Winterwind 2008

# Book of Abstracts

in program order

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**Presentations at Winterwind 2008**

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**SMHI has a vital mission**[1]

SMHI's mission is to manage and develop information on weather, water and climate that provides knowledge and advanced decision-making data for public services, the private sector and the general public. SMHI aims to contribute to increased social benefit, safety and a sustainable society.

Virtually everything in our lives is affected by the earth's climate, weather and water conditions. We cannot control the whims of Nature, but we can be increasingly better at understanding them and adapting our society accordingly. Knowledge and advance information enable us better to meet the challenges that our climate, weather and the conditions in the air and water present us with.

Government agency and business partner
SMHI is a government agency under the Ministry of the Environment. SMHI offers products and services that provide various kinds of enterprises and organisations with an important foundation for decision-making. General forecasts and weather warnings, industry-specific services, simulations and analyses, statistics, climate studies and contracted research are some examples.

SMHI conducts three different types of operation: government-funded operations, assignments from other government agencies, and business operations on a commercial basis. Although apparently different on the surface, these operations are all based on the same fundamental aim, to contribute to increased social benefit, safety and a sustainable society.

**SMHI Wind Energy**[2]

Power from wind energy represents a growing proportion of electricity production in more and more countries. SMHI now offers wind power forecasts in kWh for individual wind power stations.
kWh forecasts for individual wind power stations

Production values are based on the highest quality meteorological calculations, considering the output curve, hub altitude and location of every single wind turbine. The model processes your production figures and can also account for slopes, wind-breaking groves and other factors specific to the position of individual turbines.

* SMHI Wind Energy calculates production for each individual wind turbine. Calculations are made for each hour today and tomorrow, and for every six hours on the two subsequent days.
* SMHI Wind Energy calculates your total production, i.e. the sum of production from all your turbines.
* SMHI Wind Energy also displays summarised 24-hour values for all four days, both in kWh and as a percentage of installed capacity.
* SMHI Wind Energy is updated four times a day.

[1] http://www.smhi.se/cmp/jsp/polopoly.jsp?d=5019&l=en
[2] http://www.smhi.se/cmp/jsp/polopoly.jsp?d=5572&a=30229&l=en

**The Swedish Wind Energy Association – SVIF (As translated by Google)**
http://translate.google.se/translate?u=http%3A%2F%2Fwww.svensk-vindkraft.org%2F&sl=sv&tl=en&hl=sv&ie=UTF-8

**The European Wind Energy Association**
http://www.ewea.org/

**The European Technology Platform for Wind Energy (TPWind)**
http://www.windplatform.eu/

**Title:** Regional mapping of icing conditions from meso-scale model data
**Authors:** Øyvind Byrkjedal, Knut Harstveit, Erik Berge
**Affiliation:** Kjeller Vindteknikk AS, Instituttveien 18, 2027 Kjeller, Norway

**Abstract:**
A meso-scale model, WRF, is used to develop regional maps of wind resources and icing in Norway. The horizontal grid resolution of the model is 1km. The model has been run for one year and gives time-series of wind, temperature, humidity and cloud water at several vertical levels. The time-series of wind speed and temperature compare well with available observations.

A method to predict icing from the model results has been developed. This methodology takes cloud water, temperature and wind speed as input. The icing rate and accumulated icing on a standard body can be computed. Airport observations of cloud height can be used to estimate icing. This compares well with the meso-scale model estimates. Both the timing of the icing events and ice amounts accumulated during these events are for most cases captured by the meso-scale model.

The results from the meso-scale model show a similar dependency with height as found from the cloud observations. The meso-scale model has shown to be a promising tool in region wide mapping of icing conditions. The meso-scale model data can further be utilized to estimate potential production losses due to icing.

# On the use of the Weather Research and Forecasting (WRF) Atmospheric Model to Predict Explicitly the Potential for Icing

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## Abstract

A new bulk microphysical parameterization has been developed for use in mesoscale models of the atmosphere. Compared to previous schemes, the new scheme incorporates a number of improvements to physical processes and employs techniques found in more sophisticated spectral/bin schemes. The new scheme has been extensively tested for prediction of precipitation amount and type at the ground as well as the balance of water and ice content aloft. Though the scheme was originally designed to improve forecasts of icing on fixed-wing aircraft, it can also be readily applied to predict icing on structures at the ground, which was recently undertaken by researchers in Oslo, Norway. In this presentation, very high resolution WRF model simulations with grid spacings at or below 1 km and their application to the aircraft and ground stuctural icing problems will be discussed.

**IEA Wind R,D&D Task 19[1] - Wind Energy in Cold Climates**

This is the home page of an International Energy Agency collaboration called Wind Energy in Cold Climates, under R,D&D Wind http://IEAwind.org The purpose of this project is to gather and provide information about wind turbine icing and low temperature operation. This page also provides a new discussion forum for those who are interested in wind turbine operation in cold climates.

A report produced within the Task 19 that summarises existing experiences in wind energy production in cold climates is available here - State-of-the-art of wind energy in cold climates[2] (pdf). State-of-the-art -report will be updated until the end of 2008. Recommendations for wind energy developers in cold climates[3] (pdf). The recommendations included in the report are intended to guide wind energy developers to a position where uncertainties related to cold climate issues are reduced to a minimum. Recommendations will be also updated until the end of 2008.

[1] http://arcticwind.vtt.fi/
[2] http://arcticwind.vtt.fi/reports/state_of_the_art.pdf
[3] http://arcticwind.vtt.fi/reports/recommendations.pdf

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Abstracts
WINTERWIND 2008
Norrköping, Sweden

Title: Wind Power Icing Challenges in Alaska; a Case Study of the Village of Saint Mary's

With the high cost of energy and Alaska's near exclusive dependence on diesel power generation in rural villages and remote mines, wind power in Alaska is developing rapidly.

Wind development in rime ice-impacted sites is anticipated, especially in more inland locations where alpine, near-alpine, or other ice-prone locations are the only feasible options for wind power development.  At present, a number of wind resource studies in Alaska indicate wintertime rime icing.  The following challenges are encountered and expert assistance and collaboration desired with three principal issues of icing:  1. Detection and analysis of icing events; 2. Estimation of power loss from icing events; and 3. Mitigation of power loss from icing events.

The presentation will provide an overview of rime ice conditions in Alaska and a case study of an ongoing wind resource study in the village of Saint Marys, Alaska will be presented to highlight the rime icing challenge in Alaska and the need to identify effective ice-mitigation measures appropriate for village-scale and utility-scale wind power sites.

# Understanding Icing Losses and the Risk of Ice Throw at Operating Wind Farms

By Tracy Duncan(1), Marc LeBlanc(1), Colin Morgan(2), and Lars Landberg(2)
(1)Garrad Hassan Canada, Canada; (2) Garrad Hassan and Partners, United Kingdom

**Abstract**
The wind industry currently lacks clear understanding of the magnitude of icing losses in terms of turbine availability and performance, and therefore estimating the associated production losses is challenging. To address this issue, Garrad Hassan (GH) has analyzed icing events in detailed operational data in an attempt to answer some key questions:

• What is the frequency of icing observed at modern North American wind farms?
• What level of energy loss should be estimated per icing event?
• What are the effects of icing conditions on turbine availability?

The paper will, using North American data, describe the results of this analysis.

The second part of the presentation will about ice throw. First a simple model/some guidelines will be given, and then an example will be given.

**TITLE:**

Electro Thermal Wind Turbine Ice Protection System

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**ABSTRACT:**

A joint project between MW-Innovations, Kelly Aerospace Thermal Systems and Vindkompaniet has produced and electro-thermal ice protection system for the wind turbine community. The patented technology was originally developed by Kelly Aerospace Thermal Systems in Ohio, USA for use on aircraft wings and propellers. The technology involves installation and control of a unique heating element that allows de-icing and anti-icing of aerodynamic surfaces. The heating element is applied to the outer surface of the blade and can be installed on turbines old and new. The unique properties of the element allow it to heat up very quickly with small amounts of power allowing minimal power usage to maintain and ice free blade. The first system was installed on a V90 2-Megawatt turbine in September of 2008 at the Dortoea, Sweden wind farm. This presentation will discuss the ice protection system, steps taken during the installation process and a report on the current status of the wind turbine.

**Icephobic coating for prevention of the secondary icing**

Shigeo KIMURA Kanagawa Institute of Technology
Atsuhiko Sakabe Fuji Heavy Industries Ltd
Takeshi Sato National Research Institute for Earth Science and Disaster Prevention
Yoichi Yamagishi Kanagawa Institute of Technology

Most of icephobic coatings have no self-preventing capabilities of ice accretion yet at the present, but have an auxiliary role to play for a thermal icing prevention system with insufficient thermal capacities which may consequently cause refreezing of molten water, defined here as the secondary icing. Authors shows some examples of the secondary icing and the effectiveness of icephobic coating for prevention of runback ice on an airfoil.

**Ice data from Sveg processed by SMHI**

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Data from ice measurements at a tower in Sveg has been evaluated and the results have been compared with results from a simple model for detecting situations with occurrence.

This work has been performed in order to investigate the areas within which this model has to be improved.

# Winter wind forecast capabilities at SMHI

Ulf Andrae, Per Unden
SMHI

During the last years a new wind power forecasting system has been developed at SMHI. It utilizes the best possible model information available at all scales. The system consists of two parts, a physical modeling part and a statistical part. The physical part relies on the Numerical Weather Prediction model which predicts the flow on a discrete grid mesh. The module then takes care of interpolating the wind to the actual site and calculation the wind power for the particular wind mill or park. In the statistical part the error in the forecast is estimated and corrected using a Kalman filter technique based on previous forecast errors. The technique needs information about the actual produced on site wind power to be able to update the correction following the slowly varying errors in the model.

In the application of the Kalman filter a quality control of the observed values is of great importance. Erroneous observations will degrade the filter and the following forecast. The quality control includes both internal and geographical consistency as well as checks against the actual forecast. Production breaks due to e.g. icing of wind mills at high latitudes cannot yet be predicted, which is an obvious shortcoming of the system.

In the recent years the focus of the numerical weather prediction at SMHI has shifted from the synoptic scale to the meso scale. In the meso scale, i.e. scales below 5-10 km, effects from non-hydrostatic processes and resolved convection becomes more important. A non-hydrostatic model and a good representation of the in cloud micro physical processes is today a natural component in these models. The meso scale models are capable of describing cloud properties such as cloud ice/water rain, snow, graupel and hail. All of these are of great importance for the capability of describing the risk of winter time icing on wind mills. The physical realism in the simulations is significantly enhanced compared with the previous generation models. Data assimilation of in-cloud properties is still a great challenge as almost no direct measurements exist routinely. Indirect measurements like radar reflectivity, satellite and ground based radiances will be further employed by the modeling community at SMHI and its partner institutes in the HARMONIE collaboration. Measurements of pressure, temperature, wind and humidity are crucial to update the general initial condition.

We will give an overview of the available models working at the kilometer scale at SMHI.

## An experienced wind energy developer's view on cold climate issues

Staffan Niklasson, Vindkompaniet

Icing of wind turbine blades decreases the energy production and may induce vibrations stopping wind farms over extended time periods. Icing therefore poses the single greatest challenge to the successful implementation of wind energy in Northern Sweden.

Other concerns are:

- low temperature and icing effects on O&M and repairs
- low temperature effects on machinery and tower
- the risk of ice throw
- increased noise (source and propagation)
- the short building season
- the complex terrain issues affecting transportation and infrastructure costs
- the increased turbulence at complex terrain sites
- the lack of commercially available anti-icing equipment
- the lack of load cases in the standards taking operation with iced-up blades into account

So far, wind turbine manufacturers have shown little interest in solving the icing issue.

For planning purposes there’s also a lack of:

- electrical power for wind energy resource estimation at remote locations
- icing maps
- low temperature mapping
- energy deficiency mapping
- verification of icing models
- reliable ice detactors
- ice-free sensors
- classification of ice-free sensors
- classification of sites
- relevant standards for icing measurements on wind turbines
- market studies motivating the manufacturer’s to pay attention to cold climate issues

Decreasing the risks associated with deployment of wind farms at cold climate sites is essential, particularly in times of financial turmoil.

**Challenge Cold Climate: Different requirements for dry and icing climate**

Rüdiger Gawrisch, Repower R&D, project manager for CCV project China

Topics:

Market potential in Cold Climates
Experiences with erecting, commissioning and operating 2MW CCV machine in Inner Mongolia / China
New challenges in Canada
Other potential markets with CCV requirements

# VARIABILITY OF WIND ENERGY OUTPUTS IN RELATION WITH THE WEATHER AND CLIMATE IMPACTS IN BULGARIA

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**Abstract**

The state of the art of the wind energy sector and the official national future plans for the development of the wind energy utilization in Bulgaria in the view of climate impacts and climate changes have been discussed in the paper.

The results from different wind projects are summarized here. The influence of weather and climate conditions and the different topographical feathers on the generated wind energy by different wind generators have been presented and discussed. Special attention has been paid on the possible influence of the harsh meteorological conditions on the energy production with focus on the icing impact. The main task in this study is to compare the different opinions about this issue – on one side is the investor’s thinking, on the other side are the meteorological records. It seems that icing is an underestimated circumstance in these southeastern parts of Europe when planning to build a new wind turbine. This is due to the fact that the most appropriate regions for wind energy productions usually are often affected by this phenomenon but there is no awareness about it outside the meteorological community.

The influence of the recent climate trends in the wind regime has been also investigated.

This study could be very useful as practical recommendations to the wind energy investors.

**Key words: wind speed characteristics, wind potential and energy, energy density flow, icing and reducing of the energy production due to icing.**

**Abstract submission for WINTERWIND 2008**
**Dec 9-10, 2008 in Norrköping, Sweden**

# WIND POWER FORECAST ACCURACY UNDER ICING CONDITIONS

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In Germany the application of wind energy technology has grown rapidly within the past twenty years. Starting in the late eighties with only a small number of wind turbines with merely ten Megawatts installed capacity, the total capacity of 19,700 turbines in operation in Germany has reached the 23 GW level by September 2008. The electricity production of this wind power plant was close to 39 TWh in 2007 or almost 8% of Germany's net electricity consumption. Future plans are to further increase wind power onshore and offshore.

Due to the fluctuating nature of wind energy the availability of a sophisticated and reliable tool for forecasting, integration and combination of wind power with the conventional power system is absolutely necessary for system operators. The Wind Power Management System (WPMS), developed by ISET, is used operationally by three of the four German transmission system operators (TSO), as well as by several other TSO in Europe and world wide.

The operational experience of many years of using WPMS shows that the system has performed well, both in terms of accuracy and in terms of practical usability. In recent years, the requirements of the users as well as the capabilities of the system developed dynamically. The result is a continuous improvement of forecast accuracy, resulting in a 'learning curve' of decreasing forecast error over time. Furthermore the scope and flexibility of the system has been extended in terms of wind park cluster management .

However, a preliminary analysis of meteorological data and measurements of power output at selected referential wind farms with cold climate potential show significantly higher forecast errors for temperatures below zero. ISET is working on this issue by studying the correlation of other meteorological parameters and the development of solutions that override forecast errors caused by turbine operation under icing conditions.

The presentation at Winterwind 2008 will include an overview on wind energy development in Germany, a brief introduction to the forecast system WPMS and preliminary results about effects of icing conditions on forecast accuracy.

Abstract submission for the
**WINTERWIND 2008,**
**Dec 9-10 in Norrköping, Sweden**

**Title:**
Wind-diesel power systems in cold climates: a review of the technology, performance, and market.

**Abstract:**
In remote and isolated communities the rising costs, environmental regulations, and the carbon impacts of using diesel fuel as a prime power source are driving communities to look for alternatives. During the past few years, the use of wind energy to reduce diesel fuel consumption has increased, providing economic, environmental, social, and security benefits to the energy supply of communities. In addition to islands, many of the communities that have adopted wind-diesel technologies are located in extreme climates, such as Alaska, Northern Canada, and Antarctica.

This presentation will discuss the current status of wind-diesel system operation in extreme climates focusing on systems installed in Alaska and Antarctica. The paper will also address some of the issues experienced with the operation of turbines and wind-diesel power systems at these remote sites including usage of waste heat and the potential for considering thermal and the transportation market as expanded loads for wind technologies. The paper will also detail the expected continued development of wind turbine implementation in these areas, a bellwether for the expanding market of mid sized wind turbines for remote applications.

This presentation hopes to shed new light on a wind market that has been much discussed but until now hardly realized and encourage the expansion of a community of interest while allowing communities and nations to investigate the wind-diesel option for reducing their dependence of diesel-driven energy sources for supplying power to remote communities.

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# Selecting a Small Wind Turbine for the South African Antarctic Research Base, SANAE IV

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## Abstract

The sustainability and economy of the current South African National Antarctic Expedition IV (SANAE IV) base, diesel powered system are threatened by high fuel costs and the forced reduction of green house gas emissions. The utilisation of a small wind energy conversion system (WECS) will result to diesel fuel savings and an improved base autonomy. Results of the Vesleskarvet local climate study, the SANAE IV energy system and environmental impacts assessments are presented. Technical and economical criteria derived from these assessments were applied in the evaluation of eight commercially available cold climate wind turbines. As result three wind turbines namely the Proven 6 $kW_{rated}$, Bergey Excel-S 10 $kW_{rated}$ and Fortis Alizé 10 $kW_{rated}$ wind turbines are proposed. As a first, one of these wind turbines may be integrated with the current SANAE IV multi diesel-electric generator power system.

**Keywords:** *Antarctica, cold climate wind energy, SANAE IV diesel-electric system, economics, small wind turbine*

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[†] Prof. T.M. Harms and Prof. T.W. von Backström were the project supervisors

# COST-727 ACTION: ICING ON STRUCTURES

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**Abstract of the presentation**

The COST-727 Action ”Measuring and forecasting atmospheric icing on structures” was established in April 2004. The following general goal was then defined: to develop the understanding of icing (especially in-cloud icing) and freezing rain events in the atmospheric boundary layer and their distribution over Europe as well as to improve the potential to observe, monitor and forecast them.

Phase 1 of the action was dedicated to gathering available information for a comprehensive state-of-the-art report representing what the participants consider as a summary of today's available knowledge. The second Phase of the Action is dedicated to in-situ measurements of atmospheric icing with selected reference icing sensors at 6 stations operated in Europe and to the modeling of selected icing events with a new adaptation of the WRF model developed by Norway. The following deliverables are expected:

- Scientific and technical publications on measurements and modeling of in-cloud icing
- Publications on verification of icing modeling
- Recommendations for World Meteorological Organization WMO /Commission for Instruments and Methods of Observations CIMO for Automatic Weather Stations AWS observations.

The first 2 test stations have been installed in Switzerland (Guetsch, 2'300 m a.s.l, collocated with the highest wind turbine in Europe) and Finland (Luosto, 515 m a.s.l). The other 4 stations are located in Sweden (Sveg), Germany (Zinnwald), United Kingdom (Deadwater Fell) and Czech Republic (Studnice).

First attempts of model simulations have been performed for icing events at the Guetsch, Deadwater Fell, and Zinnwald with very promising results. In particular, the collapse of a measurement tower located in the Swiss pre-Alps region could be simulated with a good accuracy.

Apart from meteorological measurements aspects, the COST-727 Action has promoted cooperation with the wind energy production sector (ice accretion on wind turbines) and the transport of electricity (power lines collapses). In particular, joint activities with the Conseil International des Grand Réseaux Electriques CIGRE has allowed to initiate a close collaboration with Iceland (simulation of wet snow accretion).

The Final Workshop of the Action will be organized in collaboration with the 13$^{th}$ International Workshop on Atmospheric Icing on Structures IWAIS Conference in Andermatt, Switzerland, 8-11.9.2009 (more details on www.IWAIS2009.ch).

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# Icing and wind turbines – Swiss activities

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## 1. Introduction

Icing is an important issue when operating wind turbines in elevated or arctic areas as it can cause significant production losses or represent a safety risk.
In 2004, a 600 kW Enercon E-40 wind turbine with integrated blade heating was installed on Gütsch mountain, Switzerland, at 2'300 m asl. Coincidentally, a fully equipped test station of the Swiss meteorological network SwissMetNet was installed about 200 m away from the wind turbine in 2003. The immediate proximity of the two facilities operating under icing conditions led to the launching of the national research project "Alpine Test Site Gütsch: meteorological measurements and wind turbine performance analysis" which is embedded in the European "COST Action 727: measuring and forecasting atmospheric icing on structures".

## 2. Inter-comparison of ice detectors

Measurement devices which are capable of measuring either the occurrence of icing or giving information about ice are an important element of wind assessments and operation of wind turbines in areas with icing conditions. Therefore, several market available ice detectors have been tested at the Guetsch site during the winters 2006/07 and 2008/08. The inter-comparison identified quite a number of shortcomings concerning the design of these instruments.

## 3. Monitoring of the wind turbine

The performance of the wind turbine on Guetsch with respect to power production, ice detection and efficiency of the blade heating was monitored by use of the operational data as well as the installation of web cams. The results showed, that the wind turbine on Guetsch is performing well under the harsh conditions but it also identified minor shortcomings.
As the wind turbine is located close to ski slopes, ice throw is an important safety issue. Since winter 2005/06, the area around the wind turbine was inspected after every icing event for ice fragments that had fallen off the blades. The analysis of the recorded data pointed out clearly, that ice throw is a safety risk at this specific site.

## 4. Site assessment with respect to icing

When analysing measured wind data only, it is not possible to distinguish between meteorological icing (duration of a meteorological event or perturbation which causes icing) and instrumental icing (duration of the technical perturbation of an instrument due to icing). But this information becomes essential when deciding if a wind turbine should be equipped with a blade heating or not.

A straightforward procedure to estimate the presence of in-cloud icing conditions was developed based on measurements of air temperatures, relative humidity and the long wave incoming radiation. The necessary instruments were installed a the nacelle of the Gütsch wind turbine and the results were compared with manually classified webcam images of the rotor blades.

## 5. Simulation of Icing with WRF

Within the new Swiss research project MEMFIS (Measuring, Modelling and Forecasting Icing on Structures) the icing measurements in Switzerland will be extended, the weather model WRF will be used for the simulation of icing events with regard to ice mapping and the weather model COSMO-2 by MeteoSwiss will be evaluated for its suitability for icing forecasts.

## Rotor Monitoring System including Ice Detection for Maximising Turbine Performance

Mark Volanthen, Kieran Campbell, Toby King: Insensys

**Summary**
A multifunctional rotor monitoring system incorporating ice detection is presented. The system monitors the key parameters that indicate the condition of individual blades and also the rotor as a whole. Sensors located within each blade detect the presence of ice, lightning strike events, the aerodynamic performance of the blade, loads on the blade and any gross damage to the blade. Data from all blade sensors are combined to provide rotor health and status information including the build-up and loss of ice, mass and aerodynamic imbalance, and to provide information about overall wind loading to enable turbine performance to be optimised.

**Full Description**
Wind Turbines are being increasingly installed in remote locations and are routinely exposed to environmental extremes. The size of current rotors and the nature of the latest installation sites have made turbines more susceptible to environmental influences while commercial demands to maximise output remain. To enable such a wind farm to operate optimally, real-time quantitative information about the turbine status and health is required. A number of systems are available for inferring the presence of ice on blades and the condition of the rotor in general by measuring components elsewhere in the turbine and monitoring metrological conditions, but to date monitoring within the rotor, and blades specifically, has been limited.

The rotor monitoring system provides operators and manufacturers with real time quantitative data describing the health and status of the rotor.

The presence of ice on each blade is determined with a resolution of 6kg by dynamically weighing the blade using the load sensors. Ice loss is detected in the same way. Load measurements are also processed to quantify the aerodynamic performance of each blade and the aerodynamic imbalance of the rotor.

The lightning sensors detect the peak current and the peak rate of change of current of each strike. The sensors are not in physical contact with the lightning conductor and have no electrical connection out of the blade.

Loads from each blade are combined to determine the complete, three dimensional, loading transmitted from the blades to the drive train. These loads are interpreted to provide information about blade performance and about the degree of wind shear or yaw misalignment.

By measuring a broad range of rotor parameters, the rotor monitoring system is able to provide a comprehensive real-time indication of the health of the rotor that can be used to maximise energy generated. This can be achieved by optimising parameters such as yaw angle and individual blade pitch, both of which have been shown to affect turbine output power. Furthermore, the ability to dynamically detect the build up and loss of ice on each blade provides the capability to re-start generation as soon as possible, maximising revenue in icing conditions. Rotor health information can be used to modify operating and maintenance strategies, such that catastrophic failures and costly secondary damage are both minimised. This dramatically increases the proportion of issues that can be addressed through scheduled maintenance visits, lowering maintenance costs and increasing availability.

# Ice monitoring in northern regions

Per-Erik Persson, Patrik Jonsson, Lars Sahlin, Saab Security

Topics of the presentation:
• The ice load surveillance sensor IceMonitor™
• Saab's monitoring system RWiS (Road Weather information System)
• Saab's and Vestas agreement
• Saab's GreenTech project

Saab has developed an instrument for ice load surveillance called IceMonitor™. The sensor was originally developed for power line surveillance for StatNett in Norway. The design of the sensor has evolved from our participance in the COST 727 group and the sensor has been tested in Germany, Finland, Sweden, Switzerland, Poland…

Saab has a long history, since the beginning of 1980's, as a supplier of high quality monitoring systems from the development of our Road Weather information System (RWiS) that has been exported to several countries. The structure from our RWiS deliveries has been reused for the development of ruggedized ice load monitoring systems. One of the key features of the Saab monitoring systems is that any sensor or any signal can be integrated to the monitoring system. Therefore sensors from several suppliers can be integrated to the Saab field logger and also signals from wind turbines or can be integrated to the logger unit. Saab uses suitable communication techniques to retrieve data from the field stations and store the data in central databases. The retrieved data can then easily be accessed through the internet.

Saab is focusing on sustainable technology for the environment and this implies focusing on wind power energy. Recently, Saab has made an agreement with Vestas regarding cooperation in future wind projects.

Abstract submission for WINTERWIND 2008
Dec 9-10, 2008 in Norrköping, Sweden

**Cold Climate Issues and Related R&D Regarding Wind Energy in Canada**

Antoine Lacroix
Natural Resources Canada (NRCan)
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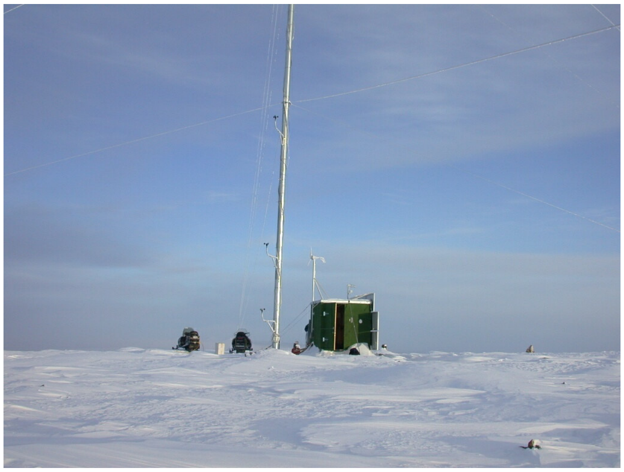
In Canada, the installed capacity in utility wind energy went from 137 MW in 2000 to 1,876 MW in mid 2008. For the year 2007, the amount of wind-generated electricity has been estimated to be around 4.3 TWh. This represents approximately 0.8 % of the national electric demand. The Canadian Wind Energy Association calls for an ambitious growth in installed capacity in order for wind to meet 20 % of the electricity demand by 2025.

Canada has slightly more than 300 remote communities scattered across its territory. These communities are not connected to the North American grid but are usually powered by diesel generators. They are located in the Northern part of the country, in the Arctic region but also under more Southern latitudes. It is estimated that half of these remote communities have an harnessable wind resource. In the last twenty five years, wind energy was regarded as a possible solution to reduce the dependency of these communities on diesel fuel but for several reasons including climate and inadequate coupling technology, the possibilities never materialized.

Canada offers what is generally considered cold climate conditions. In areas where cold air temperature is not an issue such as along the coasts, atmospheric icing becomes a concern. For instance, rime ice occurs at high elevations on the West Coast and on the Appalachian mountains while glaze prevails in Central and Atlantic Canada. Rime can also take place at lower elevations near areas of high evaporation. Either in grid-connection or in remote communities, wind turbines in Canada are impacted by cold climates issues.

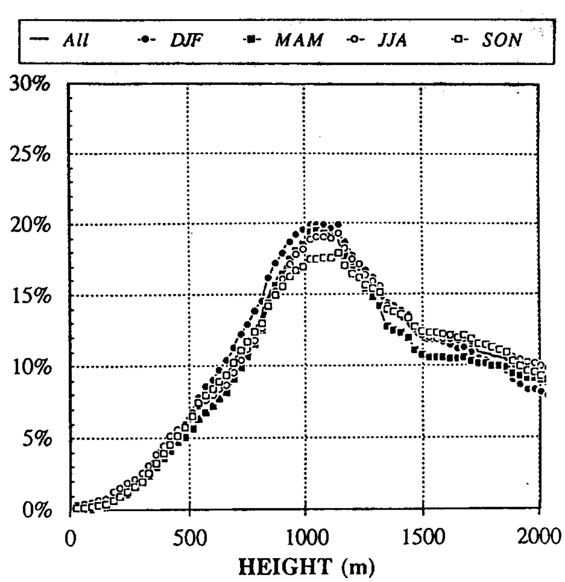
NRCan has supported several cold climates wind energy R&D initiatives in the areas of wind and icing assessment, icing modeling and mitigation and climate characterization. Yukon Energy Corporation (YEC) installed a meteorological station including an ice detector near the remote community of Old Crow, Yukon. The icing was so severe that the instruments became engulfed in ice and quickly inoperable. Experiments in the icing wind tunnel at the University of Manitoba were also carried out. This allowed studying the ice formation process on turbine blades and how power production is affected. The work also focused on optimizing ice mitigation techniques. Finally, a climate assessment project in Eastern Canada was undertaken. Instruments were attached to two towers located at an elevation of 610 m. in order to characterize the local environment in terms of wind speeds, wind direction, atmospheric pressure, humidity, duration of icing events and precipitation.

The presentation at Winterwind 2008 will cover the material presented above and introduce some elements for future cold climates R&D. Environment Canada has developed meso-scale wind forecasting and there is a possibility that they adapt their model to icing prediction. With the growing interest in offshore wind, glaze icing will also become more of a concern.



*The remote wind and icing assessment station in Old Crow. Source : Yukon Energy Corporation.*

*Icing wind tunnel : ice accretion on the leading edge of a turbine blade. Source : University of Manitoba.*




*Probability of cloud by height and month over the Appalachian domain between 1985 and 1987 Source . Bailey, B.H. (1990) The Potential for Icing of Wind Turbines in the Northeastern U.S., Windpower 1990: 286-291*

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Rapport

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**Icing on a wind power plant in Härnösand northern Sweden.**

**Power losses and other hazards due to icing measured.**

Since February 2008 HoloOptics in cooperation with Hemab, Vindforsk and Skelleftekraft is measuring the icing conditions at a wind power plant in Härnösand in northern Sweden. The plant is a 600 kW Vestas owed by Hemab.

Icing conditions are measured with two Clear Ice Indicators. One, with a de-icing system activated as ice is indicated is used to measure the Icing Rate. The other without de-icing is measuring the time the plant is covered with ice. Indications are sent to HoloOptics and Hemab as SMS messages.

As a complement the amount of ice on one wing is inspected optically by using a number of IceMarkers, which makes it possible to see the amount of ice, even clear ice.

Whether conditions e.g. wind speed and direction and air temperature and humidity is measured with 10 minutes intervals at a nearby mast. From the 30 October the power output of the plant will also be measured at 10 minutes intervals.

The aim of the project is to measure the power losses due to icing. It will also show when hazards from ice are due.

**Knut Harstveit[1] and Jarkko Hirvonen[2]**

*[1]Kjeller Vindteknikk, Norway; [2]Finish Meteorological Institute, Finland*

## Comparison of cloud water content, and meteorological parameters at Pujio tower, Kuopio, Finland

In-cloud icing, *M* increases with the wind speed, *v*, the cloud water content, *w* and the median cloud droplet size, *d*:

$$\frac{dM}{dt} = \propto_1 (v, d, A) \cdot \propto_2 (thermodyn) \cdot v \cdot w \cdot A,$$

where *t* is the time; *A* is the exposed area; $\alpha_1$ is the collision coefficient and $\alpha_2$ is the sticking coefficient. In thick, low clouds *w* increases with the height, *h-H* above cloud base, *H*. At the top of a hill, the air is partly or fully lifted from lower levels, and water will condense at the nucleation particles when the air passes the lifting condensation level, LCL (cloud base) due to cooling of the air.

If all the humid air is lifted adiabatically and all condensed water stay in the lifted cloud mass as liquid water, the cloud water increases with height according to the adiabatic cloud water gradient, $\delta$,

$$w = a \cdot \delta \cdot (h - H) \approx a \cdot 1.56 \cdot (1 + 0.034\theta_w) \cdot (h - H),$$

where $\theta_w$ is the potential wet-bulp temperature, and the right part is here approximated for the lower 500 m of the atmosphere. The factor *a* ($0 \le a \le 1$) is the deviation from the adiabatic cloud water gradient, and may be lowered from 1.0 due to loss of cloud water in old clouds or by partly or slowly lifting of the air allowing droplet loss due to mixing, freezing or precipitation washout to occur. Along the surface, loss of cloud droplets due to wet deposition also must be taken into account.

Along the Norwegian coast the mountains are often steep and parts of larger mountain areas, making the moist air from the sea easy to lift above the mountains and an adiabatic cloud water gradient to occur. For the Pujio tower this may not be the case. The hill is steep, but small and isolated, and the air is continental. An assumption of lifting from LCL to the top of the tower may fail.

Earlier a relation of visibility, *VV*, and *h-H* are given (Harstveit, K., *Using Routine Meteorological Data from Airfields to Produce a Map of Ice Risk Zones in Norway.* IWAIS 2002, Brno, Czech Republic, 2002). The relation depends on several parameters, that is the cloud water (*a* and $\theta_w$), $N_d$ (specific number of droplets), $\varepsilon$ (a measure of the deviation from the narrow droplet spectrum), *and b* (surface loss of droplets due to wet deposition). We now assume *b*=1.0 due to the distance from the surface to the measuring height in the tower (74m). From measurements of *d*, $\varepsilon$, *w* and *VV* in the Pujio tower, and H at the UKU campus, Kuopio, together with the air temperature, *T*, we find the value of *a* which gives the closest modeled values of *w* and $N_d$ to the measured values.

Now we have carried out results from one episode. Then we found excellent agreement between measured and modeled *w* (ca 0.15 gm$^{-3}$) and specific number of droplets (ca 340cm$^{-3}$) when *a*=0.6, which means significant deviation from the adiabatic cloud water gradient. We now will analyze more situations. The model then can be use at icing condition by using the calibrated values of $N_d$ and *a*, for different kind of cloud water models (WRF, airport data model) combined with the ice accretion model.

## Estimating icing using 'higher-order turbulence closure' models

Hans Bergström, Uppsala University
Stefan Söderberg, WeatherTech Scandinavia AB

To study icing of wind turbines means to seek information regarding icing at heights between 50 m and 150 m. This part of the atmosphere is highly influenced by turbulence and boundary-layer turbulent transports. In order to accurately model condensation at these heights the models used should be able to handle vertical fluxes of heat and vapour, together with the flux of momentum in order to determine the wind profile. Focus should consequently be put not only upon condensation schemes but also on the model parameterisation of turbulence. It might prove insufficient to use a model, which only roughly describes the turbulent fluxes. Mesoscale models using a 'higher-order turbulence closure' (e.g. COAMPS, MIUU, or MM5/WARF) which explicitly calculates the turbulence should be preferred as they resolve the vertical variations in both wind and turbulent fluxes. A model of this type should increase the confidence in the results of a maping of icing conditions.

**Spatial structure of synoptic icing observations in central Europe and their applicability**

Jiri Hosek, Institute of Atmospheric Physics, Prague

The automatic measurements from the mountain station at Milesovka Mt. are compared to the synoptic observations. The spatial structure of the synoptic icing data are explored, using the digital model of terrain.

# Simulation of the January 2008 Icing Event in the Central Europe

BJØRN EGIL KRINGLEBOTN NYGAARD

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ABSTRACT

The potential to explicitly forecast in-cloud icing by using the Weather Research and Forecasting (WRF) model is investigated in this case study. During the first week of January 2008 ice accretion caused by deposition of super cooled cloud droplets was measured at test stations in the UK, Germany and Czech Republic. The goal of this study is to identify how precisely a meso-scale numerical weather prediction model can simulate the conditions leading to icing in such a big area. Simulations are carried out using the WRF model with a huge domain covering the central Europe and the UK in a 3 km resolution grid. The model is configured with the "Thompson scheme" for cloud physics parameterization, which is originally designed to improve forecast of aircraft icing, but has also turned out to be very suitable to predict icing on ground based structures. Simulated ice loads on a standard reference object are compared to available measurements at the COST727 test stations in the UK, Germany, Czech Republic, and Switzerland. The results are displayed in high resolution icing maps showing accumulated ice loads, duration of icing and icing intensity.

## The relationship between chord length and rime icing on wind turbines

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Wallenius T., Technical Research Centre of Finland (VTT), Finland

Makkonen L., Technical Research Centre of Finland (VTT), Finland

Nicklasson P. J., Department of Computer Science, Electrical Engineering and Space technology, Narvik University College, 8515 Narvik, Norway

Sundsbø P. A., Department of Computer Science, Electrical Engineering and Space technology, Narvik University College, 8515 Narvik, Norway

Numerical simulations of ice accumulation on four different wind turbine blade profiles, from 450 kW, 600 kW, 1 MW and 2 MW wind turbines, were performed to determine how wind turbine size affects atmospheric icing. The simulations indicate that dry rime icing is less severe for larger wind turbines both in terms of local ice mass and in terms of ice thickness. A scaling factor for reducing ice thickness with increasing rotor radius is proposed.

**De-icing of wings – what is possible and what is not –**

Lars Bååth, Halmstad University

Wind power is one of the fastest growing industries in Sweden, and in the world, of today. Wind power is seen as a clean generation of electrical power and new taxes on green house gas emissions will make it a competitive source of energy. Large wind power parks are planned in Sweden to meet the ambitious plans. Especially the northern mountain regions, the coastal sea areas and the inner high plateau landscapes and surroundings have generated great interests for investors.

In general, all areas of Sweden do sometimes during the winter encounter times where icing may occur. When warm air lifts from the coastal seas onto the higher inland areas, it brings with it substantial amounts of water vapor. The water vapor then condenses to liquid water drop-lets when the air is cooled at higher altitudes. Such drop-lets can in sub-zero temperatures either freeze to snow or hail, or stay liquid as super-cooled drop-lets. Super-cooled drop-lets will directly freeze to form ice when they encounter a material to which it may give off energy, such as the wings of a wind turbine. Formation of ice on wind turbine wings is therefore not limited to the far north, but may occur on such southern sites as Bavaria where temperatures may reach just below zero degrees Celsius. Icing is very much a European problem.

This paper presents and discusses the ways and means, - what is possible and what is not -, to either heat water droplets or melt ice when formed on the wings of wind turbines. The situation is different from icing on wings of airplanes in that (1) the wings of wind turbines spend all of their time in the atmosphere where the risk of icing is highest and (2) the speed of wing to air varies over the wing where it is constant for an airplane. The form of the wind turbine wings also varies from tip to centre, to compensate for the varying relative air speed. Our pre-study presented here has concentrated on icing conditions at temperatures -10°C – 0°C and droplet sizes of 1-10 μm. Icing occurs also at much lower temperatures, but this will probably be because of direct freezing of water vapour to ice. This is presently outside the scope of our pilot project report.

We conclude that

- The form of the wing, especially on the contact area may be crucial to the icing problem.
- Also the nanometric structure of the wing surface can probably be designed so that the water droplets have a minimized contact area to the wing.

Our pilot investigation also suggests the following:

- Microwaves are much too inefficient to heat water or melt ice. Direct microwave devices should therefore not be developed. Indirect heating with microwaves is possible.
- Millimeter waves are sufficiently efficient, but the generation is most probably too inefficient to be of any practical use.
- Infrared waves are very efficient to heat water and melt ice and should be investigated.
- Heat conduction is also efficient and should be pursued. Using microwaves to heat the wing surface which then conduct heat to the water/ice is a very efficient and robust method.

Our pre-study suggests that the solution to avoid icing or de-ice wings of wind turbines most probably is not one single technology. The form and surface structure of the wings play important role for icing conditions. Both variables have to be modified depending on the latitude and atmospheric climate. The surface structure also has to be designed to vary over the wing, both along and across to be optimized for the mean conditions at the site. In addition, heating of the impact area, or at least the possibility to heat this, may be important to avoid loss of energy output due to ice.

Further research is required. We strongly suggest investigating the water droplet flow over the wing as function of the cross section form, and the contact with the wing surface as function of the surface structure (e.g. Lotus effect).

# A corrector for wind power estimation and its usage in estimating icing losses

Matthew C. Homola [a,1] Johan Byström [a] Per J. Nicklasson [a] and Per A. Sundsbø [a]

[a] *Department of Computer Science, Electrical Engineering and Space technology Narvik University College, 8515 Narvik, Norway*

**Abstract**

A better method for estimating the effects of atmospheric icing on power production of wind turbines is one of the specified objectives of the International Energy Agency (IEA) Annex XIX: Wind Energy in Cold Climates. One reason for this is because it is necessary to have an accurate estimate of production losses due to icing to determine if de-/anti-icing is worthwhile. Analysis of data from Nygårdsfjell windpark has shown that the IEC standard method for generating a power curve to estimate power production is not sufficient for accurately estimating power losses due to icing.

It is shown that that the 10 minute mean wind velocity does not properly quantify the energy content of the wind during a 10 minute period, but underestimates the energy content by significant amounts when there is a large variance in the wind speed. An explicit corrector is found which takes account of the standard deviation of the wind speed. This corrector is used in an alternative method for calculating the expected power production and is compared to the results given by the use of the IEC power curve reference.

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**Wind Energy in Cold Climates as a Bridge Between Onshore and Offshore**
Göran Ronsten, WindREN AB

**The past trend to deploy large offshore wind farms has largely come to a halt** due to a) the higher costs associated with offshore installations compared to onshore ditto, b) the galloping costs caused by the surge in demand for onshore wind turbines and c) the lack of key components and production capability. Therefore, a recent trend is an increased interest towards, generally less risky, onshore projects. The offshore market is still expected to take off but seems to be delayed until the conditions for large-scale offshore deployment have matured and the cheaper onshore boom has cooled down.

**Developers of onshore wind farms sometimes face resistance from locals.** Less conflict of interests may occur in remote areas, which may, or may not, be affected by icing. Consequently, if the wind resource and the grid infrastructure permit project development, one of the few remaining obstacles is icing.

**Icing of wind turbine rotor blades and wind sensors** will, in ice-infested areas, lead to low or no energy production during extended periods of time. The safety risk, caused by ice being thrown from the blades is not only important to consider thoroughly but may also lead to prohibition of operation with iced-up blades. Icing of rotor blades may also, due to the effects of unbalanced aerodynamic drag/lift and mass, cause a decrease in the useful life of the wind turbine.

**Icing frequency maps** could, if the existed and were reliable, serve as a basis for planning. However, these data are today scarce, inaccurate and unverified. Models like MM5/WRF and Hirlam/Harmonie need to be used and verified for this purpose. Icing is to be mapped in a similar manner as the wind resource. Icing measurements need to be carried out according to proposed standards.

**Energy production deficit maps**, where the energy production is influenced by not only wind but also icing, low temerature, and in some cases high turbulence, would in an ideal world be readily available for planning purposes. However, such items are scarce, inaccurate and unverified. The reasoning is the same as for "Icing frequency maps" described above. The combined results of wind and icing assessments in an energy production deficiency map, now just a dream in our minds, could serve as an important tool for project developers in icing climates.

**No commercially de- or anti-icing system** currently exists that is able to cope efficiently with medium to severe icing conditions. In fact, only one manufacturer; Enercon, has shown a clear intention to address this issue. The interest among other manufacturers varies from non-existent to awakening. While the interest is low at the corporate level, a current strong local demand for de-/anti-icing capability in Canada, US, Scandinavia, Eastern Europe and the Alps forces the manufacturers' national sales forces to reconsider their previous inattention to the challenge. It remains to be seen if the national sales organizations are successful in convincing the corporate levels to pay attention to icing of wind turbine blades.

**Government funded research** is often directed by a country's manufacturing industry. For the success of wind energy in cold climates, this might not be particularly good idea.

Abstract to Winterwind 2008

**Pioneering arctic wind power – 15 years ahead**

Esa Peltola (1), Timo Laakso (2)
(1) customer manager, wind energy, VTT Technical Research Centre of Finland
(2) vice president, wind power, Pöyry Energy

In 1993, 15 years ago, a 220 kW test turbine with electrothermal blade heating was installed on Pyhätunturi fjell in Finland. This event was preceded by some wind measurements on fjell tops showing high wind potential and tests with smaller turbines. The test turbine served as a development bed for ice prevention technology which led to first commercialisation in late 1990's. The systems, which were set up during the period of development and first commercialisation, are mostly in operation and can give valuable information on the appropriate strategies and design of ice prevention of large turbines and also to the design of wind farms in arctic environments.

Today we see that the expectations of late 1990's on the markets and development of wind power in arctic conditions have not been realized. This has been the case much because of the high growth in more conventional markets which has left little incentive to develop the technology for arctic conditions. The demand for arctic wind power solutions is growing as there are growing constraints to develop wind power in environmentally less demanding regions and as the technological development, costs and risks needed for deployment of offshore wind power are high.

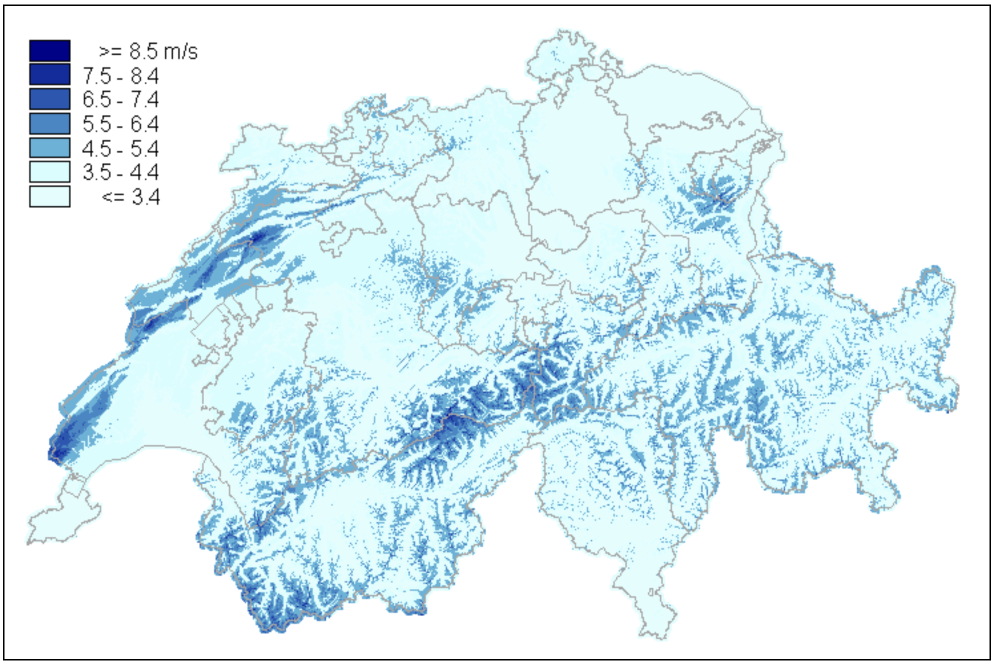
The paper first outlines the lessons learned during the past 15 years from the arctic wind power development in Finland. Based on that experience, paper discusses the development foreseen and needed – 15 years ago and 15 years ahead.

# Wind Power Development in the Swiss alps

**10 years of experiences, lessons learned and new projects.**

*Robert Horbaty, ENCO Energie-Consulting AG, Managing Director Swiss Wind Energy Association "Suisse Eole"*

## Wind Energy in Switzerland




*Most of the interesting wind energy y sites in Switzerland are located above 800m a.b.s.l., about 90 % of the entire wind potential of about 4'000 MW can be considered to be cold climate on icing sites.*

*From the actual installation, only the wind turbine in Collonges (Enercon E-82) are not affected by rime, ice and cold temperatures*

*Installation of the 900 kW-NEC-Micon turbine of Windpower AG at Entlebuch on 1000m.a.s.l*

**Feldmoos, Switzerland NEC-Micon 52/900, Arctic Version, 1’056 m.a.s.l**

*Icing is not a big problem on this site,  2- 3 times / winter the turbine has to shut down due to icing.*

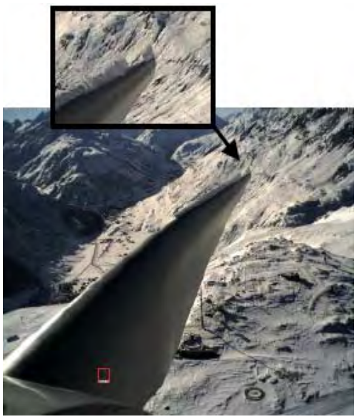
There is no blade heating device, the turbine shuts down automatically when the anemometer doesn’t not send any signal and the turbine is running. De-icing takes place with the sun, so ice throw occurs only about 30 m from the turbine.

**Grenchenberg, Switzerland, Bonus 150 kW, 1’300m.a.s.l.**

*On this site heavy rime ice occurs, but there are no possibilities to remove it – besides the radiation from the sun. This means down time up to one week.*

**Alpine wind test site in Switzerland, Enercon E-40, 600kW, Class 1, 2'350 m.a.s.l**

Thanks to the set up with measuring instruments from the Swiss Met Institute and a well equipped E-40, various research projects delivered results from this particular wind energy site, see also [Wind Test Site Gütsch]



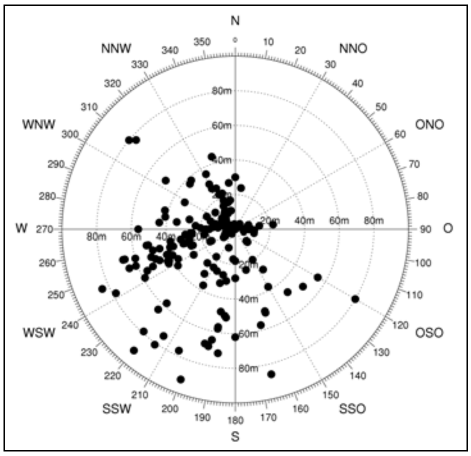
*Webcam on Hub of E-40*

*http://www.meteotest.ch/cost727/index.html*

At Mount “Gütsch”, 2’350 m.a.s.l near Andermatt in Switzerland, a interesting set up was installed in order to investigate the problems of icing on wind turbines under alpine conditions. Next to a test bench for anemometers and ice detectors from the Swiss Met Institute, there is a Enercon E40 class 1 wind turbine installed, equipped with various additional data collecting instruments:

- Wind speed at hub height
- Wind direction at hub height
- Air temperature at hub height
- Air humidity at hub height
- Liquid water content and droplet size
- Ice detector on the hub
- Ice detection by webcam

In addition, to that, a continuous observation of ice throw took place.




*Alpine Wind Test site Gütsch*

*Statistical records of ice throw on that site*

**Site assessment under cold climatic conditions (Gotthard pass 2’100 and Schwyberg 1’645 m a.s.l.)**

*Swiss developers accumulated over the years broad knowledge of site assessment under harsh climatic conditions*

*Bubendorf, 22.10.2008* *R. Horbaty*

## EU-"Icing of wind turbines" project to COST 727 and beyond

Bengt Tammelin, FMI

Cold climate wind energy research in retrospect (1991-2008) and where to go from now.

## Abstract for Winterwind08

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# Interaction between wind turbines and overhead tower lines in iced and non-iced conditions

The COST-727 Action ”Measuring and forecasting atmospheric icing on structures” was established in April 2004 to promote research on in-cloud icing, measurement on atmospheric icing, modelling of icing processes, improved forecasting systems, verification of existing icing sensors and mapping of icing occurrences and potentials in Europe. It includes information on measuring activities in Europe related to both wind turbines and electric overhead power lines. Concerns have been raised in several countries about the effect of wind turbine wake eddies on overhead lines (OHLs) and in particular tower lines close to wind farms. Many such wind farms are in icing prone areas. The presence of existing overhead tower lines prior to the erection of wind farms means that their line design took into account icing and aeolian vibration levels expected at the time. The presence of wind turbines close to overhead lines can affect these parameters and measurements are to be carried out to determine these effects. Germany has placed recommendations for the distance of OHLs from wind turbines in their National Normative Annexe (NNA) in the CENELEC European standard EN50341-3-4. A study has therefore started into whether this effect was real and significant and, if so, to lay out a programme of work to identify methods to avoid damage and specify recommendations for future OHL location with respect to wind turbines. The overall effect of the wake eddies could be to shorten the lifetime of OHL conductors due to increased vibration/fatigue periods for earthwires and turbulent air movement causing sub-span oscillations in phase conductors. Turbulence is an issue that can affect icing levels. This can affect the ‘$\alpha_1$’ factor in rime icing levels (Makonnen)

$$\frac{dM}{dt} = \alpha_1 \cdot \alpha_2 \cdot \alpha_3 \cdot w \cdot v \cdot A$$

where $A$ is the cross-sectional area of the object and $\alpha_1$, $\alpha_2$ and $\alpha_3$ are collision, collection and accretion efficiencies. Since the rapid growth in wind farms has occurred in recent years only, it is likely that conductor fatigue damage or changes in ice loads have yet to be seen in actual failures but they are potential future problems. Information in general indicates that the problem is less severe for lines situated around 5 rotor diameters of the nearest point of a wind turbine. The German study restricted OHLs from within 280m of wind turbines without appropriate damping and did acknowledge that even at this distance there was a high damage potential.

**The new Finnish wind atlas**

Bengt Tammelin, FMI

The work of providing a new numerical wind atlas for Finland has started. 72 months representing 6 years (reference period) will be simulated using the HARMONIE numerical weather prediction model with 2,5x2,5 km2 grid over the entire country, and further downscaled with WAsP to 250x250 m2 grid for the coast and other areas of major interest.