Winterwind

INTERNATIONAL WIND ENERGY CONFERENCE

Conference Program 2013

Cold climate wind energy solutions

Research and application under one roof

Visit our poster exhibition

Open on the second floor throughout the conference. See the program for poster sessions, when the authors will be available by their posters to answer questions.

Mapping and forecasting

- **Experimental investigation of ice accretion on wind turbine blades**
  – Adriana Hudecz, Technical University of Denmark
- **Challenges of data logging in Arctic conditions**
  – Attila Sukosd, Zsuatt
- **Numerical prediction of ice accretion based on LES and LPT**
  – Robert Szasz, Lund University
- **Estimation of production losses due to icing based on an improved synoptical algorithm**
  – Sebastian Haym, Graz University of Technology
- **Indirect detection of icing on wind turbine blades**
  – Timo Karlsson, VTT
- **System concept of a smart icing sensor network on wind turbine blades**
  – Michael Moser, Graz University of Technology
- **Empirical modeling of wind power production during winter season**
  – Muhammad Bilal, University of Tromsø, Norway

ANTI-icing and DE-icing technologies

- **Ice preventive coatings evaluation tests at VTT**
  – Jeroen Dillingh, VTT
- **TURBICE – the turbine blade icing model, and its further development via a new interface**
  – Saygin Ayabakan, VTT
- **Differential boundary layer model for wind turbine blade icing code TURBICE**
  – Saara Huttunen, VTT
- **Designing coatings for application in fields at risk of icing**
  – Cornelia Pfaffenroth, ZHAW
- **De-icing testing and development of ultrasonic wind sensor for cold climate**
  –Shigeo Kimura, Kanagawa Institute of Technology

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Market potential, pro and cons, financing

- **Assessment of wind energy production penalties due to cold climate in Canada**
  – Antoine Lacroix, Natural Resources Canada
- **Lessons learned from public cold climate wind power statistics**
  – Ville Turkia, VTT
- **Estimating wind power production losses due to icing**
  – Esbjörn Olsson, SMHI

Standards and certifications

- **Preliminary results from project IcedBlades – Modelling of ice accretion on rotor blades in a dynamic overall wind turbine tool**
  – Ville Lehtomäki, VTT

Operations and maintenance

- **An opportunistic condition-based maintenance strategy for offshore wind turbine blades under cold weather conditions**
  – Mahmood Shafiee, Chalmers University of Technology and University of Gothenburg

Program

11 FEB

18.30

Mingle at Triventus offices, Köpmangatan 22

– Get a head start and meet the participants before the conference officially opens! Triventus invites you for a drink. The event starts at 18.30 and you are welcome to drop in at any time during the evening.

12 FEB

8.30 – 9.00

PB-SALEN

Registration and breakfast

– Sponsored event in SONATEN! **Wind Energy in Canada – market developments and research projects**

10.30 –12.15

PB-SALEN

Opening session
Chairs: Anna Jivén and Göran Ronsten

- **Welcome back to Winterwind 2013!** Fredrik Lindahl, Chairman of the Board of the Swedish Wind Power Association
- **Jämtkraft – a driving force in the development of energy from renewable sources** Anders Ericsson, CEO Jämtkraft
- **Harnessing the potential of cold climate wind energy on a 4 degree warmer earth** Lawrence Jones, Alstom Grid
- **NCAR's Wind Power Forecasting System** Luca Delle Monache, NCAR
- **The Chinese Wind Turbine Market** Sebastian Meyer, Azure

12.15–13.00 LUNCH 13.00–13.30 POSTER SESSION

13.30–15.00

PB-SALEN

Detection, mapping and forecasting of icing
Chairs: Adriana Hudecz and Patrik Jonsson

- **Creating an icing climatology using typical months** Petra Thorsson, Uppsala University
- **Creating an icing climatology using downscaling techniques – results from Vindforsk project V-313** Hans Bergström, Uppsala University
- **Mesoscale modelling of icing climate: Sensitivity to model and model setup** Stefan Söderberg, WeatherTech Scandinavia AB
- **Forecasting production losses at a Swedish wind farm** Neil Davis, DTU Wind Energy

ARNLJOT

How to create black numbers from wind in cold climate in short term view
Chair: Anna Jivén

- **How to handle the financial risks during periods of crisis as of today?** Fredrik Bergström, Business Manager Sweden, Danske Commodities
- **On the uncertainty in the AEP estimates for wind farms in cold climate** Øyvind Byrkjedal, Meteorologist, Kjeller Vindteknikk, Norway
- **Securing financing for cold climate projects** Justin Jeffs, Head of Investment and Economics, Triventus Consulting, Sweden

15.00–15.30 COFFEE BREAK

15.30–17.00

PB-SALEN

De-Icing, Anti-Icing and Ice Management
Chairs: Maja Vernström and René Cattin

- **Anti-Icing coatings and de-icing technical approaches and status** Stephan Sell, Fraunhofer IFAM
- **Challenges and concepts how to design and operate a turbine in cold and icy climates** Lea Kirsch, REpower Systems
- **Operating experience with anti-icing systems in Nordex turbines** Astrid Löwe, Nordex Energy
- **25 years of experience with turbines in cold climate** Finn Daugaard Madsen, Siemens Wind Power

ARNLJOT

Laboratory and field tests
Chairs: Stefan Ivarsson and Sven-Erik Thor

- **Savings with use of de-icing technology for wind turbine blades in cold climate** Hans Gedda, H Gedda Consulting AB
- **Measurement of contact angle at sub-zero temperatures and implication for ice formation** Golrokh Heydari, KTH
- **The use of a large climate chamber for extreme temperature testing & turbine component validation** Pieter Jan Jordaens, Sirris / OWI-Lab

SONATEN

Market potential
Chairs: Jos Beurskens and Johanna Olesen

- **Blade heating – is there a slot for 3rd party solution providers in the wind power supply chain?** Esa Peltola, VTT
- **Icing map of Sweden** Øyvind Byrkjedal, Kjeller vindteknikk
- **Ice profile classification based on ISO 12494** Matthew Wadham-Gagnon, TechnoCentre Éolien
- **Vibration and load measurements of two MWscale turbines operating in icing conditions** Ville Lehtomäki, VTT & Matthew Wadham-Gagnon, Technocentre Éolien

19.00–01.00 MINGLE AND DINNER

Program

13 FEB

08.30–10.00

PB-SALEN
Tests and results from cold climate turbines
Chair: Stefan Ivarsson

- **Lessons learned and commercial findings or results? What has the Canadian market concluded so far?** Frédéric Côté, Technocentre Éolien
- **Progress for plans in the Nordic region** Stefan Ivarsson, Scandinavian Wind
- **SEU operation and maintenance experiences of wind turbines in cold climate** Thomas Mannelqvist, Skellefteå Kraft
- **Panel discussion** Karl Bendtsen, Siemens AB, Energy Sector, Head Sales & Proposals, Wind Power SE, Sören Plagborg Vestas, VP Turbines & R&D, Eva Sjögren, Sales Officer, Enercon, Kurt Stürken, Managing Director, REpower Systems Scandinavia AB

ARNLJOT
Health and safety (WORKSHOP)
Chair: Johanna Olesen

- **Numerical investigation on the noise generation of iced wind turbine airfoils** Richard Hann, Institute of Aerodynamics and Gas Dynamics, University of Stuttgart
- **The applications of ice throw modelling to risk assessment and planning in cold climates** Gail Hutton, RES Group
- **The effect on noise emission from wind turbines due to ice accretion on rotor blades** Peter Arbinge, ÅF Sound & Vibration
- **Challenges for the service technician in cold climate conditions** Marcus Carlström, YH-vindkraftteknikerutbildning/Nätverket för vindbruk
- **Panel discussion** Authors and Bengt Göransson

SONATEN
TIDBITS
Chairs: Åsa Elmqvist and Stefan Söderberg

- **Sjisjka Wind Farm – a wind farm in roadless country close to the Arctic Circle** Tommy Borgh, Jämtkraft
- **Temperature and wind influence on power transmission capability of power lines in the vicinity of cold climate wind farms – case studies in Finland** Sanna Uski–Joutsenvuo, VTT
- **Smart Charging matches the needs from EV's and PHEV's** Mikael Hagman, Jämtkraft

Small WT

- **Hybrid wind–diesel system with compressed air storage for remote Nordic areas** François Tremblay, Technocentre Éolien

10.00–10.30 COFFEE BREAK

10.30–12.00

PB-SALEN
Forecasting and performance
Chairs: Esbjörn Olsson and Inga-Lill Olsson

- **Modelling of production losses due to icing for individual turbines in a wind farm – development of techniques for forecasting and site assessment** Magnus Baltscheffsky, WeatherTech Scandinavia AB
- **Assessment of "ground truth" for icing events and product evaluation** Ben C. Bernstein, Leading Edge Atmospherics, LLC – Longmont
- **An investigation into turbine performance and wind flow modelling under cold weather driven atmospheric conditions** Carla Ribeiro, GL Garrad Hassan

ARNLJOT
Standards and Certifications
Chair: Bengt Göransson

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- **Recommended practices for wind energy in cold climates – resource assessment and site classification** Tomas Wallenius, VTT,
- **Towards standardization considering cold climate needs** Petteri Antikainen, VTT
- **The Havsnäs pilot project – cold climate and high hub heights** Alan Derrick, RES Group

12.00–12.30 LUNCH 12.30–13.00 POSTER SESSION

15.30–17.00

PB-SALEN
What to expect at Winterwind 2014 and beyond?
Chairs: Frédéric Côté and Fredrik Lindahl

- **CFD simulation and reduced order modelling of atmospheric icing for accurate wind energy resource assessment** Thomas Reid, Newmerical Technologies International
- **Sven-Erik's and Jos' reflections** Sven-Erik Thor and Jos Beurskens
- **What to expect at Winterwind 2014 and beyond? Panel discussion with Linda Vikström** Proposed participants: Thomas Reid, Sven-Erik Thor, Jos Beurskens, Frédéric Côté, Fredrik Lindahl and Finn Madsen
- **Welcome back to Winterwind 2014 in …!** Fredrik Lindahl

14 FEB

07.30–15.00

Field trip to Havsnäs wind park
- **Experience wind power in cold climate and mingle with staff members and scholars from Nordisk Vindkraft and RES**

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INTERNATIONAL WIND ENERGY CONFERENCE

Cold climate wind energy solutions

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Vibration and load measurements of two MWscale turbines operating in icing conditions B. Boucher, TechnoCentre Éolien

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SMALL WT

Hybrid wind-diesel system with compressed air storage for remote Nordic areas Eric Adams, Technocentre Éolien

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An investigation into turbine performance under cold weather driven stable atmospheric conditions in Scandinavia Carla Ribeiro, GL Garrad Hassan

Capturing the effect of radiative cooling when modelling wind flow over a wind farm Carla Ribeiro, GL Garrad Hassan

OTHER

De-icing testing and development of ultrasonic wind sensor for cold climate Shigeo Kimura, Kanagawa Institute of Technology, Japan

POSTER

MAPPING AND FORECASTING

ice accretion, melting, airfoil, experimental investigation, wind tunnel tests

Experimental investigation of ice accretion on wind turbine blades

Adriana Hudecz, Department of Wind Energy, Technical University of Denmark
Martin Otto Laver Hansen, Department of Wind Energy, Technical University of Denmark

It is a fact that ice accretion on wind turbine blades can cause serious problems, such as production loss or even structural damages of the turbines at cold climate sites. Understanding the ice accretion mechanism as well as the melting process could be a key in ice mitigation.

In this study, experiments have been performed on a NACA 64-618 air-foil profile in a closed-circuit climatic wind tunnel at FORCE Technology, Kgs. Lyngby, Denmark. The airfoil model was provided by LM Wind Power and has a 900 mm chord and 1350 mm width. A number of angle of attacks, 0^o, 4^o, 7^o, 9^o and 11^o, have been tested at different temperatures (e.g. -3^oC and -8^oC) in order to simulate conditions for glaze, rime and mixed ice (both glaze and rime ice). The lift force along with the accreted ice mass has been monitored from the point when ice appeared on the surface of the air-foil. Samples of ice profiles were taken in order to compare the results with numerical solutions. The melting process was monitored similarly to the ice accretion until the point when all ice disappeared from the air-foil. The melting was induced by increasing air temperature in the wind tunnel.

The results show immediate and dramatic lift force degradation during ice accretion. As soon as the surface temperature reaches 0^oC, the melting becomes a rather rapid process and the lift force quickly recoveries.

BACK

data logger, measuring equipment, arctic conditions

Challanges of data logging in Arctic conditions

Attila Sukosd, Zsuatt

Today, computing is present in nearly all imaginable fields, and wind energy is no exception. The detection, mapping and forecast of icing require specialized equipment capable of withstanding the harsh arctic environment, and at the same time provide all the reliability and functionality required to make precise measurements which can be used to back up a model.

The current data logging equipments on the market are big, bulky, limited in functionality and at the same time very expensive. They also introduce problems with software and data formats which are proprietary, thus leading to compatibility issues with other systems. Due to their closed nature, it is often very hard to integrate new sensors, which ends up being a choice between yet-another device to add in a shelter box, or choosing an inferior sensor compatible with the current device.

The proposed data logger aims to compete with other loggers on the market by offering similar as well as a range of extra functionality at a lower cost. These functions include remote firmware updates, reconfiguration and live monitoring of equipment, giving the customer full control over what is happening with a meteorological station. The hardware and the software are released as open source to the community, allowing for a larger scale collaboration on all the aspects of the product.

The data logger presented is the second revision based on the experiences collected during two years of in-field testing in South Greenland. The current version is used to monitor up to 12 sensors on a 15 and 50 meter met-masts.

BACK

Numerical prediction of ice accretion based on LES and LPT

Robert Szasz, Lund University

Laszlo Fuchs, Royal Institute of Technology

In order to avoid the harmful effects of ice accretion on wind turbines blades there is an intensive research to predict the occurrence of icing for given geographic areas. A lot of effort is put also in developing strategies to avoid icing, or if not possible, to remove accreted ice layers. Much less effort is put in the understanding of how ice accretion occurs. Such understanding would help optimizing de- and anti-icing strategies.

There are experiments carried out in wind tunnels with controlled climatic conditions (see e.g. [1] and more recent plans in [2]). Numerical computations can complement such experiments by offering greater flexibility for parametric studies and scaling. Currently, most of the prediction models are based on the Makkonen model [3].

Our goal is to develop a numerical tool to model ice deposition based on a combined Large Eddy Simulation (LES)-Lagrangian Particle Tracking (LPT) approach. The unsteady three-dimensional flow field is computed by solving the incompressible Navier Stokes equations on a cartesian equidistant grid. LES is used to account for turbulence. The solid surfaces are modeled using the Immersed Boundary Method. To model ice deposition, water droplets are released upstream and tracked using LPT. For the time being only aerodynamic forces are accounted for. It is assumed that the droplets freeze instantaneously when they impact on the solid surfaces. The parameters of the droplets at impact are logged. As a second stage, the shape of the blade profile is remorphed to account for shape changes due to the accreted ice.

The proposed model is used to model ice accretion on a NACA 63415 airfoil. The set-up corresponds to the 'In-fog icing event 1' reported in [1]. The amount and shape of the deposited ice layer will be monitored and compared to experimental observations.

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1. Hochart et al. Wind Turbine Performance under Icing Conditions, Wind Energy 11:319–333, 2008
2. Hudecz et al. Wind Tunnel Tests on Ice Accretion on Wind Turbine Blades, Winterwind 2012
3. Makkonen, L. Models for the growth of rime, glaze, icicles and wet snow on structures. Philosophical Transactions of the Royal Society, Vol.358, No.1776, pp.2913-2939, 2000

BACK

site assessment, Forecasting of production losses, synoptical methods, blade icing,

Estimation of production losses due to icing based on an improved synoptical algorithm

Sebastian Haym, Graz University of Technology

Current procedures for estimation of production losses due to blade icing include but are not limited to the comparison between wind speed measurements of heated and unheated anemometers as well as synoptical methods, where fixed limits for e.g. temperature and relative humidity are being set. Several investigations have shown that both approaches can not always deliver reliable information, as also heated anemometers can suffer from icing, and limits for synoptical calculations often depend on location, micro-climate and other impacts, which can e.g. lead to overestimation of icing hours.

In cooperation with Graz University of Technology and Salzburg AG (a regional energy supplier in Austria), possible improvements of synoptical approaches were investigated relying on an air temperature and relative humidity measurement only.

An algorithm combining the values of air temperature and relative humidity measurement showed good results in a first test. The algorithm calculates the time of increased probability for meteorological icing using probability curves for temperature and relative humidity developed according to standard methods (ISO 12 494) extended by field experience made by meteorologists and wind park operators. In a first outdoor test at an elevated (1.700 m) Austrian site during the period of March-May 2012, the results of the algorithm matched in more than 90 % of examined cases with evaluated camera pictures. During the winter season 2012/13, more data is being collected at a different test site at an altitude of 2.100 m a.s.l.

Besides developing an improved new synoptical method, investigations were made on increasing the availability of temperature and humidity measurements under heavy icing conditions. The outcome was a shell-type housing which is permeable for air and provides a heated outer surface. CFD (*Computational Fluid Dynamics*) calculations showed that due to the design of the shell, heavy liquid particles can be separated from airflow and heavy ice accretions are thus prevented. Increase of air temperature due to outside heating is of small scale and corrigible.

BACK

ice detection, fault detection, simulations, control charts, condition monitoring

Indirect detction of icing on wind turbine blades

Timo Karlsson, VTT

Wind turbine icing is a significant problem for wind power applications in cold climate conditions. Icing can cause fatigue in turbine components, shortening the lifetime of the turbine and can cause immediate production losses. Detecting ice directly is difficult to do on a reliable way. The aim of this work is to compare different methods that make it possible to detect icing indirectly from normal wind turbine process data.

The used methods are generic methods normally used for fault detection. Ice detection then becomes a question of detecting abnormal changes in turbine behaviour. All the methods introduced in this work operate solely based on historical process data without exact knowledge about the underlying system.

All the methods used here follow a similar two-step approach: First a baseline relationship between wind and different process variables is determined using historical data. Then real-time measurements are compared to the historical baseline. Possible icing events are identified by monitoring the differences between the predetermined baseline and the measurements.

Ice detection requires that the short-term effects of icing on the wind turbine behaviour and the measured variables need to be identified first. These effects are deduced from analysing results from simulation studies using several wind distributions and multiple ice cases. Later these same simulations are used to test the effectiveness of the different ice detection methods. Finally the methods are tested on real-world wind turbine data. The tests with the turbine data also offer an opportunity to compare these indirect methods with a standard ice sensor.

BACK

icing detection, smart sensor, sensor fusion, anti-icing, de-icing

System concept of a smart icing sensor network on wind turbine blades

Michael Moser, Graz University of Technology
Hubert Zangl, Graz University of Technology

We present a system concept for a network of smart icing sensors for wind turbines. Multiple smart sensors detect icing by means of a sensor fusion approach and are distributed over the surface of the turbine blades (e.g. on leading edges, tower, nacelle etc.). By monitoring the icing status on multiple points, more accurate information can be collected compared to a single or few measurement points especially at early stages of icing. The smart sensors communicate with each other in order to deliver an accurate overall picture of the icing status of the turbine. Smart sensors are a suitable technology as they are light-weight, energy efficient and come with low installation effort. A base station can communicate with the turbine management system in order to stop production only when necessary or to trigger heating when required, thus maximizing production and minimising both losses due to downtime and energy consumption of anti-icing systems. Smart sensor prototypes suited for harsh environments are presented and experimental results on their performance are reported.

BACK

Detection, modeling, mapping, icing, ice load, kriging, power output

Empirical modeling of wind power production during winter season

Muhammad Bilal, University of Tromsø, Norway
Yngve Birkelund, Dept. of Physics and Technology University of Tromsø, Norway

Arctic region presents special climatological conditions which includes low range of temperatures and icing events that are not within normal operational limits of wind turbines. Predicting wind power output under these conditions requires knowledge of these climatological conditions and the site location. Under these conditions, information about average and low temperatures is usually available but the data regarding icing events is somewhat difficult to gather. According to one study, the annual losses due to icing events were found to be 17 % to 30 % depending upon the degree of exposure to ice at the site. In electricity markets like Nord Pool Spot, such losses can correspond to about 5% of the market value of the traded energy. The power production of wind turbines depends strongly on the aerodynamic properties of the blade, and the effect of the icing on these aerodynamic properties can be hard to describe theoretically. The main focus in this paper is to model the power production using measured data and statistical signal processing methods. The power loss due to icing on turbine blades at Aapua wind park (Sweden) is investigated for the winter season 2009-2010, where the icing related loss is found to be approximated 25% of the expected production. The highest loss due to icing is found during isolated time-limited heavy icing events. Two different methods, the "`box-method"', using mean and median power production values, and kriging with weighted mean are proposed to estimate model. The model can then be applied to predict power production based on wind speed and ice load observations. Comparison of the predicted power production using wind and ice observations during the winter season 2009-2010 shows that the kriging model has the best performance based on both correlation and root-mean-square error (RMSE). The mean and median box-method gives low correlation and high RMSE. The difference between the kriging and earlier established icing models, however, is smaller. The main difference between these models is estimated power production during times of low ice loads, where earlier models underestimates production compared to the kriging model. Further developments to the proposed model can include: improved ice measurements, adaptive modeling, and detection of isolated icing events.

BACK

POSTER

ANTI-ICING AND DE-ICING TECHNOLOGIES

icing, coatings, laboratory testing

Ice Preventive Coatings Evaluation Tests at VTT

Jeroen Dillingh, VTT Technical Research Centre of Finland
Mikko Tiihonen, VTT Technical Research Centre of Finland

To mitigate the risks induced by iced rotor blades, a blade heating system can be designed and implemented inside the rotor blade. One disadvantage of these so-called active systems are that they consume energy. Maximum available power generally imposes a limitation on the size of the blade area that can be heated (in one go). Another disadvantage is that the blade heating system consists of physical parts and components that need to be integrated in the wind turbine. This takes time, planning and effort. Also, some blade heating systems infringe the blade design to that extent that the aerodynamic properties of the blade are affected.

An interesting current alternative is therefore the use of ice-shedding or ice preventive coatings. The advantages are: a protection of the whole surface, low cost, no adverse effect on blade aerodynamics, and no special lightning protection required. But, their efficiency and durability have yet to be proven for application on wind turbine rotor blades.

VTT has developed a test program for the evaluation of ice preventive coatings for wind turbine rotor blades. The program consists of different laboratory tests, addressing both the coating efficiency as well as the mechanical durability. The different test setups will be presented and the test procedures will be described. Some results will be presented for sample coatings representative for products commercially available today. The correlation with field experiments will be determined if possible.

Example results from dynamic ice accumulation test in the VTT icing wind tunnel.

BACK

wind turbines, ice prevention, ice accretion simulation, programming

TURBICE - the Turbine Blade Icing Model, and its further development via a new interface

Saygin Ayabakan, Wind Power Technologies, VTT Technical Research Centre of Finland, Espoo
Jeroen Dillingh, Wind Power Technologies, VTT Technical Research Centre of Finland, Espoo

Abstract

TURBICE (Turbine Blade Icing Model) is the in-house two-dimensional wind turbine blades ice accretion simulation program of VTT. The program had been developed in 1991, new features have been added throughout the time, and also some of the constituent models of the program have been modified since its introduction. The program has been verified via comparisons with the results of its counterpart programs as well as with icing wind tunnel experiments. The program has proved itself as one of the main components of wind turbine blades ice prevention systems development and design process by simulating required operating conditions in cold climate and arctic environments to estimate heating energy demands.

Recently, construction of a new programming architecture and interface for TURBICE is proposed and currently under progress, which envisions an object-oriented programming (OOP) interface using Python programming language, at the same time maintaining advantages of low-level programming languages, such as FORTRAN, by utilizing Python as code glue. By utilizing OOP approach, usability, modularity, flexibility and extendibility of the program will be enhanced to a great extent, which will also enable using the program coupled with other related simulation programs in order to get advantage of multi-physics simulations of engineering systems (i.e. fluid-structure interaction analysis of iced blades, fluid-structure-control mechanism interaction simulations).

In this poster, development phases and some technical aspects of the current TURBICE are highlighted, along with introducing the new programming interface for further development of the program.

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BACK

Differential Boundary Layer Model for Wind Turbine Blade Icing Code TURBICE™

Saara Huttunen, VTT Technical Research Centre of Finland

Ice accretion on wind turbine blade leading edge in cold climate is known to cause production losses, increase structural loading and affect airflow around a wind turbine. For analysis and solution development, one must understand the phenomenon of ice accretion and be able to estimate it with respect to the meteorological conditions. Icing codes exist for this purpose and they simulate ice accretion on airfoils or wings. Most of the codes are designed for aeronautical purposes, but also a few wind turbine applications exist. One of them is TURBICE, an in-house code that VTT Technical Research Centre of Finland has developed since the early nineties.

TURBICE code predicts the growth of ice on 2D surfaces by an inviscid flow panel method, a droplet trajectory calculation module and a control volume energy balance/ice growth calculation module. TURBICE is based on a quasi-steady model that takes into account all the important mass and heat transfer processes that occur when supercooled water droplets strike an airfoil. TURBICE also simulates the heat transfer from a blade heating system. Even though the calculations are made in a 2D-environment, the results are translated to those for a complete wind turbine blade, taking into account the predominant 3D effects.

A significant factor in ice accretion simulation is the heat transfer process, and especially the local heat transfer coefficient in the boundary layer along the airfoil surface. Previously the heat transfer coefficient and momentum boundary layer in TURBICE have been solved by approximate methods based on experimental results. To gain more detailed information on temperature distribution within the boundary layer, a more accurate boundary layer model is implemented. Two-dimensional, incompressible and steady-state boundary layer equations are solved by integral and differential methods for laminar and turbulent regions, respectively. Transition criteria for smooth and rough surfaces are improved and also the method for calculating the heat transfer coefficient is updated.

New model is verified by comparing the results with another icing code and the previous version of TURBICE. Validation process of TURBICE is started by comparing the simulation results with experimental results produced by NASA Glenn Research Centre for NACA 0012 airfoil in the icing wind tunnel.

This project is performed as a Master’s Thesis.

BACK

icephobic coatings, ice adhesion, ice adhesion test

Designing Coatings for Application in Fields at Risk of Icing

Cornelia Pfaffenroth, ZHAW
Markus Susoff, ZHAW
Konstantin Siegmann, ZHAW
Martina Hirayama, ZHAW

Ice adhesion on surfaces is a significant problem in numerous areas like aircrafts, power lines, telecommunications or power production by wind turbines. Ice accretion can be responsible for severe mechanical and electrical failures, has an influence on monitoring and controlling and even causes serious safety hazards. Thus there is an enormous demand for powerful methods to keep surfaces ice-free. One promising approach is the design of coatings that act as passive anti- and de-icing systems. Our research focuses on the design of coatings that decrease the adhesion of ice to a surface in such a way that accreted ice can fall off due to accreted mass as well as centrifugal and vibrational forces if so. Beside their anti-ice properties, these coatings should be inexpensive, durable and easy to apply. For determination of adhesive strengths of ice to surfaces a custom made 0° cone test was set up. A variety of materials were investigated in consideration of reduction of ice adhesion compared to bare aluminium used as reference. Some of these materials showed very interesting results with regard to icephobic performance. Standard coatings currently used on wind turbines for example show an adhesion to ice that is comparable to that of bare aluminium meaning a quite high adhesion. Also Teflon as a potentially icephobic material reduces ice adhesion only by a factor of seven compared to aluminium. The performance of superhydrophobic coatings is even worse showing an enormous increase in adhesive strengths. Therefore superhydrophobic coatings cannot be considered to be icephobic as well. A reduction of ice adhesion was achieved by applying a commercially available icephobic coating. The improvement observed for this coating could even be exceeded by viscoelastic rubbers. Those coatings were able to reduce ice adhesion by a factor up to ~100 compared to aluminium. Thus the theoretical self-deicing minimum of 100[11] assumed so far can be reached by this type of coating. Up to now this threshold is almost only reached by time-limited coatings like greases or sacrificial coatings. Based on the findings for commercially available products we started to carry out chemical modifications on the most promising materials. One of these modifications led to a further reduction in ice adhesion. Field trials carried out this winter period should give a more complete insight into ice reduction performance of this coating as well as mechanical stability.

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BACK

POSTER

MARKET POTENTIAL, PRO AND CONS, FINANCING

Canada, wind energy, wind turbines, cold climate, production penalty, atmospheric icing, GHG, losses,

Assessment of Wind Energy Production Penalties Due to Cold Climate in Canada

Antoine Lacroix, Natural Resources Canada
Melinda Tan, Natural Resources Canada
Paul Dockrill, Natural Resources Canada

Canada's total installed wind energy capacity has grown by more than 900 percent over the last decade for an installed capacity of 5500 MW in September 2012. With this significant growth in wind power development, operational impacts due to cold climate are becoming evident.

A study was undertaken to evaluate the impact of cold climate conditions on wind energy production. Actual production data were compared with reference data generated using a combination of wind data from Environment Canada's weather stations, a measure-correlate-predict algorithm (MCP), and a wind energy production simulation software. Since actual production data is affected by cold climate, and estimated production is not (because the learning period is based only on summer months), the difference between the data sets can be attributed to cold climate effects (not withstanding the possibility of losses due to unscheduled maintenance).

A total of 24 wind farms located across Canada were selected for this study. The wind farms were grouped into five regions, for the purposes of maintaining confidentiality of the data collected. The results show that cold climate issues impact wind energy production in Canada. In applying the study results, it is estimated that the cumulative weighted average loss for all wind farms currently operating in Canada is 6.6%. This also corresponds to a missed opportunity to offset 305 thousand tons of CO_2 equivalent for 2011, and a total production loss of 1,010,000 MWh. At the current wholesale price for electricity generation, this represents a value of almost $100 million.

Wind farm sites located in regions where colder temperatures occur through greater parts of the year represent a vast wind energy production potential for Canada. As fewer temperate sites become available, large wind energy projects in colder climates will increasingly be developed. Better understanding the losses associated with cold climate operation and research into areas such as icing characterization and icing maps, as well as ice detection and protection will improve the performance of existing wind farms and most certainly the wind farms of the future.

BACK

icing, production loss, statistics

Lessons learned from public cold climate wind power statistics

Ville Turkia, VTT
Tomas Wallenius, VTT
Esa Peltola, VTT

Atmospheric icing is a common weather phenomenon in countries like Finland, Sweden and Canada, and it can have significant effect on wind turbine power production.

Wind power statistics of Finland have been kept up by VTT since 1996. In addition to turbine specific production for about130 turbines, the statistics also contain downtime, components failure and production indexes from Finnish Meteorological Institute (FMI). The statistics are currently under development to better serve the purpose and end users in the future.

Early in 2012 Icing Atlas of Finland, in combination with Finnish Wind Atlas, was published by FMI. The icing atlas gives estimate of energy production loss due to icing for different heights in 2,5 km x 2,5 km grid.

By combining realized production from Finnish wind power statistics with the estimated production from Finnish Wind and Icing Atlas it is possible to estimate the economic value of lost production due to icing. In addition, the process works as validation for Finnish Icing Atlas.

The results of analysis will be presented. In the presentation lessons learned from using wind power statistics as a tool in cold climate wind energy will be presented. This includes suggestions how to improve statistics from cold climate point of view, for example reporting icing events.

BACK

POSTER

STANDARDS AND CERTIFICATIONS

wind turbine, standardization, cerfification, ice accretion, dynamics, loads

Preliminary results from project IcedBlades – Modelling of ice accretion on rotor blades in a dynamic overall wind turbine tool

Ville Lehtomäki, VTT Technical Research Centre of Finland
Kai Freudenreich, Germanischer Lloyd
Michael Steiniger, Germanischer Lloyd

Wind power is one of the fastest growing areas of power production globally, contributing to the mitigation of climate change and to the diversification of energy supply. Northern areas like Scandinavia as well as areas with high altitude feature a high potential for large capacity wind farms thanks to favourable wind conditions and mostly low populated areas. Cold climate together with humid air conditions during winter seasons, leading to ice accretion on the rotor blades, must be considered in loads analysis. Altered aerodynamics due to icing induces structural vibrations and cause large uncertainties for wind turbine design. Inhomogeneous ice aggregation on blades of an operating turbine can lead to high periodic loads.

The IcedBlades project results will also be used for revising the new IEC 61400-1 ed3 -> ed4. Currently, the draft version of the new ed4 has new information on how to take into account icing and cold climate conditions in the wind turbine design process. The following topics are of concern:

- Defining cold climate as Icing Climate (IC) and Low Temperature Climate (LTC) [1]
- Most common effects of IC and LTC
- Environmetal conditions:
    - Icing classes (days/year)
    - LTC definition [2]
    - Structural design and new design load cases from increased air density and ice accretion effects on blades
    - Assessment of site specific conditions (ice detection measurement, guidelines in interpreting the results)
    - Personal and occupational safety (ice throw, risk assessment)
    - Control, protection, mechanical and electrical system impacts

Based on the results of IcedBlades and the new IEC 61400-1 ed4 Germanischer Lloyd will develop and publish a Technical Note for the Assessment of Wind Turbines under Icing conditions. This Technical Note will consider changes in the aerodynamic properties of the blades due to icing, as well as structural modifications. These structural modifications can be changes in blade eigenfrequencies or changed center of gravity in chordwise direction. Furtheron, anti-icing and de-icing systems for the blades will be considered, as well as the impact of icing on the safety and control, the mechanical and the electrical system.

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BACK

POSTER

OPERATIONS AND MAINTENANCE

Offshore wind turbine, Cold weather, Blade, Opportunistic maintenance (OM), Condition-based maintenance (CBM), Average long-run cost.

AN OPPURTUNISTIC CONDITION-BASED MAINTENANCE STRATEGY FOR OFFSHORE WIND TURBINE BLADES UNDER COLD WEATHER CONDITIONS

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Offshore wind turbines are facing the challenges of harsh maritime environment, cold weather conditions, low accessibility and high operation and maintenance (O&M) cost. According to existing statistics, blades are among the most critical and expensive components in offshore wind turbine that suffer from different types of *internal* damages (due to degradation) and *external* damages (due to cold weather conditions). Internal damage (such as fatigue, wear, crack) weakens the system without resulting in any turbine stoppage. However, it accumulates additively and results to a blade failure when exceeds a pre-determined damage level D. External damage (such as icing, shock, storm) immediately stops the wind turbine and can only be corrected by an expensive replacement. In this paper, we develop an opportunistic condition-based maintenance (OCBM) model for a deteriorating blades system with n (>=2) blades, which is subject to both internal and external damages. In the proposed strategy, the maintenance crew is transported to the offshore platform to perform corrective replacement at the first internal damage D or when an external damage in cold weather conditions occurs. Also, opportunistic maintenance (OM) action will be performed on un-failed blade(s) simultaneously. To avoid such expensive replacements, the system is preventively maintained at the age of T or when the cumulative internal damage in one blade exceeds the threshold d (D), whichever comes first. We propose an optimization model to determine the optimal bivariate policy (T, d) such that the long-run average cost rate is minimized. The explicit expression of the long-run average cost is derived and the corresponding optimal solution is determined analutically. Finally, the proposed model is tested on the data collected from an offshore wind farm database.

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BACK

ORAL

OPENING SESSION

Wind Turbine, Atmospheric Icing, Resource Assessment, Reduced Order Modelling, CFD

CFD Simulation and Reduced Order Modelling of Atmospheric Icing for Accurate Wind Energy Resource Assessment

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Wind turbines located in cold climates can be affected by icing conditions. During icing events, ice accreting on the blades hinders their aerodynamic performance resulting in reduced power output[1]. In Quebec, Canada more than 12% of potential annual wind power production is estimated as lost as a result of icing events[2].

The ability of accurately assessing the impact of an icing event on wind turbine power production is important for both wind farm site assessment during the planning stages and for prediction of wind power production during the operational stages[3-7]. For assessment purposes, long-term measurements of the local wind are collected and analyzed to predict the potential annual power production[8-9]. Icing measurements may not correlate accurately with the icing experienced by the blades or to their resulting performance degradation[10]. Since there exists substantial uncertainty in the prediction of icing induced power loss, conservative estimates of icing-induced losses may be made in order to reduce investor risk or more losses than expected may be incurred[10]. Both of these scenarios reduce the economic viability of a wind farm.

An improved wind turbine power production simulation methodology is presented which utilizes computational fluid dynamics (CFD) and reduced order modelling (ROM) to assess the degradation of power production due to icing events. First, CFD simulations of characteristic icing events on a wind turbine blade are performed using the CFD package, FENSAP-ICE[11]. The expected wind turbine performance at specific operating conditions can be directly assessed from the CFD simulation. Next, ROM via proper orthogonal decompositions and kriging interpolation[12] is used to construct a power map of the wind turbine's performance in icing conditions, which predicts the performance degradation due to ice contamination over the complete range of icing conditions experienced by the wind turbine. Finally, using atmospheric data from historical weather measurements or numerical weather prediction software, the wind turbine power map is used to predict the expected power losses while operating in forecasted icing conditions.

The methodology will be demonstrated using the NREL Phase VI[13] wind turbine geometry operating in a simulated weather environment characteristic of wind farms prone to icing events.

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BACK

ORAL

DETECTION, MAPPING AND FORECASTING

Creating an icing climatology using typical months

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Stefan Söderberg, WeatherTech Scandinavia
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To have an icing climatology would be hugely beneficial to the wind power industry, as an icing climatology in combination with a wind atlas could help increase the productivity and lifetime of the wind turbine. There are difficulties in creating an icing climatology, as icing has not been measured for that long time period nor at many sites. To create a climatology meteorologist prefer to have 30 years of data with a good spatial and temporal resolution, so an alternative method must be used.

Here two methods using typical months of common meteorological parameters to create an icing climatology are presented. In method 1 ERA Interim geostrophic wind speed and temperature data has been used to calculate monthly means for each year in the data set as well as a long term mean for each winter month. The monthly means of wind speed and temperature have been compared to the long term means and the five best fits are chosen as typical months used to represent the long term mean. In method 2 the Lamb classification of each day in the data set is calculated for the ERA data set. Each month then gets a distribution of the different classes and a long term Lamb distribution is also calculated. The five months found to best represent the long term mean for both methods are then used to model the ice load.

The results found are that the method 1 works well, the chosen typical months represent the long term mean well for all of the parameters. Mean temperature and wind speed are reconstructed very well and when used to calculate the ice load the constructed and long term mean are comparable in amount and dynamics. The method using the Lamb classification gives reconstructs the parameters less skilfully.

The years chosen with the two methods have also been modelled with a higher resolution Numerical Weather Prediction (NWP) data set, WRF, to create a more detailed climatology (9×9 km). The results from the climatology created with ERA data and the climatology created with WRF will be compared to measurements of ice load measured at sites in northern Sweden.

BACK

Icing climatology, meso-scale modelling, downscaling.

Creating an icing climatology using downscaling techniques - results from Vindforsk project V-313

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Abstract for Winterwind 2013

Topic no 1: Detection, mapping and forecasts of icing

Creating an icing climatology using downscaling techniques – results from Vindforsk project V-313.

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Wind turbines in cold climate regions are likely to be affected by atmospheric icing. This may affect production and loads, and may due to ice throw also be a risk to people being in the neighbourhood of the turbines.

One of the goals of the Vindforsk project V-313, Wind power in cold climates, is to get knowledge necessary to make a detailed icing climatology with a 1 km^2 horizontal resolution. A number of meso-scale weather forecasting models have been run for different sites in Sweden and using different resolution for the three winter seasons 2009-2010, 2010-2011, and 2011-2012.

Results comparing modelled icing and measured icing data show that the model output in principle follows the timing of icing events quite well. The results also show that using coarse resolutions typically result in a smaller ice accretion. This is not surprising as much of the local smaller scale topography in this case will be absent in the model. Increasing the resolution will resolve more of the true topographic variations and thus the modelled ice accretion should be expected to be in better agreement with observations often made at mountain locations.

The results show that the project goal of using a resolution of 1 km^2 when modelling icing for an icing climatology is probably needed in order to describe the major parts of icing variability in response to topographic variability. But this result is of course affected by the true scales of variability of local topography. With lower variability of the true terrain a coarser resolution could be sufficient while with higher small scale terrain variability even higher resolution may be needed.

The term climatology in meteorology usually means statistics over 30 years of data and usually in the form of direct or indirect measurements. Modelling 30 years of icing using 1 km^2 resolutions would need huge computer resources why alternative methods are investigated.

An icing climatology is a complex property as icing is a derived quantity from several variables that are generally not all measured, except maybe in some special research masts. Thus icing is a function of air temperature, total moisture content (vapour, liquid water content and solid to some extent), and wind speed in the height range that the turbine blades sweep through.

Since there will never be any complete or comprehensive measurements of these variables they have to be model generated from sophisticated meteorological prediction models. The models are used to transfer the information derived at measurement sites in space and in time to construct the best possible climatology over say the last 30 years. This way of using models has rather successfully been applied for many other applications like winds, temperatures and precipitation. The models provide an internally multi-variate consistent regularly spaced atmospheric state of the variables involved.

The most complete measurements possible have been collected and have been re-analysed using several types of consistent analyses and model system, as NCEP/NCAR, ERA40, ERA-Interim. Many climatological and other diagnostic studies have been carried out from such re-analysis data. The re-analyses are however at fairly coarse resolution (50-150 km roughly). For our purposes we need to downscale these fields to the km scale of the wind power parks. There are a number of methodologies to do this and in this project the aim is to arrive at the most realistic but still feasible method.

A method is needed to develop an icing climatology without the need to model 30 years of weather. The method presented here is based upon that first 30 years of weather is modelled using a coarse model resolution. These results are then downscaled to a higher resolution using higher terrain resolution data together with actually modelled high resolution weather results, but only for shorter periods such a few winter seasons.

Basically the meso-scale model is first downscaled from the global NCEP/NCAR or ERA-Interim re-analysis data in several steps to the three resolutions 9, 3, and 1 km which are presented here. Making a 30 year icing climatology on a 9 km resolution is quite feasible, but a downscaling technique is needed to create the 1 km^2 resolution climatology.

Results using several sites for which model runs have been made on the three resolutions are presented, and statistical downscaling using the coarser 9 km resolution to create a 1 km resolution climatology is compared to the actually modelled 1 km climatology using the meso-scale model output directly. Results show that such a downscaling technique is possible to use to create a higher resolution icing climatology. Of course the result will not be exactly the same as arrived at using 1 km model runs directly, but the two are to a reasonable degree in agreement.

BACK

Mesoscale model, sensitivity test, ice load, icing climate

Mesoscale modelling of icing climate: Sensitivity to model and model setup

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Production losses due to icing is a fact in many wind farms in Scandinavia. Taking effects of icing on instrumentation and production losses due to icing into account in the resource assessment is vital for a successful project. In order to do this, a reliable icing climate is needed.

In a Swedish research project funded by Vindforsk, several sites instrumented with ice load sensors have been studied during several winter seasons. Three different mesoscale modelling systems have been used, AROME, COAMPS, and WRF.

Differences in the modelled icing climate is illustrated and discussed. It is shown that the differences found are to a large part due to differences in the modelled liquid cloud water. However, differences in modelled icing climate is not only due to which mesoscale model that is applied, it also depend on model setup.

In a series of sensitivity tests, different choices of microphysics, boundary layer schemes, and boundary conditions are used. It is found that depending on mesoscale model setup, the modelled ice load can vary substantially not only from case to case, but also over an entire winter season.

Observed and modelled icing are compared and illustrated with time series and statistics. The models capture quite well icing events and periods with active icing, here defined as ice growth > 10 g/m/h on a rotating cylindrical stick with a diameter of 0.03 m. Modelled ice load is, however, often underestimated. Which model and model setup that performs best is not straightforward to tell due to uncertainties in the observations.

BACK

Forecasting Production Losses at a Swedish Wind Farm

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Mark Zagar, Vestas Technology R&D

Production loss due to icing has been identified as a problem both when siting turbines in cold climates, and when making forecasts of energy production for wind park management and energy markets. The Makkonen icing model (Makkonen, 2000), driven by output from the WRF mesoscale model, has been shown to predict periods of icing at a wind farm in northern Sweden (Davis et al, 2012) with improved skill compared to persistence and threshold models. Based on these results, we have developed a statistical model to estimate the loss of production at the wind park due to these icing periods. We compared this statistical model with a simpler method that does not rely on a physical icing model. In that method meteorological icing is identified as periods when WRF forecasts clouds and the temperature is below freezing. During these periods it is assumed that there is no production from the turbines, however as soon as the cloud goes away in the model we assume production returns to the idealized power curve. One unique aspect of the wind park we are working with is that it is not required to shut down when icing occurs. Therefore, during icing periods production still occurs, but below the idealized power curve. This enabled us to also examine how much production would have been lost had the turbines been required to shut down during the periods when they were iced.

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BACK

ORAL

ANTI-ICING AND DE-ICING TECHNOLOGIES

coating, anti-icing, de-icing, evaluation of ice formation on surfaces

Anti-Icing Coatings and De-icing Technical Approaches and Status

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Icing on surfaces is a major and recurrent problem which impairs the function of wind turbines and incurs costs. Frosted rotor blades of wind turbines result in significantly reduced energy output. Furthermore, in some cases the shutdown of turbines is necessary to eliminate the risk of falling ice. One strategy to reduce icing is to use so-called rotor blade heating systems (hot air or hot wires).

A new approach with heatable de-icing layers[1 2] will be presented. Here the rotor blades of the stationary turbine are heated so that adherent ice melts.

An optimal solution would be a coating on rotor blades which prevents ice formation from the outset. The currently available commercial anti-icing coatings cannot prevent ice formation on rotor blades.

For the evaluation of anti-ice coatings Fraunhofer IFAM is more and more extending the test methods to be able to predict the icing behavior (rime, glaze ice and runback ice) under different icing conditions and to adapt the coating developments to the specific needs.

Our intensive work on anti-ice coatings and sprayable de-icing layers helps to identify most effective solutions. Furthermore, the study presents the use of tailor-made aerodynamic wings (design: NACA 0020) for the use in surface icing tests for the development of anti-icing coatings and/or de-icing layers.

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[1] Sell et. al. Funktionelle Beschichtungen - Anti-Eis Beschichtungen für Anwendungen im Bereich der Windenergie Workshop "Innovative Beschichtungen für Windkraftanlagen" Berlin 16.10.2012

[2] http://www.future-carbon.de/en/Carbo_e-Therm

BACK

Turbine manufacturer, CCV turbine design, Ice management, Operation under icing conditions, operational experience in cold climates, Ice detection, De-Icing

Challenges and concepts how to design and operate a turbine in cold and icy climates

Lea Kirsch, REpower Systems SE

Since REpowers first operational experience with CCV turbines in 2008 in Inner Mongolia, REpower has entered the Scandinavian and Canadian market in which cold and humid climates dominate.

During 2012 over 200 MM92 CCV turbines have been installed in Canada in a climate which favours ice accretion on the rotor blades and therefore demands particular measures for turbine operation. Additionally a cold climate variant of REpower`s new 3.2M114 turbine has been introduced in 2012 specifically dedicated to the North Scandinavian market.

The first part of the presentation will give an overview about the adaptations which have been done in the CCV turbines to allow a reliable operation over 20 years lifetime in low temperatures. By using additional heating elements, low temperature greases and an intelligent heating process for the restart of the turbine the temperature range for operation and for structural design have been extended significantly.

The second part of the presentation will explain the concept of operational control which addresses the specific challenges of turbine operation under icing conditions. Precondition to control the impact of icing and ensure a reliable turbine operation is the ability to detect icing conditions.

Ice accretion on the rotor blade can lead to additional loads caused by rotor imbalance and additional masses. This is addressed by a dedicated ice operation mode, which is a control algorithm in the turbine controller ensuring that extreme load cases (e.g. for the flap wise bending moment) will not appear and by that not impact the lifetime of turbine components. Additionally ice accretion can impact the aerodynamic performance of a turbine. Blade designs with high aerodynamic safety factors ensure that for light icing conditions the power curve is not impacted. For severe icing conditions active de-icing systems may avoid a loss of annual energy production and by that make turbine operation on sites with severe icing conditions economical.

In the presentation the concept of the CCV turbine as well as the concept of operation control under icing conditions will be explained from a manufacturer's point of view. This will be complemented with the experience from more than 600 winter months of operation from the Canadian installations as well as from several icing test sites being equipped with extensive measurement equipment.

BACK

Anti-Icing, De-Icing, cold climate, Nordex

Operating experience with anti-icing systems in Nordex turbines

Astrid Dr. Löwe, Nordex Energy GmbH
Ines Dr. Runge, Nordex Energy GmbH
Günter Steininger, Nordex Energy GmbH

In the last decade the global importance of wind energy as a renewable energy source has increased dramatically. By the strong increase of the number of turbines, the most popular locations are already built up. Out of necessity to open up new sites, more and more turbines are set up onshore, also in extreme climatic regions.

If wind turbines operate in extreme climatic regions special conditions of the turbine must be expected. For example in cold climatic regions the icing of the blades changes the aerodynamic profile of the blade and reduces the efficiency of the turbine. Furthermore, by the additional weight of the ice the plant safety is limited. Therefore in areas with icing conditions it's important to protect the turbine from this overload.

In autumn 2010 NORDEX SE installed four N100/2500 turbines in northern Sweden. With a rotor sweep of 7,854 square meters, these turbines operate particularly profitably in medium and low wind regimes. In autumn 2011 additional 14 turbine were build up in the wind park "Jokkmokksliden/Storliden". Three turbines operate as reference machines and 15 are equipped with NORDEX Anti-Icing-System.

The presentation shows the experiences with the anti-icing system. Therefore an overview about the conditions in the Wind Park and examples of the icing of the blades is presented. Particular attention is paid to the efficiency of the systems.

BACK

SIEMENS

Abstract - Winter Wind 2013

Siemens turbine in cold clime.

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Goal: Illustrate the development of cold clime turbines and blade deicing based on former and current developments in this area.

Contents:

Siemens Wind Power (formerly Bonus) was among the first wind turbine manufacturers to develop wind turbines specifically designed to operate in colder climates.

The cold climate turbine development led to integrated blade heating systems, which were installed at different locations on the northern hemisphere in the 90s, where the turbines and blade heating systems are still functioning today.

The blade heating system has since then been developed even further to deliver a complete “cold-climate-system” for our turbines. The designers of Siemens Wind Power Blade De-icing Systems will continue the development and optimization to ensure that wind turbines installed in cold climate regions all over the world can produce electricity even under extreme weather conditions.

BACK

ORAL

LABORATORY AND FIELD TESTS

Savings with use of de-icing technology for wind turbine blades in cold climate

Hans Gedda, H Gedda Consulting AB
Daniel Eriksson, Skellefteå Kraft AB
Helena Hedblom, Fortum AB

During the period October 2011- March 2012 Skellefteå Kraft AB (SKAB) has run the M easurements Analysis Wind Power for Icy Climates (MAWIC 1) project together with Fortum. The purpose with the project is to get a greater understanding of how ice accretion affects the operation and production. This project involves measurements from three different sites namely Jokkmokksliden, Uljabuouda and Blaiken where Blaiken is under construction. Continuously measurements are done at all sites.

At Jokkmokksliden and Uljabuouda the energy consumption of the de-icing systems is measured. Blaiken is under construction; therefore no data is available regarding energy production etc. The data analysis indicates that ice related production losses per turbine potentially could have been reduced by 450-650 SEK for Uljabuouda and 350-425 SEK for Jokkmokksliden with turbine availability close to 100% and a properly functioning de-icing system throughout the measurement period from Oct 2011- Mar 2012.

The overall impression is that the system is capable of keeping the rotor blades almost ice-free under severe icing conditions. But observations show that there is room for improvement of the control algorithm. Periods can be found when the de-icing system has been inactive despite observed icing and conversely power consumption has occasionally been registered during ice-free conditions. Icing conditions will vary from one year to another. For this reason it was decided to run a continuation project under period October-April 2012-2013 (Mavic 2).

This presentation will show an overview over the most interesting results from Mawic 1 together with the latest observations and results made from Mavic 2 between Oct-Dec 2012.

BACK

Measurement of contact angle at sub-zero temperatures and implication for ice formation

Golrokh Heydari, Department of Chemistry, Surface and Corrosion Science, KTH Royal Institute of Technology
Mikael Järn, YKI, Institute for Surface Chemistry
Eric Tyrode, Department of Chemistry, Surface and Corrosion Science, KTH Royal Institute of Technology,
Esben Thormann, Department of Chemistry, Surface and Corrosion Science, KTH Royal Institute of Technology,

Per M. Claesson, Department of Chemistry, Surface and Corrosion Science, KTH Royal Institute of Technology,

Superhydrophobicity has been extensively considered to achieve icephobicity, and dynamic contact angle measurements have been widely used to evaluate the water repellency. However, the temperature dependence of surface wettability is crucial for applications dealing with icing. The anti-icing performance of superhydrophobic surfaces evaluated by the contact angle at room temperature could be criticized since the real contact angle at sub-zero temperatures is needed. No systematic study has been published that reports the work of adhesion of water as a function of sub-zero temperatures. Most studies have focused on correlating the contact angle of a water droplet with macro scale ice adhesion strength. In this work we report the freezing point and the temperature-dependent contact angle of microliter-sized water droplets on superhydrophobic and hydrophobic surfaces down to the sub-zero freezing point. A water droplet on a superhydrophobic surface shows a Cassie-Baxter to Wenzel transition around the dew point, i.e. water condenses in the voids between asperities and results in an increased contact angle hysteresis. This affects the performance of superhydrophobic surfaces in anti-icing applications.

BACK

Reliability, Climate chamber, Cold climate regions, Standards & certification for extreme temperatures, Testing, Components, Gearboxes, Operations & Maintenance, Cold starts

The use of a large climate chamber for extreme temperature testing & turbine component validation

Pieter Jan Jordaens, Sirris / OWI-Lab
Stefan Milis, Sirris / OWI-Lab

Wind industry is fast expanding in remote areas where wind turbine generators (WTG) need to work under extreme conditions. Usually onshore and offshore wind turbines are designed to operate in a temperature range from -10°C to +40°C, but in some locations like for example Finland and Mongolia the temperature can even drop to -40°C. On the other hand, WTG's located in for example India can suffer from extreme heat that could reach up to +50°C. These inhospitable locations form a huge challenge for the machine itself and also for the maintenance and repair teams. In some cases repair works have to be postponed because of temperatures and thereby affects the turbine availability and its business case.

This is why the industry needs robust and validated wind turbine components capable of surviving in extreme conditions in order to be cost-effective.. The validation of WTG components in its operating temperatures is important to make sure the components are reliable enough and avoiding unplanned maintenance repairs in remote locations. For example in case of start-up of a WTG after idling in cold conditions, the rotating elements in a gearbox can be at risk because of insufficient lubrication and/or differential thermal expansion of sub components. Also the performance of the heating & cooling system and other auxiliaries of the gearbox can be reduced. This case illustrates the requirement for certification of gearboxes in cold temperatures and the need of large climatic test chambers for cold start testing.

The lack of multifunctional climate chambers is known within the wind industry in comparison to available test chambers for the automotive industry for example. Wind turbine components are much bigger and heavier than cars and therefore cannot be tested in the same climate chambers. To come to this necessity a dedicated test facility in the Port of Antwerp has been built by OWI-Lab containing a large climate chamber for wind turbine component testing in a wide range of temperatures. Both mechanical, hydraulic and electrical turbine components like gearboxes or transformers up to 150 tonnes can be tested in a temperature range from -60°C to +60°C. Typical testing activities in the facility include design verification testing (DVT), and prototype component testing. Dedicated R&D tests will be supported by providing the required auxiliaries like for example a flexible set of power supplies and a drive to give speed to rotary parts.

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[2] Only a cost optimized and reliable wind turbine is bankable, Huby J., Wind Energy update, Sept 2012

[3] GL Wind Technical Note 067 Certification of Wind Turbines for Extreme Temperatures (here: Cold Climate), Scope of Assessment, Rev 4, Edition 2011

[4] State-of-the-art of wind energy in cold climates, VTT Working papers 152, Oct 2010

BACK

blade icing, turbine dynamics, vibration, design, loads

Vibration and load measurements of two MW-scale turbines operating in icing conditions

B. Boucher, TechnoCentre Éolien
V. Lehtomäki, VTT Technical Research Centre of Finland
S. Rissanen, VTT Technical Research Centre of Finland
T. Karlsson, VTT Technical Research Centre of Finland
M. Wadham-Gagnon, TechnoCentre Éolien
D. Bolduc, TechnoCentre Éolien

E. Bechoefer, NRG Systems

The scarce availability of standard wind resource sites combined with technological advancements are making cold climate sites more and more attractive for wind farm deployment. Many of these remote sites which are at high altitudes and/or in Northern areas such as Scandinavia and Canada, are prone to ice accretion on rotor blades. While there has been progress over recent years in understanding the effects of ice throw on health and safety, as well as developing technologies to reduce the production losses caused by ice accretion on blades, there is still very limited understanding of the longer term effects of dynamic loads caused by ice on the design life of a wind turbine.

In order to investigate these dynamic effects, two separate measurement campaigns, one in Canada and one in Finland, were conducted on pitch controlled turbines. Vibration and load measurements were collected between 2007-2010 on a 2MW turbine in Southern Finland and between 2011-2012 on a 2MW turbine in Eastern Canada.

The study in Canada was conducted on data from accelerometers installed on components of the turbine in the nacelle and compared to data collected during an ice measurement campaign. The results of the analysis revealed that ice accretion on the rotor blades can cause measureable effect on rotor imbalance and could potentially lead to accelerated fatigue of turbine components such as the gearbox.

The study in Finland consisted of long term load measurements with strain gages installed in the blades, tower top and tower bottom. The results of the case study in Finland also indicate that ice accretion affects the dynamics of the turbine. Especially tower base fatigue loads increased significantly, indicating a reduction to the tower fatigue design life.

Finally, the two cases support each other well. It can be concluded that icing may cause aerodynamic imbalance and vibrations which need to be considered in turbine design and load assumptions.

BACK

ORAL

MARKET POTENTIAL

Ice prevention, de-icing, anti-icing, blade heating, 3rd party solutions, business opportunity

Blade heating – is there a slot for 3rd party solution providers in the wind power supply chain?

Esa Peltola, VTT Technical Research Centre of Finland
Petteri Antikainen, VTT Technical Research Centre of Finland
Geert-Jan Bluemink, VTT Technical Research Centre of Finland

Atmospheric icing is a common weather phenomenon in countries like Finland, Sweden and Canada. It has significant effect on wind turbine availability and power performance. Lower performance and availability leads to lower than expected revenue and increasing operation and maintenance cost and can ruin the project economy.

By developing knowledge, tools and solutions to keep the wind turbine blades free of ice, VTT has aimed at maintaining the wind turbine availability and performance high over the windy and icy winter period. The carbon fibre based solutions developed or in the development until now cover stall regulated fixed speed rotors from 25 m to 54 m in diameter and pitch regulated variable speed rotors from 80 to 120 m in diameter.

VTT has commercialized the solutions both by licensing it to a 3rd party solution provider in late 1990’s, known in the market as JE-System by Kemijoki Arctic Technology Oy, and later by a scheme combining direct co-development, piloting and licensing.

The presentation elaborates on the business opportunities of a 3rd party solution provider of blade heating systems in the present market situation. First, the markets in late 1990’s and now and their differences are described. Based on this possible business models for a 3rd party solution provider are studied in comparison to direct piloting and licensing scheme. Finally, the outcome of an on-going commercialisation project of the technology is summarized as our judgment and answer to the question - is there a slot for 3rd party blade heating solution providers in the wind power supply chain?

BACK

Map, Icing, meso-scale model, WRF,

Icing map of Sweden

Øyvind Byrkjedal, Kjeller Vindteknikk

Analysis of meteorological observation data of ice loads from 8 sites in Sweden has lead to a development of the model used to calculate icing from model simulations. Data from the meso scale model WRF is used to calculate ice loads. It is shown that the model results validates well with the observation with regards to timing of icing events and sublimation/melting events. However, the model tends to underestimate the observed ice load.

Based on the new model development, an icing map for Sweden has been developed. This map is freely available from the web page of Kjeller Vindteknikk. The map is based on meso-scale simulations with the WRF model. The model has been run for 2 full winters with a spatial resolution of 1 km x 1 km. The icing calculations have been long term corrected toward the years 2000-2011.

In the model with a 1 km x 1km spatial resolution the topography will also be represented with the same spatial scale. The topography is thus quite smoothed compared to the actual terrain. A good description of the topography is however important in order to describe the icing realistically.

The first order terrain effect on icing is the lifting of the air to a larger height with lower temperature that leads to an increase of the condensation and cloud amounts locally. The second order terrain effect is sheltering effects. The increase of the condensation over a hill means that less moisture will be available for icing on the lee side of the mountain and for the next hill in the upstream direction.

High resolution topographical data has been incorporated into the icing maps in order to give a more realistic representation of the terrain effects on the icing. A local terrain adjustment is used to create the icing map. This method will adjust for the first order terrain effect. The second order terrain effect is much more difficult, and an adjustment of this has not been included. However we find that sheltering effects are simulated to some extent with the 1 km x 1km model resolution.

The final icing maps are presented with a horizontal resolution of 50 m x 50 m.

BACK

blade icing, weather mast icing, ice throw, classification, ISO 12494, measurement campaign

Ice Profile Classification Based on ISO 12494

Matthew Wadham-Gagnon, TechnoCentre Éolien
Dominic Bolduc, TechnoCentre Éolien
Bruno Boucher, TechnoCentre Éolien
Amélie Camion, REpower Systems
Jens Petersen, REpower Systems
Hannes Friedrich, REpower Systems

In 2011, the TechnoCentre Éolien (TCE) and Repower initiated an ice measurement campaign conducted at TCE's Site Nordique Expérimental Éolien CORUS (SNEEC) in Rivière-au-Renard, Qc, Canada. The outcome of this ongoing campaign will serve the following objectives:

- Study ice loads on blades

- Improve ice detection methods

- Have a better understanding of ice throw

- Correlate to weather forecasts

- Assessment of ice protection systems such as passive anti-icing, ice detection, ice operation modes and active de-icing

- A database with visual observations and meteorological data

The infrastructure at the SNEEC consists of two REpower MM92 CCV turbines, installed in 2009 and a 126m met mast, installed in 2011. The ice measurement campaign involved documenting visual observations during icing events, meteorological data from the wind turbines and met mast as well as an ice throw study. Pictures of ice on blades, on the nacelle weather masts, of ice throw and of ice on the 126m met mast were taken with cameras from the ground as well as from remote cameras installed on the nacelles of the turbines. Ice throw was documented relative to weight, dimensions, density as well as distance and position from turbine. Meteorological data assessment included heated and unheated anemometers, a HoloOptic ice sensor, temperatures, relative humidity, solar radiation and cloud height.

Correlations between meteorological icing, instrumental icing, production losses and visual observations have already been established following the 2011-2012 winter season.

But one of the most significant outcomes to date of the measurement campaign resulted from a dimensional analysis of the different observations (ice on blades, ice on nacelle weather mast and ice throw) which has led to a classification of ice profiles for different icing events with a distinction between rime and glaze. This classification was largely based on ice classes as defined in ISO12494.

With this methodology and results, the severity of ice on blades during an icing event can be correlated to meteorological data and productions losses. Furthermore, the distribution of icing severities over the course of a year combined with correlations to production losses could eventually lead to improved resource assessment and site classification.

BACK

ORAL

HEALTH AND SAFETY

Abstract for Winterwind 2013

Topic 5: Health and safety, permission and environmental requirements – installation, O&M, repairs, public safety

Numerical Investigation on the Noise Generation of Iced Wind Turbine Airfoils

Richard Hann, Alexander Wolf, Dimitrios Bekiropoulos, Thorsten Lutz, Ewald Krämer
IAG - Institute of Aerodynamics and Gas Dynamics, University of Stuttgart, Germany

The vast development of wind energy within the last decade has led to an increased awareness of the public to noise pollution. This has resulted in today's strict noise regulations and substantial scientific efforts to understand and decrease wind turbine noise. However, very little work has been done to take into account the special conditions in cold climate regions. This study takes a first approach to investigate the increased noise generation of iced airfoils and blades for wind turbines in cold climate.

The main source of wind turbine noise is aerodynamic flow induced noise, e.g. trailing edge noise and inflow turbulence noise [1]. During in-cloud and precipitation icing, ice is typically formed on the leading edge of a blade, causing local flow separation associated with a thickening of the boundary layer and an enhancement of turbulence. The little literature which is available indicates that even slight icing conditions can increase the blade noise by 3-5 dBA [2].

The present paper conducts computational fluid dynamic (CFD) and computational aeroacoustic (CAA) simulations on different iced airfoil geometries. Steady CFD simulations are carried out using TAU, a solver for the Reynolds-averaged Navier-Stokes (RANS) equations. These simulations are the basis for CAA calculations using PIANO, a solver for the governing equations of the inviscid dynamics of pertubations. PIANO is thus able to simulate the noise generation of vorticity interaction with solid structures or gradients in the flow field [3]. Both, TAU and PIANO, have been developed by the German Aerospace Center (DLR) mainly for aircraft applications, but have been successfully applied for wind energy related problems. To generate 2-d iced airfoil geometries LEWICE is used, a validated code developed by NASA Glenn Research Center.

In the scope of this study, numerous simulations are conducted to investigate the mechanisms of the increased noise generation on 2-d iced airfoils. Various combinations of geometrical, meteorological and aerodynamic parameters are considered, as well as typical problems of anti- and deicing systems, i.e. runback-icing. The numerical simulations are validated using aerodynamic (clean and iced) and aeroacoustic (clean) experimental data found in the literature. The analysis of the results yields fundamental insights into the mechanisms of aerodynamic airfoil noise generation for various cold climate icing conditions.

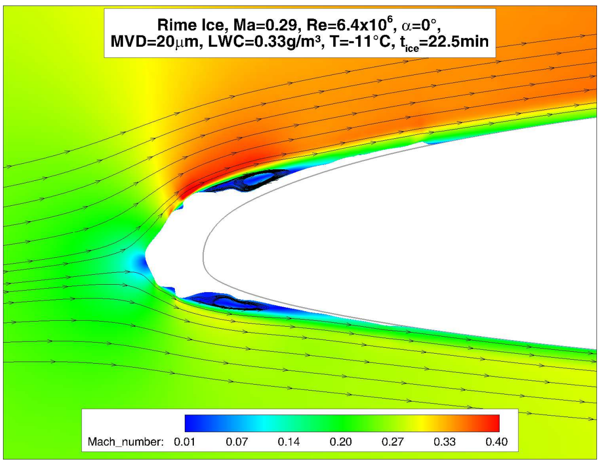

Figure 1: Flow field around the leading edge of an iced airfoil with separation zones increasing turbulence.

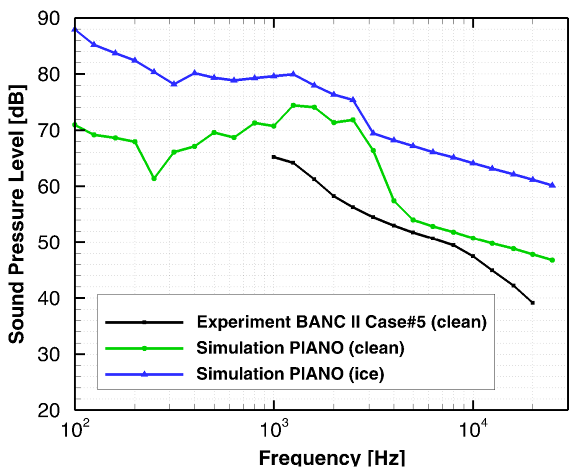

Figure 2: Frequency spectrum of the sound pressure level (SPL) for a clean and iced airfoil configuration

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[2] H. Seifert: Technical requirements for rotor blades operating in cold climate. Technical Report, DEWI, Deutsches Windenergie-Institut GmbH, 2003.
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BACK

Ice Throw, Risk Modelling, Public Safety

The Applications of Ice Throw Modelling to Risk Assessment and Planning in Cold Climates

Gail Hutton, RES Group
Alan Derrick, RES Group
Lenton McLendon, RES Group

The ability to map and quantify the risk of ice strike around a wind turbine deriving from ice thrown from the blades is critical to understanding the safety of a wind farm. The quantification of risk should allow for a better agreement on safety policy in cold climates and a more complete – and objective - assessment of the risk to infrastructure (e.g. to overhead power lines) from thrown ice.

This presentation outlines the current program of work within RES to understand better ice strike risk at its wind farm locations in Sweden from both of these (public safety and infrastructure) perspectives. Specifically, it discusses a model recently developed in-house and the way in which this can be used to inform planning, design aspects of the wind farm itself, and turbine shutdown strategy.

Given the importance of the decisions that ice throw modelling can be used for, the accuracy of the model itself is crucial. Validation of the RES ice throw model with reference to site observations will also be discussed.

This work was partly funded by the Swedish Energy Agency (Energimyndigheten) under the Havsnäs Pilot Project

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BACK

The effect on noise emission from wind turbines due to ice accretion on rotor blades

Peter Arbinge, ÅF Sound & Vibration
Paul Appelqvist, ÅF Sound & Vibration
Martin Almgren, ÅF Sound & Vibration

Swedish EPA (Naturvårdsverket) noise level guide-lines suggest that equivalent A-weighted noise levels must not exceed 40 dBA at residents. Thus, in the planning of new wind farms and their location it is crucial to estimate the disturbance it may cause to nearby residents. Wind turbine noise emission levels are guaranteed by the wind turbine manufacturer only under ice-free conditions.

The purpose of the project has been to evaluate the effect on wind turbine noise emission due to ice accretion. This, by trying to quantify the ice accretion on the rotor blades and correlate it to any change in noise emission. A literature study showed that the rotor blades are to be considered the primary noise source. Hence, ice accretion on rotor blades was assumed to be the main influence on noise character.

A field study was performed in two parts; as a long term measurement based on the method out-lined by IEC 61400-11 and as a short term measurement in strict accordance with IEC 61400-11. Thus, noise emission levels for the case of icing conditions and ice-free conditions (reference conditions) as well as background noise levels were obtained.

Analyses were performed, which set out to correlate ice measurements with wind turbine performance and noise emission. Data reduction procedures were performed according to IEC 61400-11.The apparent sound power levels were evaluated. The analyses were performed both for the case of icing conditions and for the case of ice-free conditions. A statistical evaluation of icing events was carried out.

The results showed that ice accretion on wind turbine (rotor blades) may lead to drastically higher noise emission levels. The sound power levels according to IEC 61400-11 showed an average increase of 10.6 dB at 8 m/s. However, increases were shown to occur at all wind speeds from 6 m/s to 10 m/s. These may be caused by very small amounts of ice accretion. Statistically, increases in momentaneous noise levels of 8 dB or higher are to be expected 3 % of the time during the winter or 1 % of the time during one year for the wind turbine studied.

Taking into account the noise level guide-lines of 40 dBA at residents, as is recommended by Swedish EPA (Naturvårdsverket), the increased levels of wind turbine noise due to (the risk) of ice accretion may force the power production to a halt.

BACK

SEU Operation and Maintenance Experiences of Wind Turbines in Cold Climate

Thomas Mannelqvist, Skellefteå Energiunderhåll

SEU is a business area within Skellefteå Kraft that is also working as a supplier of Maintenance Service's to other Power Utilities in Northern Sweden.

Skellefteå Energiunderhåll (SEU) is working with wind turbines in Northern Scandinavia at Jokkmokksliden/ Storliden/ Uljabuouda and Blaiken Wind Farms.

This presentation will emphasize on the working conditions and risks that arises from cold climate conditions during Maintenance and Service on the Wind Turbines and is based on case studies. Not only ice throw is a potential threat against Maintenance Staff, also other risk needs to be handled.

BACK

ORAL

SMALL WT

Hybrid, wind, diesel, wind-diesel, small wind, compressed air, storage, Nordic areas, microgrid, energy, Technocentre, SMART, grid, off-grid, Photovoltaïque, research, generator, synchronous

Hybrid wind-diesel system with compressed air storage for remote Nordic areas

Eric Adams, Technocentre Éolien

Hussein Ibrahim, Technocentre Éolien

In Canada, there are 300 off-grid communities, including 200 in Nordic climates and that have an interesting wind potential. The TechnoCentre Éolien (TCE) has implemented research infrastructures that will allow it to become a leader in the field of the optimization of hybrid wind-diesel system for the Nordic off-grid communities. This infrastructure consists of a hybrid wind-diesel system with compressed air storage.

The modernization of energy systems towards more intelligent systems is underway in many countries to improve the reliability and better manage the production and consumption of energy. This modernization also aims to facilitate the integration of renewable energies. Motivated by important factors such as economic development, national security, environment and the integration of renewable energies, the TCE will use the microgrid as a tool for research and development in order to make the "Smart Energy Systems" more intelligent.

The design of the microgrid was performed to emulate, a distributed production connected to a grid, an off-grid supplying isolated Nordic communities, and a low power off-grid supplying, for example, a telecommunication station or residential loads.

The microgrid includes the following equipment:

1. Wind farm

   - 2 direct drive wind turbines, equipped of pm synchronous generator of 25 kW.

   - 1 wind turbine of 7,5 kW

1. Diesel plant

   - 2 diesel generator of 50 kW equipped of variable speed transmission.

   - 1 diesel generator of 15 kW

1. Photovoltaïque plant of 5 kW
2. Diesel generator emulator (powered by an electric motor with a drive)
3. Compressed air energy storage system
4. Batteries bank
5. Resistive loads bank
6. Command, power flux management and monitoring system (SCADA)
7. Measuring equipment and data acquisition system
8. Secondary loads (Heating, lighting, electronic equipment)

TCE has implemented a comprehensive research plan that included the participation of several academic institutions and industry players. The scientific objectives are:

1. Develop, test and validate detailed theoretical and experimental models of a wind-diesel-solar system
2. Optimise the operation of hybrid systems in accordance with the penetration rate of renewable resources and other technical and operational factors

3. Study and monitor the deterioration of the hybrid systems' components and subcomponents
4. Create a technological showcase for equipment and systems designed for use in remote Nordic areas
5. Create a training centre for hybrid systems

TechnoCentre Éolien (TCE)

BACK

ORAL

WORKSHOP:
STANDARDS AND CERTIFICATIONS

Remote Sensing Devices in Cold Climates

Iain Campbell, RES Group
Alan Derrick, RES Group
Euan George, RES Group
Marine Lannic, RES Group
Gail Hutton, RES Group

Given increasing hub heights and an increasing gap between mast height and hub height (due to cost of installing hub height ice rated masts), remote sensing devices (RSD) offer a great opportunity to validate mast measurements at hub height and across the rotor diameter.

RSD have the potential to:

- Provide hub height measured climatic conditions data (maximum and minimum wind speed, shear and turbulence intensity data), data which cannot be provided economically by a fixed mast.
- Validate fixed mast measured shear assumptions and forest canopy assumptions.
- Offer insight into the effects of low turbulence intensity and high shear on turbine energy yield, characteristics that are often seen in cold climates where highly stable atmospheric conditions prevail.

This presentation will consider:

- The usefulness and reliability of climate conditions data from remote sensing devices
- The validity of mast measured shear for extrapolation to hub height and the forest canopy assumptions
- The assumed uncertainty in extrapolating fixed mast measured shear to hub height and explore the validity of this uncertainty
- The impact of low turbulence intensity (and stable atmospheric conditions) on:
    - Wind speed and shear distributions, and therefore
    - Turbine power output (with consideration given to rotor equivalent values)

This work was funded by the Swedish Energy Agency (Energimyndigheten) under the Havsnäs Pilot Project

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BACK

Standards, best practices, coatings, anemometers, ice detectors, instruments, icing conditions

Towards standardization considering cold climate needs

Petteri Antikainen, VTT Technical research centre of Finland
Esa Peltola, VTT Technical research centre of Finland

Presentation will describe current developments in standardization and turbine certification considering cold climate.

Presentation will also include proposals for best practices for testing requirements for icephopic coatings, icing climate test condition definitions and measuring instrument classifications.

BACK

The Havsnäs Pilot Project – Cold Climate and High Hub Heights

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At the time of construction, the 95.4MW Havsnäs wind farm was the largest on-shore wind farm in Sweden and a pioneering and complex project in many ways, not least due to its location in the cold, inland climate of Jämtland in northern Sweden. In recognition of this, the developers, NV Nordisk Vindkraft, were awarded a grant by the Swedish Energy Agency (Energimyndigheten) to document and further research various aspects of the planning, development, construction and operation of the wind farm and the lessons learned with a view to reducing the risk to the future development of wind farms in this environment.

Cold climates bring with them not only the obvious problems of snow and ice but also significant variations in atmospheric stability from summer to winter and from day to night. With the periods of high atmospheric stability come shear and turbulence conditions which can invalidate the industry standard assumptions on wind speed extrapolation to higher heights, the linear wind flow models used to extrapolate the wind regime across the wind farm and the turbine's performance. All of these aspects attract additional uncertainty which has an impact on project financing.

This presentation gives an overview of the final results and recommendations of the Cold Climate and High Hub Height sub-topics of the project. The keys to the research were the comprehensive instrumentation systems installed on 3 of the 95m (hub height) masts located on the site together with a lidar remote sensing device, all permanently powered from the grid. The instrumentation together with several years of data on the actual performance of the wind farm have allowed comprehensive validation of the shear, wind flow and turbine performance models and assumptions which underpin the pre-construction estimates of wind speed and energy yield and build confidence in our ability to accurately predict wind farm performance.

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ORAL

FORECASTING AND PERFORMANCE

WRF, mesoscale numerical weather model, production loss, wind farm, forecast, icing climate

Modelling of production losses due to icing for individual turbines in a wind farm - development of techniques for forecasting and site assessment

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A new model for forecasting and hindcasting production losses due to icing for an entire wind farm has been developed. In order to accurately calculate the icing for every turbine individually high-resolution model data that resolves the features of the wind farm is needed. For this study the WRF model (www.wrf-model.com) has been run at 250m resolution for 1 year at a site in northern Sweden. The modelled atmospheric data has been used together with an adjusted version of the Makkonen model to calculate the production loss due to icing of each turbine. This enables the inclusion of sub- wind farm effects, due to e.g. various small-scale features of the terrain, in the park production loss calculation.

A comparison between observed production and the modelled results of different resolution is shown. Climatological statistics are also presented and the effect of long-term correction of icing is shown. There is also an evaluation of the accuracy of this model when running it operationally in forecasting mode.

The results show that the terrain dependence of production losses is strong and that high-resolution modelling improves the description of local features of the atmosphere. It is also made clear that the annual variation of production losses for a wind farm is large and that there is a high probability of several extreme years occurring within a 30-year period.

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wind turbines, icing, cold climate, site assessment, best practices

Recommended practices for wind energy in cold climates – resource assessment and site classification

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Deployment of wind energy in cold climate (CC) areas is growing rapidly. The main issues of wind energy in CC arise from icing of wind turbine rotor blades which reduces energy yield, mechanical life time of turbines and increases safety risks due to ice throw. Another aspect of CC is low temperatures which can affect turbine’s mechanical lifetime. Wind resources in CC areas are typically good and large-scale exploitation of cold climate sites has started, but despite of new technical solutions for wind turbines for CC the question “how CC affect to wind resources and resource assessment” still remains.

Cold Climates is defined by Task 19 – Wind Energy in Cold Climates, research collaboration under the IEA Wind, as regions where icing events or periods with temperatures below the operational limits of standard wind turbines occur, which may impact project implementation, economics and safety. The Task 19 collaboration has produced a report called “*Recommended practices for wind energy projects in cold climates*”. This report gives best available recommendations for project developers about special requirements of CC wind projects in order to reduce uncertainties and lower risks of a wind energy project.

The severity of the CC issues at the site under interest is to be determined in the resource assessment phase. In the “Recommended practices for wind energy projects in cold climates” report IEA Wind Task 19 introduced for the first time a site classification which allows planners to classify a project site according to the site-specific icing frequency. Based on this site ice classification, the order of magnitude of production losses due to icing can be estimated and classified already in the planning phase. This is the first step towards the classification of wind energy sites with respect to atmospheric icing and forms the basis for a future wind turbine classification related to icing. The Recommended practices –report describes also how to set up measurements for resource assessment in CC, how to interpret the measurement results, and what kind of counter measures are needed for icing and low temperatures.

The presentation in Winterwind 2013 will show why and how to use the Recommended practices -report in order to improve resource assessments in CC site. The presentation will include a practical example how to plan a measurement campaign, how to define an “Ice classification” for a site, and finally what is recommended for the site and the project in order to minimize extra risks and costs in the project in CC.

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Assessment of "Ground Truth" for Icing Events and Product Evaluation

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Over the last several years, four meteorological organizations have generated real-time and post-analysis products that estimate expected wind power and the effect of icing thereon for a set of operational and proposed wind power sites across Sweden. Though some bulk statistics have been generated to compare these fields to power observations taken at a few sites, "predictions" of icing events, power and loss have mostly been subjectively compared to met mast and (in some cases) turbine observations in a subjective manner.

The lack of objective hour-by-hour evaluations of icing and power loss estimates is at least partially driven by the lack of reliable measures of the presence, absence and intensity of icing events. Though icing load measurements were taken at most sites, both the values and trends in loads were confounded by a variety of issues, such as ice bridging, and were sometimes found to provide little or no useful information. In an effort to provide a more reliable, hourly record of the presence (and absence) of "active" icing, several months of web cam images and met mast data were examined during the 2011-12 icing season. This included the manual examination of measurements of temperature, wind speed, visibility, ceiling height, and (with great caution) icing load. Turbine measurements were also examined for select cases.

For the 2012-2013 icing season, the manual webcam/met-mast assessments will be extended regularly include turbine measurements at several sites. Code will also be developed to automatically combine several of the met-mast parameters (e.g. temperature and visibility) to provide alternative sources for objective (but flawed), hourly indications of the presence or absence of icing at sites where such data are available. The combination of the objective and manual assessments will provide a robust dataset that allows for statistics such as POD and FAR to be generated for the icing and power "predictions" from each of the meteorological groups participating in the 2012-2013 campaign.

In this presentation, the techniques described above will be demonstrated and some initial comparisons with one or more sets of icing products will be shown.

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An investigation into turbine performance under cold weather driven stable atmospheric conditions in Scandinavia

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In situations where temperature increases with height, the atmosphere is very stable and thus very resistive to vertical motion. Such inversions can be produced in several ways. Low-level inversions (altitudes of a few 100 m) are commonly produced during calm winter nights, as a result of radiative cooling of the surface. A second type of low-level inversion, common in many subtropical regions, is known as the trade-wind, or just trade, inversion. Air in the subtropics is, on average, descending and thus warms adiabatically as it does so this can produce a persistent inversion [1].

Stable atmospheric conditions caused by radiative cooling of the surface are, according to GL GH experience, common in cold climate regions such as Scandinavia. Snow cover enhances those conditions.

On a local scale snow cover influences the thermal stability of the air immediately above it. Snow cover is a radiative sink. Its high short-wave albedo is combined with a high thermal emissivity which increases the amount of infrared radiation lost near the Earth's surface. The radiative losses are not replaced quickly by heat fluxes from below because of the thermal insulating properties of the snow. It is a particularly good insulator at night when radiative exchange is concentrated in the surface layers of the snow. Surface exchange processes are further modified by the small aerodynamic surface roughness of snow cover which reduces turbulence and vertical transfer [2,3,4].

Under stable atmospheric conditions turbulence levels are typically low (< 10%). Thus low turbulence is seen as a proxy for stable conditions. These conditions materially differ from the wind flow conditions for which power curves are usually valid for. GL GH has seen empirical evidence of lower performance levels in a number of IEC standard power curve measurements on such conditions.

Those power curve measurements were however undertaken across North American sites where, although stable conditions occur frequently, the climatic, topographic, forestry and snow cover conditions can be substantially different from Scandinavian sites.

In this study, we survey a set of IEC standard power curve measurements at sites located across Scandinavia and Northern Europe. We analyse the data in search for evidence of lower turbine performance under low turbulence conditions and, based on the results, we will look to validate our current global model of estimating wind farm energy losses, to the Nordic region.

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[1] John Marshal, “Physics of Atmosphere and Oceans”, Lecture notes, Chapter 4 “Convection”, MIT, 2004/2005.

[2] T. D. Davies, “Snow and Ice Covers: Interactions with the Atmosphere and Ecosystems” (Proceedings of Yokohama. Symposia J2 and J5, July 1993), Climatic Research Unit, University of East Anglia, IAHS Publ. no. 223, 1994.

[3] D.A. Robinson, “Snowcover as an indicator of climate change. In: Large Scale Effects of

Seasonal Snow Cover" (ed.by B. E. Goodison.R. G. Barry & J. Dozier) (Proc. Vancouver Symp., August 1987), 15-25. IAHS Publ. no. 166, 1987.

[4] J. Cohen & D. Rind, "The effect of snow cover on climate", J. Climate 4, 689-706, 1991

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Capturing the effect of radiative cooling when modelling wind flow over a wind farm

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In situations where temperature increases with height, the atmosphere is thermally stable and thus resistive to vertical motion. Such inversions can be produced by different mechanisms. In particular, low-level inversions (altitudes of a few 100 m) are commonly produced during calm winter nights, as a result of radiative cooling of the surface [1].

Stable atmospheric conditions typically result in a quite different spatial distribution of mean wind speed than that observed during unstable or near-neutral conditions and are, according to GL GH experience, common in cold climate regions such as Scandinavia. Moreover, snow cover enhances the importance of these conditions via its insulative and radiative properties [2,3,4].

Wind flow models that assume a neutral atmosphere can provide reasonable predictions of unstable and near-neutral flows, but the predictions of stable flows are often comparatively poor. Thus, for sites where stable conditions are frequent, such as in Scandinavia, wind flow simulations specifically accounting for stability should be considered.

In this study, we survey a diverse set of sites located across the world, representing a broad range of geography, topography, and land cover. At each site (13 in al) we analyze measured data from multiple masts and compare it with linear and CFD models, with and without the capability of simulating stable flow. Based on the results of this, we assess the accuracy of the models, with a focus on achieving a better understanding where and to what degree it is important to capture stability effects.

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[1] John Marshal, “Physics of Atmosphere and Oceans”, Lecture notes, Chapter 4 “Convection”, MIT, 2004/2005.

[2] T. D. Davies, “Snow and Ice Covers: Interactions with the Atmosphere and Ecosystems” (Proceedings of Yokohama. Symposia J2 and J5, July 1993), Climatic Research Unit, University of East Anglia, IAHS Publ. no. 223, 1994.

[3] D.A. Robinson, “Snowcover as an indicator of climate change. In: Large Scale Effects of Seasonal Snow Cover” (ed.by B. E. Goodison.R. G. Barry & J. Dozier) (Proc. Vancouver Symp., August 1987), 15-25. IAHS Publ. no. 166, 1987.

[4] J. Cohen & D. Rind, “The effect of snow cover on climate”, J. Climate 4, 689-706, 1991.

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Wind sensor, De-icing, Cold climate

DE-ICING TESTING AND DEVELOPMENT OF ULTRASONIC WIND SENSOR FOR COLD CLIMATE

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The wind energy industry upgrades continuously requirements for the wind measurement in wind turbine control, power curve measurement, and site assessment applications. This is due demand of producing more wind energy with reduced production losses. From this trend follows the increased hub height level of new wind turbines. In addition, more and more often new wind turbine installations locate in more severe environments. Thus, conditions for icing can occur more regularly. To meet these requirements, continuous wind sensor evolution includes not only the implementation of the sensor de-icing system, but also the evaluation and development of testing methods and tools. In this paper, applied snowing and icing wind tunnel test facilities are represented and icing mechanisms are discussed. A scale model experiment was performed to study the temperature distribution on the surface. The de-icing development of the WMT700 ultrasonic wind sensor is introduced. The sensor development work has led to the ultrasonic wind sensor with enchanced heating system, including the implemention of the sensor body heating for cold climate installations.

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