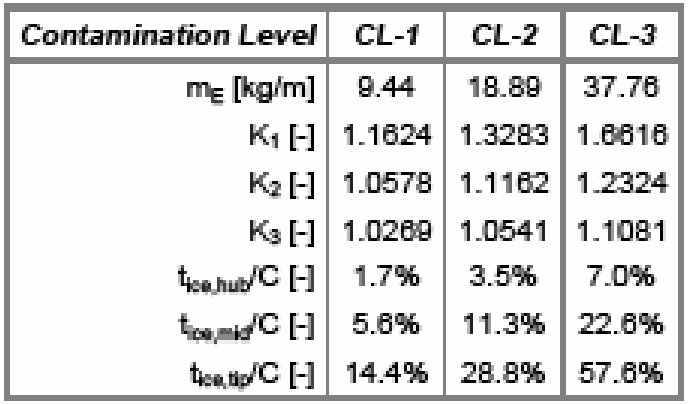
Seifert H, A recipe to estimate aerodynamics and loads on iced rotor blades, Boreas IV, 1998

Measured airfoil data using the plastic moulds for different Contamination levels

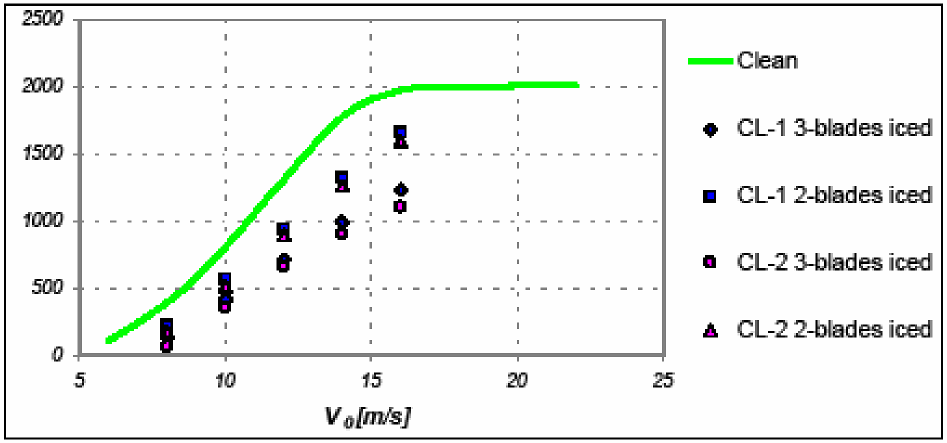
Seifert H, A recipe to estimate aerodynamics and loads on iced rotor blades, Boreas IV, 1998



Lift and drag forces non-dimensionalized with respect to blade chord with no ice accretion



Contamination Level	*CL-1*	*CL-2*	*CL-3*
m_E [kg/m]	9.44	18.89	37.76
K_1 [-]	1.1624	1.3283	1.6616
K_2 [-]	1.0578	1.1162	1.2324
K_3 [-]	1.0269	1.0541	1.1081
$t_{ice,hub}/C$ [-]	1.7%	3.5%	7.0%
$t_{ice,mid}/C$ [-]	5.6%	11.3%	22.6%
$t_{ice,tip}/C$ [-]	14.4%	28.8%	57.6%



Calculated power curve

Soraperra G, Analysis on Aerodynamic and Aeroelastic behaviour of a wind Turbine Rotor During Icing, MSc thesis MEK-FM-EP 2005-01, DTU.

The results of up to 50% drop is consistent with observations from

T.Laakso et al., State-of-the-art of wind energy in cold climates, IEA annex XIX, 2003

Summary

Ice reduce production, lower P(V).

Can also give an unbalanced rotor stopping the rotor due to vibrations

Ice affects anemometers. An overiced anemometer may prevent the wind turbine to start even in high winds

Iced wind vane can force the wind turbine to operate in yaw-misalignement and increase fatigue loads

Anti or de-icing techniques exist, but they cost both as investment and running cost (heating power)

Special care on lubrication for gearboxes, yaw motors etc. must be taken

Electrical installation must be protected from moisture/condensation. Further, insulation on electrical wires can become brittle and break off.

Fixed pitch on stall regulated wind turbines may need to changed to prevent overheating the genarator in extreme cold.

References

[1] T.Laakso et al., State-of-the-art of wind energy in cold climates, IEA annex XIX, 2003

[2] Hochart C, Wind Turbine Performance under Icing Conditions, Wind Energy, to be published 2008

[3] Tammelin B and Seifert H, Large Wind Turbines go into cold climate, EWEC 2001

[4] Seifert H, A recipe to estimate aerodynamics and loads on iced rotor blades, Boreas IV, 1998

[5] Soraperra G, Analysis on Aerodynamic and Aeroelastic behaviour of a wind Turbine Rotor During Icing, MSc thesis MEK-FM-EP 2005-01, DTU