

Vad säger bl.a. vindkraftsbranschen själv om vindkraftverk i kallt/isigt klimat (*extraordinär klimatzon*)?

Utdrag bl.a. ur ett par presentationer vid "Vintervinds konferens i Piteå 3-4 februari 2010".

<http://vintervind.se/index.php?q=node/9>

- Vindforsk III, projekt V-313, "VINDKRAFT I KALLT KLIMAT":

- Moln/nedisningsproblematiken måste vi förstå bättre.
- Att vi kan förvänta oss nedisning i princip, i hela landet. Mindre risk i södra Sverige, med undantag för sydsvenska höglandet. Störst är risken i norra Sverige, norra och inre Svealand och norrut.
- Att följande projekt uppges vara pilotprojekt inom 'kallt klimat':
 - Storskalig vindkraft i fjällmiljö – O2Vindkompaniet AB
 - Storskalig vindkraft i norra Sverige – Svevind AB
 - Pilotprojekt Uljabuoda – Skellefteå Kraft AB
 - Pilotprojekt Storrún – Dong Energy

- Av Göran Ronstens (VindRen) presentation vid Vintervinds konferens i Piteå 3-4 februari 2010 - "IEA RD&D Wind Task 19 - Wind Energy in Cold Climates" framgick bland annat följande:

Conclusions with respect to icing:

- We've got started!
- Items in red need attention. Se IEA RD&D Wind, Task 19, bild
- Relevant icing measurements at relevant heights for model verification of wind turbine specific icing do not yet exist
- Site specific modelling verification studies needed - to be followed by regional icing studies at 1 km resolution
- Commercial de-/anti-icing systems not yet available for medium and severe icing conditions.
- Detailed national mapping
- O&M issues to be looked into

Göran Ronsten uppgav även, att han tror att problemet med nedisning är underskattat och att nedisningsproblem är mycket svårare på 100 meters höjd än vi har i kraftledningshöjd. Dessutom uppgav Göran Ronsten bl.a. också, att "andra problem är att isstycken kan lossna och givetvis orsaka skador om människor träffas". "Ljudet från vindkraftverken har också en tendens att öka i samband med nedisning."

Nedisning och avisning är alltså enligt vindkraftsbranschen själv, fortfarande ett olöst problem!

- IEA RD&D Wind Task 19 - Wind Energy in Cold Climates uppges också, att "Commercial de-/anti-icing systems not yet available for medium and severe icing conditions".

- IEA uppger även bl.a. i Task 19:s slutrapport, av 2.4.2009, 4.3 Key findings – **Safety**, att **“No fallen ice chunks have been found further than 5 rotor diameter from the tower base of a wind turbine. The size of fallen ice chunks can be everything between few grams to several kilograms. Thus, there is a clear need to protect the risk area ...”**.

NOTERA även, att i Statens Officiella Utredningar, SOU, 1999:75 uppges, att ”det finns rapporter om att blad/bladdelar lossnat och isbitar har slungats iväg från vindkraftverk på mer än 300 m avstånd”. Notera att vid denna tidpunkt var navhöjden 60 meter och rotordiametern 60 meter, dvs. 5x60=300 meter.

- Av tester som tillverkare av vindkraftverk utfört framgår bland annat att **iskast, som är en farlig säkerhetsrisk, förekommer i stort sätt alltid under och efter varje avisningscykel**
- Av testresultat framgår också, att det är tre (3) gånger vanligare att isbitar kastas ut via rotorbladens spets än från rotorn.
- IEA Wind Energy Projects in Cold Climate, Edition 2009 (sidan17)
"Turbine operation with iced blades may not be permitted in certain countries or permitted only in case of rime ice, **as glaze ice is considered dangerous. However, rime ice can be almost as dense as glaze ice, so there is no obvious reason to make such an exception”**.
- Av rapporten “Wind Energy Projects in Cold Climate, Edition 2009” (sida 22-23) framgår också följande:
 - **4.4 Wind measurement; ”Wind measurements in Cold Climate can be challenging”**.
“Many factors can reduce their quality and availability”. **“No sensor can stay ice free under all conditions”**.
 - **4.5 Ice detection; “only few, if any, of the ice detectors are well proven”**.

Winterwind 2011, 9th-10th February 2011, Umeå, Sweden

- IS commercially available:
 - Heated wind sensors for project development
 - Turbines for low temperatures
 - Ice mapping services e.g. local icing maps
 - Models for calculation of ice accretions
 - De-icing for mild icing climate
- **NOT available commercially**
 - Long term icing statistics e.g. through national met services
 - **Reliable and calibrated ice detectors**
 - **Models and methods for calculation of ice loads and ice induced loading on wind turbines**
 - Verified method for the estimation of the effects of atmospheric icing on energy production

- Question marks?
 - **Wind turbine technology for severe icing climate. Improve the understanding of the risks and the mitigation strategies regarding ice throw.**

SUMMARY ON KEY FINDINGS

- Requirement number one – **reliable site data** often omitted due to the extra cost. Tools i.e. ice maps and appropriate measurement systems available
- **Cold climate solutions especially anti- and de-icing solutions for heavy icing conditions and acceptable ice detection not yet commercially available in the market**
- The economical risks involved in cold climate wind energy projects are not fully taken into account in the project development phase. Methods to estimate the effects of ice on energy production have been developed to assess the risks for investor.
- **The ice induced extra loading wind turbines can stem from increased operation in rotor imbalance and increased number of start/stop cycles. There are no requirements concerning these loads in the present standards.**
- The market for cold climate wind technology, including wind farms, remote grid systems and stand-alone systems is showing growth in Canada, Sweden, Norway and Finland.
- **Wind turbines will be build in numbers on areas where cold climate criterions will be met regardless of slow progress in technology development side**

Definition of cold climate site / conditions:

Normal climate ambient temperatures:

- $\theta_{\text{mean year}} = 15^{\circ}\text{C}$
- $\theta_{1\text{year min/max}} = -20 \text{ to } +50^{\circ}\text{C}$ (survival temperature)
- $\theta_{\text{min/max operation}} = -10 \text{ to } +40^{\circ}\text{C}$ (operational temperature)
- standard air density $\rho = 1.225\text{kg/m}^3$

Cold climate criterion and ambient temperatures:

- 9 days per year below -20°C (appr. $p=0.02$)
- operation of turbines below -15°C
- manufacturer defines $\theta_{\text{mean year}}$, $\theta_{1\text{year min}}$, $\theta_{\text{min operation}}$

Cold Climate Class A (e.g. Cartwright)

- identical to approach up to now (Rev. 1 to 3 of Technical Note):
- high air densities and wind speeds $\geq v_{\text{rated}}$ occur simultaneously
- can be assumed to be fulfilled, if mean air density $\rho_{\text{mean year}} \geq 1.25 \text{ kg/m}^3$ for $v \geq v_{\text{rated}}$
- air densities calculated with
- $\theta_{\text{mean year}}$
- $\theta_{1\text{year min}}$
- $\theta_{\text{min operation}}$

Cold Climate Class B (e.g. Pincher Creek)

- new in Rev. 4
- high air densities and wind speeds $\geq v_{rated}$ do not occur simultaneously
- application of lower extreme air densities
- $\rho_{1year\ min}$ is calculated with $\theta_{1year\ min} + 35\ K$
- $\rho_{min\ operation}$ is calculated with $\theta_{min\ operation} + 25\ K$
- corresponds to approach for normal conditions (of existing guidelines)
- $\rho_{mean\ year}$ is calculated with $\theta_{mean\ year}$

Example for temperatures and air densities

- $\theta_{(example)}$ $\rho_{acc. Class A}$ $\rho_{acc. Class B}$
- $\theta_{mean\ year} = +5^{\circ}C$ 1.269 kg/m³ 1.269 kg/m³
- $\theta_{1year\ min} = -40^{\circ}C$ 1.514 kg/m³ 1.317 kg/m³
- $\theta_{min\ operat} = -30^{\circ}C$ 1.452 kg/m³ 1.317 kg/m³
- basis: ideal gas law with standard air pressure
- corrections for different altitudes possible

Information for safety and control system

- Adjustment of safety concept and safety / control system to cold climate conditions
- Description of measurement instruments and sensors
- Systematic consideration of possible faults
- Description of start-up procedure(s)
- Overheating protection on heatings

Information for automatic ice detection

- Ice detection systems (ice sensors) can be certified according to GL Guideline
- Useful hints and requirements are included in the Technical Note, Rev. 3 for GL 2003/2004 (for GL 2010 this is included in the Guideline itself).

GL-Technical Note for Cold Climate – An Overview

Contents

- Introduction – GL
- Introduction – CC
- Definition of cold climate conditions
- Information for
- Load assumptions
- Safety and control system
- Automatic ice detection
- Manuals
- Rotor blades, nacelle cover and spinner
- Machinery components
- Strength verifications
- Building structures
- Electrical installations
- Summary

Further improvement of certification rules required to account for specific demands on cold climate certification.

Additional Technical Note on Icing?

- cold climate sites and icing of wind turbines are not necessarily connected
- demand for independent technical note on icing
- e.g. with standard ice classes 3 days per year, 10 days, 20 days,...
- displays icing capabilities of turbine (ice class X) clearly in certificate (not somewhere hidden in different certification reports)

Vestas erfarenheter av is - utdrag:

- **Kunder investerar fortfarande i projekt med risk för isbildning**
- **Is faller/sprids från turbinen under vintern detta utgör en säkerhetsrisk!**

http://windren.se/WW2011/45_Vestas_Plagborg.pdf

Utdrag ur ett par presentationer vid Vindkraftsforskning i fokus, 18-19 januari, 2012,

CHALMERS Göteborg.

<http://www.chalmers.se/ee/swptc-sv/evenemang/handelser/vindkraftsforskning6184>

Cold Climate Wind Energy Development - Göran Ronsten, WindREN

IEA RD&D Wind , TASK 18

Wind Energy in Cold Climates, Sweden

Technology development for WE in cold climates requires a market study - **not available**

We've discovered surprising issues – LED obstacle lights need heating

Are signs, sirens and light enough to prevent accidents?

Wind pilot projects - From offshore to cold climate and forests:

- 30 WT, 70 MW, Sjisjka
- 10 WT, 30 MW, Uljabouda
- 10 WT, 20 MW, Dragaliden
- 18 WT, 36 MW, Bliekevare
- 20 WT, 40 MW, Gabrielsberget
- 48 WT, 95,4 MW, Havsnäs
- 12 WT, 30 MW, Storrån
- 10 WT, 30 MW, Gässlingegrund
- 5 (20) WT, 15 MW (60 MW), Mönsterås (Idhult)
- 12 WT, 24 MW, Oxhult
- 5 WT, 13 MW, Brunsmo
- 48 WT, 110 MW, Lillgrund
- 128 WT, 640 MW, Kriegers flak

Wind pilot project - Planning and project approvals 2010:

- 10 WT (20 MW) on Dragaliden 2011
- 8 WT (27 MW) on Stor-Blåliden

Storrån-Icing of WT 2009-,

Pilot project activities – February 2009 – December 2011:

- WTG effect on birds in mountain areas

- Verification of orographic efficiency
- Icing of wind turbines

Havsnäs is Sweden's largest onshore windfarm. The production is influenced by icing.

Conclusions with respect to icing

- **We're under way!**
- Items in red need attention
- Icing measurements at relevant heights for model verification of wind turbine specific icing do not yet exist
- Site specific modelling verification studies needed - to be followed by regional icing studies at 1 km resolution
- Detailed national mapping of icing is about to become a meaningful task
- Commercial de-/anti-icing systems **might be** available for medium and severe icing conditions
- **O&M issues to be looked into ice throw, site access, rescue, availability, low temperature work**

Vindkraft och nedisning – Hans Bergström, Uppsala Universitet

Nedisning - vad vet vi idag? Resultat så här långt från V-313:

- Modeller fångar ofta väl nedisningstillfällen
- Men ibland stora skillnader i mängd is mellan modell och mätning
- Mätning av islast dock problematiskt

Standardisering inom vindkraftsområdet – Bengt Göransson, Pöyry Swedpower

IEC 61400-1 DESIGN METHODS SITE ASSESSMENT

Leverantören och beställaren har bägge en skyldighet att se till att vindkraftverket klarar förhållandena på platsen där det ska ställas upp

Utdrag ur **VIT – Presentation: "State of-the-art of ice detection"**

Presentation by Petteri Antikainen at Winterwind 2012, Skellefteå

VTT Technical Research Center of Finland

In general there is a need for (page 10)

- Best practises, recommendations, rules and regulations, classifications, standards
- Not for ice detection only, the same applies to other instruments as well
 - There is practically no classified anemometers for cold climate!
 - Turbines, loads etc...
- Bankability!

Draft version of Elforsk report 12:13 "Icing of Wind Turbines" prepared for Winterwind

2012 7-8 feb 2012 – Några utdrag.

2.4 Icing measurements

State of the Art

One of the most reliable ways to identify icing today is still by visual inspection.

2.5 De-Icing and Anti-Icing

The hot air heating de-icing system of ENERCON.

Electro-Thermal systems consist usually of heating surfaces which are installed typically on the leading edge of the wind turbine. Today, many prototypes exist and are been tested on wind turbines.

The electrical heating uses an electrical resistance embedded inside the membrane or laminated on the surface. Electrically heated foils can be heating wires or carbon fibers.

Heating elements cover the leading edge area of the blade. The ice detector and blade surface temperature are used to control the operation of the heating system. Additional temperature sensors are installed to protect the blade from permanent damage induced by overheating.

Apart from the technical challenges related to Electro-Thermal systems for removal of ice, the control of such a system is another important field. The right timing for switching on and off the heating systems has to be identified during operation of the wind turbine on the most economical way to optimise the cost/benefit in terms of the used energy for heating versus additional production.

Currently, it is not possible to predict icing turbine-specifically in order to start up de-icing systems before there is ice on the blades. Only after the detection of ice, the process of removing the ice can be started. A preventive de-icing, which would then be anti-icing is not possible.

No information of long term effects of heating systems on the blade structure. As de-icing systems mostly focus on the leading edge of a rotor blade, there is a probability for secondary icing, i.e. the ice is melted but re-freezes on the unheated parts of the rotor blades.

2.6 Safety issues

2.6.1 Ice throw

The most often approach to identify risk zone for ice throw and ice falls are the formulas presented by Henry Seifert:

$d = 1,5(D+H)$ for an operating turbine

$d = \frac{D \cdot (2 + H)}{15}$
for a turbine at standstill

d = Maximum falling distance of ice fragments [m]

D = Rotor diameter [m]

H = The hub height [m]

v = The speed at the blade tip [m/s]

The major drawback of the formulas is the fact, that the dependency of the ice throw risk on the wind statistics under typical icing conditions is neglected.

Finally there is a clear lack of validation data for the simulation results.

The Guetsch study.

This study is still unique in the world and therefore referenced many times. It showed a clear dependency of the ice throw on the prevailing wind condition during icing events and gave indications on preferred rotor positions for ice throw. However, as **the wind turbine at the Guetsch is rather small**, 600 kW Enercon E-40 wind turbine with integrated blade heating, **compared to nowadays standard wind turbines**, the question was often raised, how these results can be transferred to larger wind turbines. In addition, there is no difference between ice fall and ice throw.

2.6.2 Noise

Today there are hardly any studies on the influence of icing on the noise emissions of a wind turbine. It is mainly unknown how this works.

3 Future research needs

3.1 General thoughts

While wind speed and temperature are today relatively easy to measure, the results of ice detectors are not very accurate and LWC is almost impossible to be measured.

On the wind turbine side, there exist studies on ice accretion on rotor blades. However, these simulations are only run for constant conditions. Finally there is no mechanical model.

The future research should focus on the correlation between the external meteorological conditions and the rotor blade of an operating turbine. Furthermore, there is a clear need for better validation data. This implies a strong need for better instruments to detect icing on the blade of a wind turbine.

3.5 De-icing and Anti-icing

It is crucial to be able to understand the effects of icing on wind turbines and to develop reliable anti-icing and de-icing systems and to control them efficiently i.e. the ice accretion on a heated blade or a blade treated with an anti-icing surface:

- Prototypes
- Independent validations within research projects
- Anti-Icing coatings tested in the field
- Intelligent turbine control for de-icing systems

3.6 Safety issues

3.6.1 Ice throw

There is a clear need to carry out more experimental studies in order to better understand the characteristics of ice throw. Special emphasis has to be put on:

- the exact time of ice throw
- distinction between ice throw and ice fall
- difference between unheated and heated blades
- preferred blade position for ice throw
- correlation between wind direction and ice throw direction
- trajectories of ice fragments, behaviour in the air, “sailing” effects
- ice throw for different ice fragments
- mechanical models for ice on blades

3.6.2 Noise

There is hardly any knowledge on the effect of iced blades on the noise emissions of a wind turbine. The following questions remain unanswered:

- **What's the increase in db when operating with iced blades?**
- **How can it be measured?**

http://winterwind.se/wp-content/uploads/2012/01/Icing_of_windturbines_elforsk_report_12_13_draftversion_120127.pdf

2012-02-16

Claes-Erik Simonsbacka