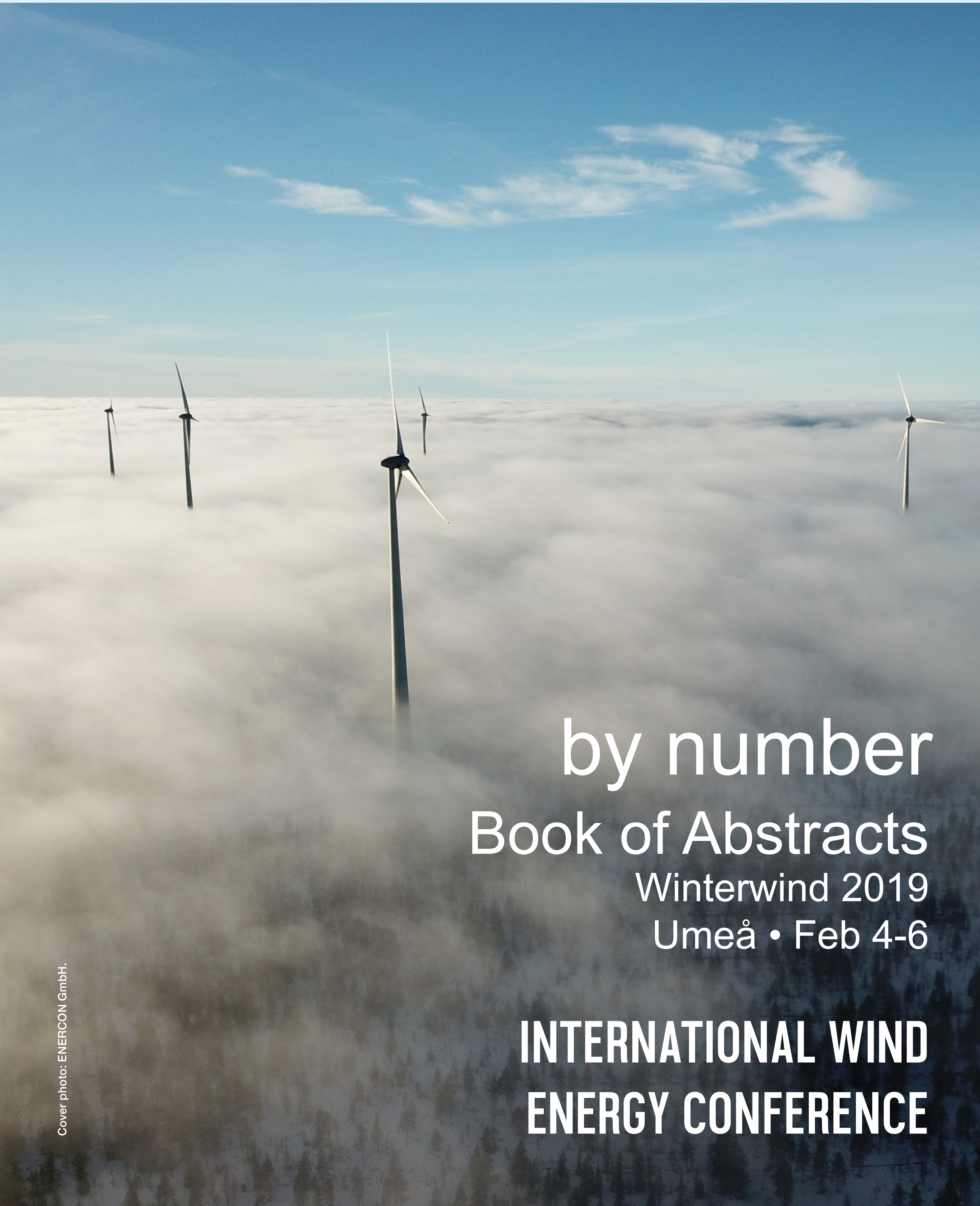
Winterwind

INTERNATIONAL WIND ENERGY CONFERENCE



by number

Book of Abstracts

Winterwind 2019

Umeå • Feb 4-6

INTERNATIONAL WIND ENERGY CONFERENCE

Cover photo: ENERCON GmbH.

4

MONDAY

FIELD TRIP DAY

10:00-18:00 — Field trip day (The time of return in Umeå is approx.)

18.00-20.00 — Poster and exhibition set-up

18:00-20:00 — Registration

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TUESDAY

08:30-10:30 — Registration and Exhibition

Main Hall

10:00-11:30

OPENING SESSION
Moderator: *Linda Vikström*

Welcome
Ulla Hedman Andrén
Director of Operations Swedish Windpower Association

Short introduction
Göran Ronsten
Program coordinator

KEYNOTE PRESENTATIONS

Joint efforts towards a fossil free future
Daniel Gustafsson, Head of Development Sweden Vattenfall (55)

Why we do all the things we do
Karin Bodin, CEO Polarbröd (56)

OPEN INNOVATION CONTEST

Open Innovation Contest

Jury
Linus Palmblad, Åsa Elmqvist, René Cattin & Ville Lehtomäki.

led by Tanja Tränkle, RISE Research Institues of Sweden (57)

11.30-13.00 — Lunch

12:30-12:55 — **Poster presentations** moderated by *Ingvar Bartholdsson and Carl-Arne Pedersen*

- Clear air in cold climates: performance of continuous-wave ground-based lidar — *Wulstan Nixon, ZX Lidars (33)*
- Wind-farm-scale blockage in stable regime associated with cold climates — *Till Beckford, DNV GL, Netherlands (42)*
- Verification of numerical weather model predictions and wind turbine production-loss due to ice using ceilometer measurements — *Niklas Sondell, Modern Energy, Sweden (44)*
- Load monitoring and lifetime assessment for wind turbine towers — *Carsten Ebert, Wölfel Wind Systems GmbH, Germany (49)*
- Icing Predictions for the Canadian Wind Energy Industry — *Simon-Philippe Breton, Environnement et Changement Climatique Canada (ECCC), Canada (54)*

13:00-14:30

Väven	P5 Event	P5 Room 1
Health, Safety and Environment (HSE) incl. ice throw and noise *Chairs: Liselotte Aldén and Magnus Fjelde*	**De-/anti-icing including new technologies, ice detection & control incl. standards** *Chairs: Chairs: Åsa Elmqvist and Shigeo Kimura*	**Forecasting cloud physics and aerodynamics** *Chairs: Emelie Bolin and Sten Lillienau*
IEA Wind Task 19: International Recommendations for Ice Fall and Ice Throw Risk Assessments *Andreas Krenn, Energiewerkstatt e.V. (20)*	Unmanned aerial vehicles (UAVs) in cold climate and wind energy applications, Richard Hann *Norwegian University of Science and Technology (NTNU), Norway (3)*	Forecasting of atmospheric icing – validation and applications within wind energy *Leon Lee, Kjeller Vindteknikk (25)*
Importance sampling for ice throw in QBlade *Matthew Lennie, Technishe Universitat Berlin (18)*	Using 1Hz data to monitor turbine integrity *Carla Ribeiro, DNV GL (39*	Numerical Weather Prediction of Supercooled Low Stratus Clouds over Heterogeneous Surfaces using the MUSC One-Dimensional Model: First Results *Erik Janzon, Uppsala Universitet (9)*
Uncertainties and choices in ice risk assessments - How to get the results you want *Markus Drapalik, Institute of Safety and Risk Research, University of Natural Resources and Life Sciences, Vienna, AT (15)*	Proof of concept of a tower based blade icing detection system for low to moderate icing sites *Pieter Jan Jordaens, OWI-Lab (17)*	Improving short-term forecasting of turbine icing using machine learning *Till Beckford, DNV GL, UK (6)*
		Probabilistic forecasting of wind power production losses due to icing *Esbjörn Olsson, SMHI (31)*

14.30-15.30 — Break

15:00-15:25 — **Poster presentations** moderated by *Bengt Göransson*

- Nabralift Tower: Challenges of Icing Conditions in Open Tower Structures — *Emilio Rodriguez Saiz, Nabrawind Technologies, Spain (48)*
- On the formation of an icing atlas in Austria — *Heimo Truhetz, Wegener Center for Climate and Global Change (WEGC), University of Graz, Austria (38)*
- A new approach for the assessment of ice induced power losses — *Patrice Roberge, Université Laval (7)*
- The effect of atmospheric aerosol particles on cloud icing rate — *Antti Ruuskanen, Finnish Meteorological Institute, FI (32)*

15:30-17:00

Health, Safety and Environment (HSE) incl. ice throw and noise *Chairs: Olivia Andrén and René Cattin*	**Pre-construction site assessment, measurements, models and standards** *Chairs: Jeanette Lindeblad and Sven-Erik Thor*	**Commercial** *Chairs: Eva Sjögren and Matthew Wadham Gagnon*
A cross-comparison of the IceThrower database with 10 years of SCADA and meteorological forecast data - What can we learn? *Rolv Bredesen, Kjeller Vindteknikk, NO (35)*	WICE 2.0 – The new generation of ice loss models *Stefan Söderberg, DNV GL, SE (23)*	Blade based ice detection – knowledge base for efficient operation in cold climate conditions *Timo Klaas, Wölfel Wind Systems GmbH (47)*
R.Ice: Risk Analysis of Wind Turbine Icing *Alexander Stökl, Energiewerkstatt e.V. (21)*	Validation of pulsed Lidar as ice detector *Timo Karlsson, VTT, FI (11)*	Presenting ice detector research results from wind turbine field tests and icing wind tunnel tests *Tatu Muukkonen, Labkotec Oy, FI (43)*
State of the art risk reduction of wind power facilities *Daniel Swart, Lloyd's Register Consulting (28)*	Effective validation for time series icing modelling using operational SCADA data *Christian Jonsson, ABO Wind, DE (8)*	fos4X experience improving the performance of wind farms installed in cold climate *Christian Lindemann, fos4X GmbH (19)*
	Cold climate test center in Sweden *Martin de Maré, RISE Research Instítues of Sweden (52)*	Increased turbine efficiency during icing conditions by means of pre-emptive blade heating control *Michael Moser, eologix sensor technology gmbh, AT (45)*
		Field Validation of a Hot-Air Blade Deicing Retrofit *Daniela Roeper, BorealisWind, Canada (12)*
		Is wind industry ready for disruptive solutions? *Martins Ummers, Aerones, Latvia (2)*
		To heat or not to heat? *Xavier VANWIJCK, XANT, Belgium (46)*

Case study; controlled environment in up-tower blade repairs
Ville Karkkolainen, Bladefence Oy (14)

Clear air in cold climates: performance of continuous-wave ground-based lidar
Wulstan Nixon, ZX Lidars (33)

Nabralift Tower: Challenges of Icing Conditions in Open Tower Structures
Emilio Rodriguez Saiz, Nabrawind Technologies, Spain (48)

17:00- **Mingle and poster presentations in exhibition hall.**
Open innovation awards, based on presentations in Session 1, will be presented by Ville Lehtomäki at 17:30.

19:00- **Networking dinner - only for pre-booked**

6 WEDNESDAY

	Väven	P5 Event	P5 Room 1

09:00-10:30 — Väven

Wind turbine manufacturers (commercial)
Moderator: Linda Vikström

Technology retrofit and service approach for performance optimisation in cold climates
Ulrik Rydstroem, Siemens Gamesa Renewable Energy (41)

Nordex advanced Anti-Icing System for N149/4.0-4.5
Konrad Sachse, Nordex Energy GmbH, DE (5)

ENERCONs strategies for minimizing and assessing icing losses
Julian Schödler, ENERCON, DE (27)

Vestas Cold Climate Solutions
Brian Daugbjerg Nielsen, Denmark (53)

10.30-11:30 — Break, Poster presentations moderated by *Jeanette Lindeblad*

- Blade based ice detection – knowledge base for efficient operation in cold climate conditions — *Timo Klaas, Wölfel Wind Systems GmbH (47)*
- Presenting ice detector research results from wind turbine field tests and icing wind tunnel tests — *Tatu Muukkonen, Labkotec Oy, FI (43)*
- fos4X experience improving the performance of wind farms installed in cold climate — *Christian Lindemann, fos4X GmbH (19)*
- Field Validation of a Hot-Air Blade Deicing Retrofit — *Daniela Roeper, Borealis Wind, Canada (12)*

11.30-13:00

Benchmarking
Chairs: Tanja Tränkle and Andreas Krenn

How efficient is your blade heating?
André Bégin-Drolet, Canada (4)

Performance benchmark analysis of four Ice prevention system
Timo Karlsson, VTT, FI (10)

Benchmark of four Blade-based Ice Detection Systems
Paul Froidevaux, Meteotest AG, CH (36)

Wind turbine rotor icing detectors performance evaluation
Charles Godreau, Nergica, Canada (22)

Design and construction
Chairs: Helena Wickman and Stefan Söderberg

Construction of wind farms in cold climates areas – Owner's Engineer experiences
Joachim Binotsch, Ramboll, Germany (30)

Design features of wind diesel hybrid power plants in Russian Arctic climate, Viktor Elistratov, Science-education center «Renewable energy sources»
Peter the Great St. Petersburg Polytechnic University, Russia (16)

Icing alleviation for wind turbines with no ice-protected blades
Masafumi Yamazaki, Kanagawa Institute of Technology (34)

Laboratory and full-scale testing, small wind turbines
Chairs: Carla Ribeiro and Martin de Maré

Validation of Droplet Size in the VTT Icing Wind Tunnel Test Section
Tuomas Jokela, VTT Technical Research Centre of Finland Ltd (24)

Siemens Gamesa test case: extreme cold start-up validation of a wind turbine gearbox by the use of a large climatic test chamber
Pieter Jan Jordaens, OWI-Lab (51)

Industrial research on the design of wind turbines for icing conditions
Inken Knop, Technische Universität Braunschweig, DE (40)

EFAFLU test case: cold start-up validation of transformer pumps by the use of a large climatic test chamber
Daniele Brandolisio, OWI-Lab, BE (50)

13:00-14:00 **Lunch**

13:30-13:55 **Poster presentations** moderated by *Fredrik Lindahl*

- Case study; controlled environment in uptower blade repairs — *Ville Karkkolainen, Bladefence Oy (14)*
- To heat or not to heat? — *Xavier VANWIJCK, XANT, Belgium (46)*
- Increased turbine efficiency during icing conditions by means of preemptive blade heating control — *Michael Moser, eologix sensor technolocy gmbh, AT (45)*
- Is wind industry ready for disruptive solutions? — *Martins Ummers, Aerones, Latvia (2)*

14:00-15:00

Grand finale Next?
Moderator: Linda Vikström

IEA Wind Task 19 – key results from 2016-2018 and future plans 2019-2021
Ville Lehtomäki, KjellerVindteknikk, FI (26)

Q&A from the audience

14:40-14:50 Summary of Conference

14:50-15:00 Final words
Ulla Hedman Andrén, Director of Operations Swedish Windpower Association

R&D areas/s: 02. De-/anti-icing including new technologies, ice detection & control incl. standards, Heavy lift drone usage for wind turbine maintenance

Is wind industry ready for disruptive solutions?

Martins Ummers, Aerones, Latvia

Janis Putrams, Dainis Kruze, Endijs Bernics (Aerones)

When we come up with an idea of building heavy lift drone nobody believed except ourselves. When we made our first prototype with operational lifting power of 150kg we got a massive recognition via media. When we started to offer our technology to wind energy we again faced with disbelief to our technology. We are stubborn enough not to quit but deliver the most advanced technology. We have developed three technologies which we start to deliver at the end of 2018- cleaning, deicing, and hydrofobic coating apply. Others will come later, like painting of warning signs, checking lightning system of the blade, drainage drilling in the top of the blade for condensate, taping application and repair of small cracks. We applied for a grant for a research project called "Heavy lift drone technology for wind turbine maintenance". We faced with a challenge to get a partners who own WTG in order to test coating materials. It wasn't easy to get some. And I had a question "Is wind energy sector ready for disruptive solutions"?

Web site: https://aerones.com/eng/wind_turbine_maintenance_drone/

Short biography: Bachelor in mechanics, Engineer's degree in vehicle maintenance, MBA, joined Aerones on 2018. Mainly focused on customer relations and sales. Willing to bring to the society Solutions with sustainable results.

R&D areas/s: 02. De-/anti-icing including new technologies, ice detection & control incl. standards, 13. Other

Unmanned aerial vehicles (UAVs) in cold climate and wind energy applications

Richard Hann, Norwegian University of Science and Technology (NTNU), Norway

Richard Hann (NTNU)

In recent years there has been a strong development and an increased utilization of unmanned aerial vehicles (UAVs). These automated drones are suitable for a wide range of applications and are used in many different industry areas today. Cold climate conditions are a very special challenge for UAVs that has only recently shifted into the focus of research.

The physical mechanisms leading to icing on wind turbines and fixed-wing UAVs are highly related to each other, as they both operate at flow velocities of the same order of magnitude. This does distinguish them from aircraft icing, which is typically experiencing much higher velocities and Mach-numbers. Therefore, the same modeling and simulation tools that are used for UAVs can also be applied for rotor blades. This is in particular relevant when it comes to the validation of these simulation tools. The most widespread ice protection method on UAVs are electrothermal systems. These are closely related to the anti- and de-icing systems implemented on wind turbines. Moreover, both UAVs and wind turbines face very similar operational challenges. For example, the need for reliable and autonomous icing detection, energy efficient icing protection control systems and low maintenance design.

This study discusses the overlapping research areas between UAV icing and wind turbine icing. Common questions are for example the impact of icing and frost on aerodynamic performance degradation, impact of icing on structural loads, and optimization of energy demand of icing protection systems. Furthermore, the use of cold climate certified UAVs in the wind energy sector is discussed. There are several applications with highly beneficial prospect for the future. For instance, drones are already operated today for blade inspection and maintenance purposes. However, there is a significant unused potential to apply drones with icing protection for specialized cold climate wind energy challenges. Examples for this are the in-situ forecasting of icing or autonomous icing detection for wind turbine farms.

Web site:

Short biography: Richard Hann graduated as an aerospace engineer (Dipl.-Ing.) at the University of Stuttgart in 2013. He is a specialist for computational fluid dynamics (CFD), computational aeroacoustics (CAA) and icing simulation. Richard has been involved with cold climate wind energy since 2011 and has focused on several topics such as anti-icing, performance degradation and noise generation. In the past he collaborated with the wind turbine manufacturer Kenersys GmbH and also with the Technical Research Centre of Finland (VTT). Richard has started a PhD at NTNU in 2016 on the topic of icing simulation.

R&D areas/s: 02. De-/anti-icing including new technologies, ice detection & control incl. standards, 04. Operational experiences incl. performance optimization, big data, production losses and repairs, 07. Laboratory and full-scale testing, small wind turbines

How efficient is your blade heating?

André Bégin-Drolet, Canada

Patrice Roberge (Université Laval, Canada), Jean Lemay (Université Laval, Canada), Jean Ruel (Université Laval, Canada)

Blade heating, or any ice protection systems (IPS), can improve wind power production in cold climate. However, as any system, its limitations are not always easy to understand. It has been observed on many sites that when harsh conditions prevail wind turbine IPS may become inefficient. Then how can we rely on them? Why is your turbine down even though blade heating has been activated? What should you expect from a wind turbine manufacturer IPS? These are all questions that will be addressed in this presentation. We have analyzed the performances of more than 100 heated wind turbines located within a 10km radius in eastern Canada over a 2-year period. More than 26000 wind turbine stoppages caused by icing were recorded even though all wind turbines were equipped with IPS. A 1D heat transfer model of a heated blade was developed to explain the reasons related to those stoppages. This model was used to generate the IPS performance envelope, a tool that can be used to characterize the efficiency of an IPS. The IPS performance envelope is a concept used to predict the behaviour of a wind turbine and its simplest form relies only on 2 external parameters that are widely available: wind speed and air temperature. If IPS performance envelope were made available by wind turbine manufacturers, wind developers could use them to select the appropriate system based on the historical data from a wind test site and wind operators could better understand the behavior of the turbines they use.

Web site: http://www.gmc.ulaval.ca

Short biography: André Bégin-Drolet is a professor of mechanical engineering at Université Laval in Canada. His research, in the wind energy sector, focuses toward improving wind power production in cold climate where atmospheric icing is prevalent. His research led him to the design of a patented smart sensor, the Meteorological Conditions Monitoring Station (MCMS), adapted to measure meteorological conditions in cold and icy environment. Moreover, he is very interested in developing methods to improve the production of wind energy in icing conditions using this novel instrument. Wind is also part of his hobbies as he is an active racing sailor who loves to perform in both inshore and offshore regattas.

R&D areas/s: 06. Wind turbine manufacturers – cold climate solutions, test centres, turbines and components

Nordex advanced Anti-Icing System for N149/4.0-4.5

Konrad Sachse, Nordex Energy GmbH, DE

Ines Runge (Nordex Energy GmbH), Stefan Magnus (Nordex Energy GmbH), Jochen Birkemeyer (Nordex Energy GmbH)

Since 2010 Nordex has been offering an Anti-Icing System (AIS) for its various wind turbines. In 2018 Nordex has done the next step, which was introducing the further advanced AIS for the N149/4.0-4.5. The advanced system offers very high performance for heavy icing conditions using a new technology for the heating element. The new technology improves the robustness of the system while reducing the complexity and allowing the system to continue operation in case of local defects. Additionally the control system and power supply is further optimized and simplified. The nominal power is increased to cover a larger surface area without decreasing the heating power per square meter.
The Nordex advanced AIS has experienced some changes to maximize the reliability and to achieve highest maintainability. Nevertheless the key features of the Nordex AIS remain unchanged: the AIS is fully operational during turbine operation, it provides high energy deposition on the blade surface to minimize ice formation even in strong icing conditions and the turbine availability and production can be significantly increased.
The components of the advanced AIS have been intensively tested and qualified regarding the heat distribution as well as the lightning protection system since 2013. A brief overview of test results and field experiences will be presented.

Web site: http://www.nordex-online.com

Short biography: Mr. Konrad Sachse was born in 1983 and received his Diploma of Physics in 2008. He then worked in the field of nanotechnology research and had the chance to visit research institutes all over the world. Since 2013 he has been working on the Anti-Icing System in the blade engineering department at Nordex Energy. In 2018 he was appointed Expert Engineer for the Nordex Anti-Icing System.

R&D areas/s: 01. Forecasting, cloud physics and aerodynamics

Improving short-term forecasting of turbine icing using machine learning

Till Beckford, DNV GL, UK

Beatrice Brailey (DNV GL, UK), Ayumu Suzuki (DNV GL, UK)

Abstract
DNV GL will present improvements to its icing forecasting model through machine learning and the use of liquid water content forecasts.
In 2015, DNV GL designed a model which estimates icing losses as part of a short-term wind energy forecast, using an ensemble of meteorological condition forecasts to predict the presence of icing conditions. The model uses an adapted Makonnen model to calculate ice load on turbine blades, and a power reduction model to make icing corrections to the forecast energy production. Analysis shows that while the adapted Makonnen model of ice accretion is very accurate, the ability to predict the onset of icing conditions is more challenging. A new model has been developed that takes advantage of the ability of machine learning classification models to find patterns in multivariate data sets, and introduces liquid water content into the ensemble of meteorological forecasts.
The original model was shown to improve forecast accuracy, reducing annual Mean Absolute Percentage Error (MAPE) by up to 1%, and reducing MAPE by up to 5% for icy months. In this new validation, the improved model has been benchmarked against the original using 2 years of SCADA data from 3 wind farms in Sweden. It shows significant improvement in the accuracy of short-term forecasting of turbine icing, and will provide a financial benefit to end-users of icing forecasts used within DNV GL's wind power forecasting system. DNV GL has also carried out a "market value analysis", showing the approximate increase in revenue that can be generated by trading the resulting forecasts on the Elspot day-ahead energy market.
Icing has been shown to cause significant power losses for wind turbines in cold climates, such as Scandinavia. Studies have shown that over the course of a year wind farms can lose up to 13% of power due to icing, with monthly losses up to 50%. Individual icing events can lead to full power loss for a wind farm for over a week at a time. Quantitative fore-warning of such events is therefore a necessary requirement in incorporating the generation from these wind farms on the grid system. DNV GL has been providing short-term wind power forecasting services since 2003 globally for TSOs, utilities and asset operators, and currently forecasting for over 50GW of total installed capacity. We have recognised that forecasting icing events accurately is crucial for both AO&M purposes and for energy trading in some regions, and therefore have continuously investigated methods to better capture these events.

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Web site: https://www.dnvgl.com/services/forecaster-introduction-3848

R&D areas/s: 01. Forecasting, cloud physics and aerodynamics

Short biography: Till Beckford has been working in the renewable energy sector with DNV GL since 2012. Working in the Renewable Energy Analytics department, Till focuses on undertaking analyses of wind farms throughout their life cycle – from project development through to operational analyses. In his current role, Till leads a team of engineers serving the Nordics & Baltics markets and is the technical lead for DNV GL's pre-construction services. Till has worked on some of the largest wind farms in northern Europe and has extensive experience in Cold Climate projects. Till has a Masters in Mechanical Engineering from the University of Bath.

R&D areas/s: 03. Pre-construction site assessment, measurements, models and standards

A new approach for the assessment of ice induced power losses

Patrice Roberge, Université Laval

Jean Lemay (Université Laval, CA), Jean Ruel (Université Laval, CA), André Bégin-Drolet (Université Laval, CA)

Predicting precisely the potential losses caused by ice formation on wind turbines on a given site is a challenge that has yet to be resolved. The current preferred approach to assess the losses is achieved by interpolating data coming from nearby meteorological stations. The method is limited to the prediction of the duration of the icing events and its precision is restricted by the proximity of the stations. The impact of icing on the turbine is subtle and not only depends on icing occurrence, but also on its severity, the temporal variations of ambient conditions and the characteristics of the ice protection system (IPS) of the wind turbine. In this presentation, a method of site assessment using field data retrieved by a meteorological conditions monitoring station (MCMS) is described. This approach presents the advantage to take into account the temporal sequence of the ambient conditions that can have important implications on power production. The measurement of droplet impingement flux combined to the ambient conditions (wind speed, temperature, humidity, ...) and the wind turbine state (running, idling, de-icing, anti-icing, …) are used to model the ice thickness along the blade span. This model, based on the accretion model of Makkonen, uses a 1D approach to compute the IPS efficiency. Thereafter, the ice thickness on the different sections of the blade is linked to the power production using a neural network. The network is trained using the thickness, the wind speed, the ice density and the actual power production of the turbine. This method has already shown promising results. With a well-trained network, the method could allow the accurate prediction of production loss of a turbine to be installed on a given site by retrieving the data of a MCMS. Knowing the fraction of the annual production loss due to icing is crucial for project managers, since it can influence greatly the investment.

Web site:

Short biography: Patrice is currently doing his master's degree in mechanical engineering at Laval University in André Bégin-Drolet's lab. He has been working on the operation of wind turbines in cold climates for 3 years where he had the chance to contribute in the development of an ice detection device. This opportunity allowed him to develop skills in understanding thermal behaviors, in modeling various systems and in programming. He completed his bachelor's degree in physical engineering with a distinction mention. He is a very curious person that loves to learn and understand the why and the how of the everyday phenomena. In addition to American football, he is passionate about trekking and most of the outdoor activities, especially in the winter (skiing, snowshoeing).

R&D areas/s: 03. Pre-construction site assessment, measurements, models and standards

Effective validation for time series icing modelling using operational SCADA data

Christian Jonsson, ABO Wind, DE

Daniel Ramos (ABO Wind, DE), Stefan Klose (ABO Wind, DE), Pau Casso (Vortex, ES) , Albert Bosch (Vortex, ES) , Gil Lizcano (Vortex, ES)

Effective validation is the key to enhancing capabilities to model the impact icing has on wind turbine operation. The methodology of validation is challenging, and does itself merit careful consideration; the best set of metrics for testing a model against a specific observational dataset is rarely obvious. This is particularly true when the aim is for the model to achieve a good time series representation of icing events, rather than just aggregates such as a long-term annual production loss. Furthermore, successful validation methodology is critical for developing methods to tune a model with available observational data (e.g. correct for bias).

The development of successful validation strategies requires thorough understanding and investigation of both the model itself and the data against which it is to be validated. Vortex and ABO Wind have engaged in a collaboration to combine expertise in atmospheric modelling with expertise in wind turbine operation, ice detection systems and wind measurements, aiming to determine how best to use different types of datasets from operational wind turbines to validate an icing model. Using a set of case studies, an investigation has been carried out to explore how to interpret and process icing-related data from wind turbines, what key aspects the model needs to capture for different applications, what variables provide the most useful comparison between model and observations, and how the comparison can be best utilised to draw conclusions about accuracy of model inputs, parameters and dynamics.

The work focuses entirely on time domain analysis of wind turbine icing. Hourly time series of a high resolution WRF mesoscale modelling stream, driven by ERA5 Reanalysis, were produced for a set of validation sites across Europe. For each site, icing occurrences and characteristics were determined from observed SCADA records (including data from ice detection systems, where available) and analysed in conjunction with the modelled icing rate and atmospheric conditions (including temperature, stability, wind speed and in-cloud moisture). To guide the investigation into validation methodology, it was considered in detail how modelled and observed icing compare in terms of event synchronicity, amplitude and cycle.

The results of the work provides insights into how available operational SCADA data can be made more effective use of for validation tasks necessary to achieve robust applications of model data, and into how icing modelling time series can be employed and interpreted. While standard operational SCADA datasets have limitations in this context, they have the significant advantage of abundant availability, and with effective validation methodology large validation datasets bring significant value. The work has allowed identification of different scenarios for model versus detected icing behaviour, representing different climatic conditions, operational restrictions and types of technology. For each of these, ways to classify systematic model errors (for post-processing bias correction applications) and estimate modelling uncertainty were identified, which also open up interesting topics for further investigation.

Web site: https://www.abo-wind.com/en/

Short biography: Christian Jonsson joined the wind industry in 2013, upon having completed a master's degree in mechanical engineering and spent a brief period working on academic research in fluid mechanics. He started his career in industry as an independent technical advisor, with a focus on energy yield assessment. During this time, he undertook assessments of many cold-climate sites in the Nordic region and was deeply involved with the topic of wind turbine icing. In 2017, he joined project developer and operational management services provider ABO Wind, supporting development activities with expertise on aspects related to wind resource, meteorological conditions and energy production, and supporting operational management activities with turbine performance analytics. He is particularly involved with the company's undertakings in Finland and is part of the internal turbine icing expert group. He has a keen interest in modelling and analysis across a broad range of topics related to wind energy, and in techniques and software development for data analytics. In his free time, he enjoys running ultramarathons and rock climbing.

R&D areas/s: 01. Forecasting, cloud physics and aerodynamics

Numerical Weather Prediction of Supercooled Low Stratus Clouds over Heterogeneous Surfaces using the MUSC One-Dimensional Model: First Results

Erik Janzon, Uppsala Universitet

Heiner Körnich (SMHI, SE), Johan Arnqvist (Uppsala Universitet, SE), Anna Rutgersson (Uppsala Universitet, SE)

Wind turbines located in cold climates and in elevated terrain are often at risk of ice accretion when supercooled water droplets within clouds interact with the surface of the turbine blade structure. The accurate forecast of generation losses during these icing events is necessary for the operation of wind farms. In order to accurately predict wind generation losses, meteorological input is required from numerical weather prediction (NWP) models that are in turn required to resolve the complex interaction between the surface and the atmosphere—more specifically the wind, temperature and clouds within the atmospheric boundary layer. Surface-boundary layer interactions are sub-grid scale processes within operational NWP models and must be parameterized. To further add to the complexity wind farms are often located within regions of heterogeneous land use, which can hinder accurate representation of the surface in the NWP model. The impact of the land-use on the low-level clouds can potentially be important for the forecasting of icing and related power generation losses. This study will explore the sensitivity of land use on the forecast of low-level supercooled clouds using a one column model called Modèle Unifié, Simple Colonne (MUSC), which was developed in a collaboration between Météo-France and the Aladin and Hirlam consortiums. MUSC is a one-dimensional version of the HARMONIE-AROME operational mesoscale model, which utilizes the SURFEX surface scheme. First results will be shown and validated against ceilometer data from the Swedish Hornamossen meteorological observation site, which will be used to detect periods of low-level cloud cover.

Web site:

Short biography: Erik Janzon is a meteorology PhD student from the United States in the Department of Earth Sciences at Uppsala Universitet. Erik completed his Bachelor's degree in Meteorology in 2009 at Northern Illinois University and his Master's degree in Atmospheric Science at the University of Wisconsin-Madison in 2012. Prior to his studies at Uppsala Universitet, Erik worked as an operational weather forecaster for real-time energy trading at Avangrid Renewables and as a fundamentals meteorologist at Portland General Electric in Portland, Oregon USA. In his spare time, Erik plays the electric guitar and enjoys exploring the outdoors.

R&D areas/s: 04. Operational experiences incl. performance optimization, big data, production losses and repairs

Performance benchmark analysis of four Ice prevention systems

Timo Karlsson, VTT, FI

Ville Lehtomäki (Kjeller Oy, FI), Simo Rissanen (VTT, FI)

The number of ice prevention systems (IPS) for wind turbines in the market has improved over the past few years, with most large wind turbine manufacturers offering their own solutions and an increasing number of third-party system providers entering the market. Despite the increased increased number of IPS available in the market, there is a lack of publically available analyses on IPS performance. There is a market demand for an independent, neutral, third party analysis of IPS performance and maturity. A joint industry project between Vattenfall AB, BlaikenVind AB, Taaleri Energia Oy and VTT has been set up to meet this demand for an independent evaluation.
In this project, production data from several sites with turbines equipped with IPS has been analysed to assess both the IPS performance and the system maturity. The goals of the project were to assess:

1. The production losses due to icing
2. Gain of production due to IPS (difference between turbine without IPS and a turbine with IPS)
3. IPS maturity and reliability using system availability as a metric

Data was made available from four different sites in Europe and Scandinavia for this project. On these four sites, there were turbines from four different vendors (Dongfang, Enercon, Nordex, Vestas).
For the purposes of this project, a new method for analysing the SCADA data of a turbine with an IPS system was developed. The solution is based on the existing T19IceLossMethod [1], but extends it allowing to evaluate icing losses and IPS performance on any turbine. The source code for the solution will be made available in 2019 Icing conditions on the sites and the potential losses of a turbine without IPS on the analysed sites were evaluated using VTT WIceAtlas and a numerical weather model. The numerical weather model results were provided by Kjeller Vindteknikk.
The results of this project are presented in a publically available report [2], and will be used in the IEA Wind Task 19 "Ice Protection System Warranty Guidelines" in the future. In this presentation the method to analyse the production gain of an IPS system, along with anonymized results from four different sites, will be presented.

References

[1] IEA Wind Task 19, "T19IceLossMethod Free Software Start Up Page," IEAwind Task 19, 2017. [Online]. Available: https://community.ieawind.org/task19/t19icelossmethod.
[2] Ville Lehtomäki, Timo Karlsson & Simo Rissanen: Wind Turbine Ice Protection System Benchmark Analysis, VTT Technology 341. https://www.vtt.fi/inf/pdf/technology/2018/T341.pdf

Web site: https://www.vttresearch.com/services/low-carbon-energy/wind-energy

Short biography: My background is in industrial automation and electrical engineering. I've worked in wind power for nearly ten years now, the last 7 at VTT on cold climate wind. During this time I've worked on different parts of the cold climate wind field from ice detection to ice prevention system development and from condition assessment to production data analysis.

R&D areas/s: 03. Pre-construction site assessment, measurements, models and standards

Validation of pulsed Lidar as ice detector

Timo Karlsson, VTT, FI

Paul Mazoyer (Leosphere, FR), Andrea Rouanet (Leosphere, FR)

Ice accretion on wind turbine blades is a problem when operating wind turbines in cold climates. Icing causes production losses and falling ice can be a health and safety issue. Because of this ice detectors are often installed on operating turbines, and measuring icing conditions is important during site assessment in icing climate sites.

In Scandinavia and central Europe, the most common form of icing is in-cloud icing. In a cloud, even when temperature is below zero there is some amount of liquid water. These cloud droplets will freeze when they come in contact with a surface when temperatures are below zero Celsius. If a cloud is low enough ice will accrete on wind turbine blades that pass trough the cloud.

Conventional ice detectors are often spot measurements that measure icing on the sensor itself. As turbines get larger, the distance from nacelle to blade tip grows, and the probability that the icing conditions are different also grows. During site assessment, as turbines get bigger and hub heights grow, in order to measure icing conditions at relevant heights - tip height - becomes increasingly difficult.

In order to deal with these issues a remote sensing method for icing is needed. VTT has developed a method to use a conventional wind LIDAR as an ice detector [1]. The method makes remote sensing of icing conditions possible remotely, without purpose-built hardware. LIDAR ice detector is an algorithm that uses data collected from an unmodified LIDAR. Ice detection with LIDAR has the same benefits as wind speed measurement with LIDAR: portable device, remote sensing, multiple heights, no construction required.

Together with Leosphere and other partners, VTT has conducted a beta test program of the LIDAR ice detector method. In the test program, the effectiveness of the ice detection method is tested against conventional ice detectors and the icing measurement accuracy and reliability of the LIDAR-based method is evaluated. In the presentation, basic principles of method are presented together some results of the beta test program.

References

[1] Esa Peltola, Petteri Antikainen, Andrea Vignaroli: Arrangement and method for icing detection, US Patent 2014/0192356

Web site: https://www.vttresearch.com/services/low-carbon-energy/wind-energy

Short biography: My background is in industrial automation and electrical engineering. I've worked in wind power for nearly ten years now, the last 7 at VTT on cold climate wind. During this time I've worked on different parts of the cold climate wind field from ice detection to ice prevention system development and from condition assessment to production data analysis.

R&D areas/s: 02. De-/anti-icing including new technologies, ice detection & control incl. standards

Field Validation of a Hot-Air Blade De-icing Retrofit

Daniela Roeper, Borealis Wind, Canada

Daniela Roeper, Borealis Wind, Canada

Borealis Wind has developed a hot air blade de-icing retrofit. Development work began in September 2014, at which point Borealis began by talking to wind farm owners and operators to better understand their needs with regards to de-icing. It was found that the installation cost and maintenance cost required for currently available technologies outweighed the benefit of de-icing. With this knowledge, Borealis Wind then began to focus on a system that would be installed inside the blade, therefore easy to maintain and able to be installed without using a crane or rope access. Technical development continued for 3 years. Borealis Wind began field trials of the de-icing system in January 2018, on Siemens 2.3 turbines in Canada. This presentation will focus on the lessons learned from these field trials, specifically on the installation process, maintenance requirements and de-icing performance. The installation process is slightly longer than expected, requiring 7 working days, with 4 technicians to complete. The de-icing performance exceeded expectations, the system is able to remove ice down to -30C, and prevent ice down to -4C. Furthermore, the system is able to shed ice in under 30 minutes. The presentation will conclude with next steps for Borealis Wind in the development of the blade de-icing system, as well as the ice detection and control system.

Web site: https://www.linkedin.com/in/danielaroeper/

Short biography: Daniela Roeper is the founder and CEO of Borealis Wind. She is a mechanical engineer with experience in the renewable energy industry through her work at ORTECH Consulting Inc. in Mississauga, ON, Canada. During her time at ORTECH, Daniela worked on feasibility studies for wind and solar sites. She discovered the problem of wind turbine blade icing during her time at ORTECH, and was eager to find a solution. She put together a team of engineers to begin R&D work, and has led Borealis Wind since 2014. Daniela is an outdoors enthusiast and passionate about developing technical solutions to minimize the global carbon footprint.

R&D areas/s: 04. Operational experiences incl. performance optimization, big data, production losses and repairs

Case study; controlled environment in up-tower blade repairs

Ville Karkkolainen, Bladefence Oy

Ville Karkkolainen, Bladefence Oy

Rotor blade repairs have traditionally been very difficult, sometimes even impossible, in cold climate areas, especially during winter time. Often repairs require a summer like conditions, as conventional blade repair systems generally require an ambient temperature of more than +15 Celsius and a maximum RH of 60% to work properly. In the case of more significant issues, a de-mounting of the blade might be needed for on-ground repairs under controlled weather environment.
We present a novel approach, developed in co-operation with a major OEM and first introduced during the 2018 repair season, where a rapid and safe skylift access is combined with a controlled environment for blade repairs. This controlled environment, or a habitat, will enable the usage of conventional blade repairs materials in conditions which typically have completely prevented blade repairs. Although habitats have been used in the industry before, this is the first of its kind where the flexibility and speed of skylift access is combined with a controlled blade repair environment.
Experiences gathered during the 2018 repair season shows that the usage of a controlled environment significantly reduces weather related downtime, lowers costs, increases repair quality and expands the works scope that can be completed during a repair season. Controlled environment also enables permanent repairs to be carried out during cold climate season, reducing the number of temporary repairs which be repaired again during summer season.

Web site: http://www.bladefence.com

Short biography: Ville Karkkolainen has been the managing director of Bladefence Canada since 2016. Prior to his current position, for six years, he was the managing director of Bladefence Ltd., based in Helsinki Finland. During this period the company grew to become one of the leading independent blade service providers in Europe. Ville has been an active speaker in dozens of industry events and a promoter of advanced blade repair procedures and pre-emptive blade maintenance programs. Outside of wind energy he is an enthusiastic Harley-Davidson rider.

R&D areas/s: 02. De-/anti-icing including new technologies, ice detection & control incl. standards, 08. Health, Safety and Environment (HSE) incl. noise

Uncertainties and choices in ice risk assessments - How to get the results you want

Markus Drapalik, Institute of Safety and Risk Research, University of Natural Resources and Life Sciences, Vienna, AT

Markus Drapalik (ISR BOKU, AT)

The soon to be published IEA Wind Task 19 Guidelines [IEA 2018] for Ice-fall/ice-throw risk assessments aim to pave the way for standardized procedures for ice-throw risk assessments. While these guidelines represent a huge and important step towards this goal, they necessarily leave a number of different approaches for assessments. Accordingly, different choices of input data and models results in vastly different risk results. This presentation compares some possible strategies and their consequences.
Considering the meteorological/climatological input, the IEA recommendations advise for 10 min or less data and a long term dataset (or correction therefore). These demands can often not be satisfied, when long term data is only available in 1 day averaging. Similar problems arise for horizontal and vertical extrapolation of wind statistics, since local measurements hardly exceed one year. Thus, it is equally justifiable to use two years of local, high resolution data or 50 years of low resolution data. This choice again influences not only the yearly number of icing events, but also the wind statistics during and after icing. With careful choice of parameters, a difference in calculated risks of up to one order of magnitude can be achieved. Similar arguments apply for the choice of parameter ranges, when using a synoptic approach for defining icing periods. It can also be shown, that different ice load distributions, while resulting in the same amount of ice, can shift the risk due to the position of ice on the rotor.
For the actual ice throw (or shed) the recommendations favor a ballistic model using at least drag and gravity. It is also pointed out, that more elaborate models which respect lift and/or changing effective frontal areas, are available. Again, the choice of model has significant impact on the assessment results. As opposed to the meteorological modeling, where data availability is a significant constraint, ballistic models generally lack validation. Comparison with experiments show a difference of up to 50% between simulation and measured data [DRAPALIK 2017]. In order to respect these systematic errors, a correction factor depending on the ice fragment characteristics can be applied, which again modifies the risk distribution with respect to distance from the turbine.
An additional factor is the set of ice fragments considered in the ballistic simulation. These may consist solely of actual observed fragments as well as a random continuum of area and mass distributions. This has direct impact on the total number of fragments, as well as their throw or shed distances.
Finally additional safety measures such as warning signs and barriers can be included in the overall risk using a global risk reduction factor. Since little quantitative research has been done on such measures, factors can easily vary by one order of magnitude.
The multitude of choices and uncertainties in ice risk assessments cannot be avoided and has significant impact on results. While further research reduces uncertainties, it is important to be aware of the wide range of possible results and the impact on risk communication, in order to avoid a dubious appearance.
Clear communication of the current state of knowledge is of utmost importance for plausibility.
[DRAPALIK 2017] M. Drapalik, "Risiken der Vereisungsproblematik bei Windenergieanlagen unter besonderer Berücksichtigung der Situation in Österreich," Universität für Bodenkultur Wien, 2017.
[IEA 2018] IEA Wind TCP Task 19: International Recommendations for Ice Fall and Ice Throw Risk Assessments, November 2018

Web site:

Short biography: Markus Drapalik is a physicist at the Institute of Safety and Risk Research (ISR) at the University of Natural Resources and Life Sciences, Vienna. He has been working on wind turbine icing for the last seven years and received his Ph.D. for working on the risk of ice shed from turbines.
Following his preferences for hands-on experiences, his main interest is in experimental investigation of ice shed and ice throw from turbines, which covers large and small turbines alike. For this, he maintains a small monitoring program for ice shed, which provides the necessary input and validation.
Currently he is working on a project to develop an accurate and validated model for the simulation of ice shed and throw, which uses stationary CFD solutions for the aerodynamic properties of falling ice fragments.

R&D areas/s: 02. De-/anti-icing including new technologies, ice detection & control incl. standards, 08. Health, Safety and Environment (HSE) incl. noise

Since the ISR is focusing on technology assessment, his work group is expanding from ice related topics to questions of resource use, sustainability and environmental impacts of wind energy.
His personal time is mostly spent with his family and their horses.

R&D areas/s: 03. Pre-construction site assessment, measurements, models and standards, 04. Operational experiences incl. performance optimization, big data, production losses and repairs, 06. Wind turbine manufacturers – cold climate solutions, test centres, turbines

Design features of wind diesel hybrid power plants in Russian Arctic climate

Viktor Elistratov, Science-education center «Renewable energy sources» Peter the Great St. Petersburg Polytechnic University, Russia

Konishchev Michail (Science-education center «Renewable energy sources» Peter the Great St. Petersburg Polytechnic University, Russia), Denisov Roman (Science-education center «Renewable energy sources» Peter the Great St. Petersburg Polytechnic Universit

The total installed capacity of diesel power plants (DPP) working in the northern regions are more than 500 thousand kW. DPPs produce about 2.5 billion kWh, which requires the consumption of about 1 million tons of diesel fuel per year. Delivery of diesel fuel in these regions is carried out in the "northern" delivery. DPPs are characterized low reliability, long life of service, they consume expensive long-imported fuel, and therefore the unit cost of electricity generated by diesel power plants is 0.22-2.23 $/kWh.
The northern regions of Russia locate in the climatic conditions that significantly differ from the European and American climate. In addition, the territory of the Far North are characterized by infrastructural and logistical problems. At the same time, these regions have high wind potential (average 450 W/m2 at 50 m).
In the article a series of steps of designing wind and diesel hybrid power plants for replace of expensive diesel fuel are offered. The method of wind resource assessment in the areas with shortage of weather and climate information is developed in order to improve the accuracy of resources determining. The method is based on a three-level approach. Each level corresponds to a more accurate model of the wind flow: meso- and microscale modeling and more accurate assessment of the spatial distribution of the wind resource. In order to create an effective and competitive energy supply system for northern conditions Russia the multi-level method of determining the optimal composition, parameters and operating modes of an autonomous hybrid system is designed.
These methods are implemented for the project in the village Amderma (Nenets Autonomous Okrug), operating in Russia in the Arctic Circle. The wind resources was calculated by authors; the potential of this region is 36,700 TWh per year, average power of the wind flow is 474 W/m2 (at 50 m). For the project adaptation measures for elements of structures and wind turbine with a 50 kW capacity are proposed. They reduce losses from underproduction of energy by 10-20%. In addition, the project introduced the technology of crane-less installation and the special foundation based on the permafrost is designed. An intelligent system of energy management and distribution based on active networks for adaptive architectures is developed to ensure the work of WDPPs with high penetration level. In 2017, the project was implemented, and a wind-diesel power plant, consisting of 4 wind turbines 50 kW each and a diesel station of 750 kW was created. The effect of the optimization of the composition, parameters and modes of the power plant operation is estimated to save 169 thousand liters of diesel fuel. Additionally it can reduce CO_2 emissions of 600 tons/year.
Key words: wind-diesel power plants, hybrid system, smart grid, penetration level, severe conditions, controlling system, optimization, parameters and modes.

Web site:

Short biography: Viktor Elistratov is a Dr. Sci. (Tech.) (1996), professor (1999), Director of Science-Education Center «Renewable Energy Sources» of Peter the Great Saint Petersburg Polytechnic University. He is an author of more than 150 publications including 6 monographs, 7 certificates of recognition and patents, more than 20 textbooks and manuals concerning hydro power and renewable energy sources issues.
Viktor Elistratov is a deputy chairman of Associated Scientific Council for Energy, chairman of Scientific Council for Renewable Energy Sources Problems of St.Petersburg Centre of Russian Academy of Sciences, co-chairman of the Technological Platform Council "Promising technologies in renewable energy", member of scientific and technical Council of JSC RusHydro, deputy chairman of Renewable Energy Sources Committee of Union Of Scientific And Engineering Associations of Russia, expert in renewable energy sources for Skolkovo Foundation.

R&D areas/s: 03. Pre-construction site assessment, measurements, models and standards, 04. Operational experiences incl. performance optimization, big data, production losses and repairs, 06. Wind turbine manufacturers – cold climate solutions, test centres, turbines

Viktor Elistratov is a full member of "International Higher Education Academy of Sciences" (IHEAS), corresponding member of Russian Academy of Natural Sciences, International Academy of Energy, Academy of Electrotechnical Sciences, Saint Petersburg Engineering Academy.
He is a member of international energy organization EUROSOLAR and Worldwide Wind Energy Association (WWEA).
Viktor Elistratov is also an Honoured power engineering specialist of Russian Federation.

R&D areas/s: 02. De-/anti-icing including new technologies, ice detection & control incl. standards, 04. Operational experiences incl. performance optimization, big data, production losses and repairs, 07. Laboratory and full-scale testing, small wind turbines

Proof of concept of a tower based blade icing detection system for low to moderate icing sites

Pieter Jan Jordaens, OWI-Lab

Dr.ir. Wout Weijtjens (VUB/OWI-Lab), Dr.ir Christof Devriendt (VUB/OWI-Lab), Ing. Pieter Jan Jordaens (Sirris/OWI-Lab)

One of the largest concerns of wind turbine operators in cold climate sites is the risk of ice throw when it comes to safety and annual lost production hours. Also in low to moderate risk icing sites with densely populated areas (such as harbour sites for example) the risk of ice throw cannot be neglected when it comes to safety concerns. For low to high risk icing locations an array of safety measures, such as direct and indirect ice-detection or blade heating, have been developed and adopted by the industry in the past years for continued safe operation and increased production gains. However, the current set of solutions comes at a cost that might not be reasonable for sites with only a limited number of icing hours. This applies in particular for densely populated areas in Belgium, the Netherlands, France, the German Ruhr-area etc…

In this contribution the efforts of the OWI-Lab to design a more cost-effective solution for such low risk icing sites are discussed. The currently proposed solution is to use a single vibration sensor mounted in the turbine tower. This simplifies both the installation and the maintenance cost of the system. Meanwhile the sensitive sensor is able to pick up the rotor vibrations from its position on the tower. An automated operational modal analysis (OMA) algorithm is tuned to track the resonance frequencies of the rotor. Observed variations in the frequency of rotor modes allow to decide whether ice is present on the blade. During this presentation we will present and discuss the used technique of using tower-mounted accelerometers for low-cost ice detection and show early results on an on instrumented onshore wind turbine that was subjected to icing events in the winter of 2017 as part of an test campaign. Open challenges and the envisioned continued developments are discussed in this contribution.

Web site: http://www.owi-lab.be/

Short biography: Pieter Jan Jordaens joined Sirris (Belgian technology center – www.sirris.be) in 2010 as a project leader. Since then he has been responsible to built-up and roll-out 'OWI-Lab' (www.owi-lab.be) which is the Belgian research, development and innovation lab for wind energy. This platform is supporting innovation within the full value chain of wind energy but is focusing on the emerging sector of offshore wind energy and wind energy in harsh environments as 'cold climate wind energy'. The aim is to reduce investment and O&M costs, and make the technology efficient and reliable as possible to compete with traditional energy sources .

Pieter Jan focused on developing the innovation and test services of the lab as business developer. Specifically on topics as 'climate chamber testing' of wind turbine components for offshore, cold, hot, and tropical climates the OWI-Lab team has built-up international recognition. One of the largest climatic test facilities in Europe was built up in the port of Antwerp to test and demonstrate the ability of wind turbine machinery to operate in harsh conditions worldwide in which they are currently installed. In cooperation with the university of Brussel (VUB) also an RD&I trajectory was set-up on the topic of structural health monitoring (SHM), structural integrity and the use of big data for (offshore) wind turbine applications. OWI-Lab has been one of the first actors in the offshore wind energy value chain in addressing the SHM topic. Also a spin-out company was set-up as a valorization result of the R&D trajectory.

Before joining Sirris, Pieter Jan obtained a Master's degree in Electro-Mechanical Engineering at the International University College Group T (now KUL) in Leuven. After that he studied the International Postgraduate Programme in Entrepreneurial Engineering.

R&D areas/s: 03. Pre-construction site assessment, measurements, models and standards

Importance sampling for ice throw in QBlade

Matthew Lennie, Technishe Universitat Berlin

David Marten (TU Berlin), Oliver Christian Paschereit(TU Berlin).

Site assessments need icing risk forecasts. Common method is to simulate the ice trajectories with a simple ballistics model with each particle and each operating condition having properties from Monte-Carlo sampling. The landing place of each ice particle is recorded and used to construct a probability distribution of risk for each location surrounding the wind turbine. The first moments of the risk distribution are not really the main issue for site assessments. The safety boundary surrounding each wind turbine is set based on a maximum acceptable risk threshold. This maximum risk threshold is usually set at a very low level meaning that the probability field has to stable well out into the tails of distribution. The most commonly used Monte Carlo sampling method is the Markov Chain Monte Carlo method because of ability to handle higher dimension sampling efficiently. This efficiency stems from the attraction towards the ridges of the probability distributions, a fine property for converging the mean or variance of the distribution, but an unhelpful property for converging the tails efficiently. In these kinds of cases, the sampling can be done to favour ice scenarios that present the highest risk onsite. The probabilities can then be re-applied through a simple weight term which results in a risk distribution that is well populated at the regions of low probability. This approach is commonly referred to as importance sampling a technique which falls under the broad umbrella of variance reduction sampling. This approach was tested within the Open Source QBlade wind turbine software developed by the Technische Universitat Berlin.
The presentation will:

- Provide an overview of the modelling techniques used within QBlade for Ice Throw
- Make some brief comments about currently available datasets of Ice Throws.
- Present the importance sampling method and discuss convergence issues

Web site: https://www.linkedin.com/in/matthew-lennie-a547a547/

Short biography: Matthew is a researcher at the Technical University of Berlin. His interests are wind turbine aeroelastic simulations and numerics. His recent work has had him shifting towards topics requiring heavy statistical analysis and machine learning. In his spare time, Matthew is outdoors doing sports like white water kayaking, climbing or trail running.

R&D areas/s: 02. De-/anti-icing including new technologies, ice detection & control incl. standards, 04. Operational experiences incl. performance optimization, big data, production losses and repairs, 05. Onshore turbines, aerodynamics, loads and control, Fiber-optic

fos4X experience improving the performance of wind farms installed in cold climate

Christian Lindemann, fos4X GmbH

Luis Vera-Tudela (fos4X GmbH)

Enormous pressure on the costs of energy (COE) due to worldwide arising auction schemes currently affects the whole wind industry. Strong competition with other renewables, like biogas or solar installations, leads to the need to significantly improve the operation and maintenance of wind assets. Furthermore, almost one fourth of worldwide wind turbine installations in 2012 were located in cold climate regions, and, depending on site and wind turbine characteristics, losses could amount up to 20% to 50% of annual energy production (AEP). Results presented by the International Energy Agency (IEA) agree with such estimations, and the classes of ice defined are associated with an expected impact on AEP. Wind farm optimization and the acquisition of application-relevant data is the next step in intelligent wind farm operation and optimization. These optimization “levers” range from events with measurable direct impact such as rotor icing and structural damages to indirect measures as the estimation of wind field parameters. However, since both the impact that cold climate and the proposed solutions depends on site-specific conditions as well as wind turbine operational characteristics, it is extremely relevant to exchange results from field experience in order to better estimate COE impact.
In this publication, field experience with fos4X Rotor Ice Control is discussed. The evaluation of 70 wind turbines in the range of 2-3 MW during the winter of 2017-18 in the Northern Hemisphere is presented. The data available from sites in five countries serves to account for the impact that different conditions have on system response. An overall increase of several percent proven in field tests is presented.

Web site: https://www.fos4x.de/x4edge/

Short biography: Christian leads the Key Account Management team and is responsible for the OEM and operator business at fos4X. Before joining fos4X, Christian has gained 8 years of work experience in measurement technology, application engineering and customer-specific data analysis at HBM. He holds a diploma degree in Electrical Engineering with focus in measurement & control from the University of Applied Sciences, Leipzig.

R&D areas/s: 08. Health, Safety and Environment (HSE) incl. noise

IEA Wind Task 19: International Recommendations for Ice Fall and Ice Throw Risk Assessments

Andreas Krenn, Energiewerkstatt e.V.

Andreas Krenn, Alexander Stökl (Energiewerkstatt e.V., AT)
Nina Weber, Sten Barup (ENERCON - WRD Management Support GmbH, DE)
Thorsten Weidl, André Hoffmann (TÜV SÜD Industrie Service GmbH, DE)
Rolv Erlend Bredesen (Kjeller Vindteknikk AS, NOR)
Marine Lan

In the meeting of the executive committee of IEA Wind in October 2018, the document "International Recommendations for Ice Fall and Ice Throw Risk Assessments" has been released for publication and is now available in the download section of the IEA Wind website. These recommendations have been compiled over a two-year creation process by an international working group formed under the umbrella of IEA Wind Task 19. The aim of this document is to enhance the international standardisation of ice throw / ice fall risk assessments that are requested by the authorities during the approval procedure of wind farm projects in an increasing number of countries. Collecting the current knowledge of ice fall and ice throw from wind turbines and best-practices from the industry, the recommendations therefore cover the main building blocks required to assess the risk of ice fragments to cause harm to persons under or near the wind turbine. The information given can thereby either have the character of a strict recommendation, or describe one or several viable options, if there is no clear consensus in the field or if there are differing requirements in individual countries.
In the presentation, we will give an overview to the contents of these international recommendations. The main topics and conclusions will be discussed, with a specific focus on points of practical relevance for the creation on ice fall / ice throw risk assessments.
The contents of the recommendation includes:
- The effects and influences that have to be considered in the mathematical model used to compute the trajectories of the ice pieces.
- The type and quality of data on which the assessment has to be based. To this end, the recommendations also provide observational data on the properties (size and mass) of the ice fragments and on the number of ice pieces that have to be expected, depending on the IEA Icing class of the wind site.
- An introduction to the methods of risk analysis. In particular, approaches to the definition of acceptable levels for the individual and the societal (collective) risk are discussed. Possible risk reduction measures are listed together with ranges for their efficiency.
- A section on the treatment of the uncertainties involved in ice risk assessments.
Together, it is hoped, that these recommendations provide an international baseline reference for the creation of ice fall and ice throw risk assessments and thus to pave the way forward to increase the quality, consistency, and transparency of ice-risk assessments internationally.

Web site: http://www.energiewerkstatt.org/

Short biography: Andreas Krenn holds an MSc degree in soil and water management from the University of Applied Sciences Vienna and an MBA from JKU Linz. He has been working for Energiewerkstatt as a project manager for national and international wind energy projects since 2006. Andreas Krenn is the Austrian representative in IEA Wind Task 19 and alternate member in the ExCo of IEA Wind. He is currently coordinating an international expert group that aims at enhancing standardization of ice-fall / ice-throw risk assessments.

R&D areas/s: 08. Health, Safety and Environment (HSE) incl. noise

R.Ice: Risk Analysis of Wind Turbine Icing

Alexander Stökl, Energiewerkstatt e.V.

Alexander Stökl, Andreas Krenn (Energiewerkstatt e.V., AT)
Biber Jürgen, Felix Bruckmüller (Austrian Institute of Technology, AT)

R.Ice (www.eisatlas.at) is a project funded by the Austrian Research Promotion Agency (FFG) and covers risks related to ice-fall from wind turbines with particular consideration to the legal and meteorological situation in Austria. Because of the geographic and climatic conditions on wind energy sites in Austria, i.e. mountainous terrain and/or densely populated areas, the risk from ice fall is a significant concern for the erection and operation of wind turbines. Ice fall risk assessments and measures to reduce the risk from icefall to an acceptable level have thus become an important part in the approval process of wind energy projects. This problem is further compounded by the Austrian legislation, which requires that wind turbines are shut down once ice has been formed on the rotor bade; and thereafter, they may not be restarted automatically without visual inspection.
For the creation of ice fall risk assessments, factual information on the icing events is of foremost importance. Therefore, the research project R.Ice aims at the improvement of the data basis and knowledge on local icing conditions, ice fall events, and risk aversion strategies, specifically for Austrian wind energy sites. For doing so, R.Ice follows the approach of combining theoretical models with field observations and a legal perspective. The project includes the following main parts:
(1) Creation of an icing map for Austria with a horizontal mesh width of 3x3 km containing data for ice accumulation on a 3 cm standard cylinder, in accordance with ISO 12494. This data, in turn, can be used for estimates of the average meteorological/instrumental icing, icing intensity, and icing frequency.
(2) Calibration of model-results for the specific icing conditions on Austrian wind energy sites with operational data and observations from wind parks. Together with (1) this gives a regional icing climatology for wind turbines.
(3) Monitoring of icing events at wind turbines using an innovative stereo imaging method in order to obtain the number, size, and trajectories of falling ice fragments. In contrast to collecting ice pieces from the ground, this method uniquely allows an unbiased recording of the complete spectrum of ice debris.
(4) Creation of ice fall probability maps for the main geographical/meteorological regions in Austria by modelling the respective landing locations of ice pieces around wind turbines of typical dimensions. These probability maps can directly be used to determine the ice fall risk for persons and infrastructure.
(5) Determination of scientifically verified measures and policies for a further reduction of ice-fall risks, in collaborations with legal experts and wind energy experts
Information on (1) an (2) can be found on a poster contribution to this conference by Wienerroither et al., Topic (5) will be finalized in a workshop to be held in early 2019. In this presentation, we will focus on the topics (3) and (4), where we will each give a short overview of the adopted methodology, discuss the data basis, and present the results obtained.

Web site: http://www.energiewerkstatt.org/

Short biography: Alexander Stökl earned his PhD in astrophysics and has worked in this field for many years, mostly on fluid dynamics and numerical methods, interrupted by a two years stint in the wind energy business at AMSC WindTec. In 2018 he has joined Energiewerkstatt e.V. where he now primarily focuses on wind energy research projects.

R&D areas/s: 02. De-/anti-icing including new technologies, ice detection & control incl. standards, 04. Operational experiences incl. performance optimization, big data, production losses and repairs, 05. Onshore turbines, aerodynamics, loads and control, 07. Laborat

Wind turbine rotor icing detectors performance evaluation

Charles Godreau, Nergica, Canada

Nicolas Jolin (Nergica, CA), Dominic Bolduc (Nergica, CA), Hatem Hosni (Nergica, CA)

Atmospheric icing is an important issue when implementing wind energy in cold climate (CC); it has been estimated to be responsible for $100 M losses annually in Canada (Kilpatrick, 2016). In order to reduce performance losses and better control iced wind turbines the development of highly reliable icing detectors is required. Rotor ice detectors, as opposed to nacelle ice detectors, are relatively new on the market and have not been submitted to a quantitative study on their performance.
In this independent study, over winter 2017-2018, three commercially available ice detectors were tested: Fos4X Rotor Ice Control, Weidmuller BladeControl and Eologix. The detectors were installed on one of Nergica's 2MW wind turbine and tested against two hub cameras taking blade pictures every 10 minutes and the turbine Ice Operation Mode (control in icing condition).
Four Key Performance Indicators for rotor ice detectors were defined: Availability, Icing Duration, Time Accuracy and Ice Severity. Over 1000 hours icing were then observed at Nergica's research facility. The complete performance analysis of the three rotor icing detectors covers all these icing events. The performance metrics will help wind farm owners and operators to choose the right sensor for their application. This novel analysis will also allow technology developers to improve the performance of their icing detectors.

Web site:

Short biography: As Project Manager, Research and Innovation, Charles Godreau specializes in wind turbine performance assessments in cold climates and icing detection/protection systems. Besides possessing strong skills in data analysis for operational turbines as well as developing, planning and implementing research projects, he has also participated in a number of conferences and represents Canada on the IEA Wind Task 19 research group. Outside of work, Charles enjoys snowboarding and improv theater.

R&D areas/s: 03. Pre-construction site assessment, measurements, models and standards

WICE 2.0 – The new generation of ice loss models

Stefan Söderberg, DNV GL, SE

Jon Collins (DNV GL, UK), Till Beckford (DNV GL, UK), and Carla Ribeiro (DNV GL, UK)

In September 2018 DNV GL joined forces with Swedish cold climate experts WeatherTech. For many years, both organizations have taken an active part in the development of the knowledge base and innovative services for areas affected by atmospheric icing. The combined expertise of both companies has enabled the development of state of the art models, allowing customers to better predict the performance of turbines in cold climates.

WeatherTech has been developing a combined atmospheric and machine learning model to predict production losses caused by ice accretion on turbine blades, the WICE model [1,2,3]. DNV GL's approach has been to rely on the considerable amount of both production data from wind farms in cold climate, as meteorological data from measurement masts, to develop and empirical method of estimating these production losses [4]. By combining WeatherTech's WICE model, with DNV GL's unique database of production data and experience in analysing such data, an unparalleled tool to predict icing losses has been developed. This model will be applicable worldwide when fully developed, and will be able to predict the benefit of IPS (Ice protection Systems) in reducing such losses.

In the present work, the authors have undertaken an independent validation study of the current version of WICE, in which model predictions have been compared with SCADA data from several wind farms and winter seasons not previously known to WeatherTech or used in the training of the model. The analysis has been carried out on a wind farm level as well on a turbine by turbine level. Fundamentally, a unique long-term validation has also been undertaken. For sites with a long data record, an evaluation of long term correction methods has also been carried out.

In parallel with the validation study, the authors have also worked on improving the model. Improvements in many areas have been made, namely the machine learning setup used, the processing of the production data, the addition of more training sites, and the long-term correction method. The authors propose to present the outcome of the independent validation and quantify the model improvements, and how these can aid the cold climate industry in reducing uncertainties.

References:

[1] Söderberg, S., M. Baltscheffsky, and H. Bergström, 2013: Estimation of production losses due to icing - a combined field experiment and numerical modelling effort. EWEA 2013, Wien, Austria.

[2] Baltscheffsky, M. and Söderberg, S., 2013: Estimation of Production Losses Due to Icing – Development of methods for site assessment and forecasting. Winterwind 2013, Östersund, Sweden.

[3] Söderberg, S. and M. Baltscheffsky, 2014: A novel model approach to test de-icing strategies and de-icing efficiency. Winterwind 2014, Sundsvall, Sweden.

[4] Beckford, T., 2018: Understanding Icing in the Nordics and North America. Winterwind 2018, Åre, Sweden.

Web site: https://www.dnvgl.com/energy

Short biography: Stefan has worked in the wind industry since 2006. In DNV GL Stefan is an expert in numerical mesoscale modelling and icing climate studies. Prior to DNV GL, Stefan founded and worked in WeatherTech Scandinavia developing services based on mesoscale model data such as wind resource mapping and estimates of production losses due to icing. In his spare time, he enjoys mountain biking in rough terrain.

R&D areas/s: 13. Other

Validation of Droplet Size in the VTT Icing Wind Tunnel Test Section

Tuomas Jokela, VTT Technical Research Centre of Finland Ltd

Tuomas Jokela (VTT, FI), Mikko Tiihonen (VTT, FI), Timo Karlsson (VTT, FI) & Raul Prieto (VTT, FI)

Cold Climate applications in the wind power sector particularly ice detectors, wind anemometers and material solutions are not uniformly tested and rated. There is a particular need for better understanding of the ice accretion phenomena in the wind power solutions. That´s why, it is very important to develop continuously laboratory facilities and validate the testing environment and to be sure, that applications perform as they are designed. Validated experimental icing wind tunnel data is urgently needed in the R&D projects to reach new high quality instruments and other wind power related products for wind power applications in the icing conditions. /1/
VTT icing wind tunnel is placed in a cold climate chamber with operational temperatures of +23°C...-25°C and flow velocity up to 50 m/s. Test section dimensions are 700 mm x 700 mm x 1000 mm and the section is equipped with heated windows. The mass flow rate of the atomizing air and sprayed water is controlled by calibrated equipment during the tests. During the ice accretion tests, conditions in the wind tunnel must be repeatable and resemble natural icing conditions. In the VTT Icing Wind Tunnel test section glaze, rime and mixed ice can be formed on the surface of different test specimens.
So far, in our ice accretion tests, theory based on ISO 12494:2001 standard "Atmospheric icing of structures" was used to calculate a theoretical icing intensity. In these indirect liquid water content (LWC) [g/m3] validation tests, a special test setup based on theory from ISO 12494:2001 using a vertically mounted, slowly rotating 500 mm long Ø 30 mm steel tube was used and placed in the icing wind tunnel test section. To calculate the theoretical LWC [g/m3] in the test section based on the above-mentioned standard, droplet size [µm] plays a key role. Therefore, it is essential important to know as precisely as possible the droplet size [µm] distribution in the test section during the ice accretion. If the droplet size [µm] value is not accurately defined, then it is impossible to evaluate indirectly the LWC [g/m3]. This impair the quality and repeatability of the conditions in the icing wind tunnel tests.
Customers presume more specialized, reliable and high quality icing wind tunnel tests. Therefore, VTT decided to plan project where the droplet size distribution (DSD) is verified in the different test parameters. Three partners were chosen to validate the VTT Icing Wind Tunnel droplet size distribution (DSD) in the test section. The Finnish Meteorological Institute and Technical University of Denmark (DTU) used both commercial Cloud Droplet Probe (CDP) /2/ in their validation measurements. University of Oulu used instead their own developed ICEMET probe /3/ in the droplet size measurements. These droplet size [µm] distribution measurements executed between May and August 2018. Part of the validation measurements executed so that probe was mounted alone in the centre of the icing wind tunnel test section. Some of the measurements executed in the way that probe and slowly rotating 500 mm long Ø 30 mm steel tube were mounted side by side into the centre of the test section. Depending of the test conditions the length of the droplet size [µm] validation measurements varied between 5 minutes up to 30 minutes.
After DSD data-analysis is completed, more characterized data would be available for the customers. Therefore, the repeatability and the accuracy of the icing wind tunnel operation parameters would be improved. This study would give higher customer value and would broaden the range of icing wind tunnel test services.

References:

1) https://community.ieawind.org/task19/ourlibrary/viewdocument?DocumentKey=7cb6e63a-0e0e-4ac3-87f3-4d1daf7269bc
2) http://www.dropletmeasurement.com/products/airborne/CDP-2#Software
3) http://www.oulu.fi/icemet/

Web site:

Short biography: Biography:
Tuomas Jokela
Date of Birth:
2.12.1974, Helsinki, Finland
Education:
06/2010 - Helsinki University of Technology (M.Sc), mechanical engineering

R&D areas/s: 13. Other

11/2000 - Mikkeli Applied University (B.Sc), measurement and instrumentation
Working at VTT:
I have been working at VTT as a Research Scientist from 6/2010. During the last years my tasks have been focused into the icing wind tunnel related customer driven development projects. I have also taken care of different metmast and lidar measurements related projects. Also site working safety issues have been on my responsibility in our team.
During my leisure time I am an enthusiastic trail runner! :-)

R&D areas/s: 01. Forecasting, cloud physics and aerodynamics, 02. De-/anti-icing including new technologies, ice detection & control incl. standards, 03. Pre-construction site assessment, measurements, models and standards, 04. Operational experiences incl. performanc

Forecasting of atmospheric icing – validation and applications within wind energy

Leon Lee, Kjeller Vindteknikk

Johannes Lindvall (KVT), Rolv Bredesen (KVT), Øyvind Byrkjedal (KVT), Martin Grønsleth (KVT), Leon Lee (KVT)

General summary
In order to achieve optimum operation for wind turbine generators the suitability and cost of key components should be quantified enabling fair comparison of decision options. For WTGs operating in cold climates the skill in detecting adverse icing conditions at an early enough stage is especially important when e.g. controlling the risk of ice throw or when avoiding prolonged production losses. In this presentation we attempt to quantify the uncertainty and evaluate the performance of a state-of-the art icing forecast system against relevant production data.
Simulated icing have been translated into a traffic light alarm system for 20+ wind farm sites. SCADA data from 20+ wind farms with a total of more than 300 individual wind turbines in Sweden, Norway and Finland have been analyzed and all icing events have been identified following the IEA Wind Task 19 icing identification method (Davis et al., 2015).
Pro-active uses for a proper detection system(s) include risk mitigation such the operational strategy of stopping the turbines in time before adverse icing may occur, in turbine controllers for preemptive heating of turbine blades, alert notifications for the public and workers with sufficient warning time using the common alerting protocol, or simply to trigger closer monitoring and awareness depending on the forecasted icing severity.
Method
Hindcast data for Nordics have produced for the period 2000 to present by the use of the Weather Research and Forecasting model (WRF). The grid resolution of the forecasts is 4 km x 4km. From these hindcast dataset, icing have been calculated as the icing rate on a freely rotating cylinder according to the description given in ISO 12494 – Atmospheric Icing on Structures. Icing rate has been calculated for the lower model levels. A local adjustment of the atmospheric moisture content and liquid water content has been carried out to adjust for the subgrid scale terrain in the model and thus make the icing forecasts representative for typical wind power sites also in complex terrain.
Results
The skill scores of the icing forecasts are calculated for each of the wind farms and presented in ROC diagrams. The results show that for a majority of the wind farms, 70-80% of all icing periods identified from the SCADA data are also captured by the forecast model. The false alarm rate is typically in the range 5-10%.
However, the skill scores are sensitive to the threshold settings of the traffic light conditions. By including icing signals from higher model levels or neighboring model grids the hit rates of the icing forecasts are generally improved, but with compensating increase of the false alarm rate.
Conclusions
The skill score of the modeled icing depends on thresholds and the setup of the individual wind farm and can thus be tailored toward the user needs. Proper quantification of uncertainty measures and performance indicators enables fair comparison between options as well as informed decisions and judgments on suitable operational strategies.
The actual icing levels for defining the probabilistic take-action or traffic-light signals will vary from case to case and on the cost-effectiveness of different systems and the choices presented here are therefore considered an exemplification.
For example, to handle possible risks of ice throw from turbines it will be important to capture as many as possible of the icing events while the forecasting of icing losses for energy traders will achieve the best value as best possible compromise between the false alarm rates and hit rates.

Web site: http://www.vindteknikk.com/

R&D areas/s: 01. Forecasting, cloud physics and aerodynamics, 02. De-/anti-icing including new technologies, ice detection & control incl. standards, 03. Pre-construction site assessment, measurements, models and standards, 04. Operational experiences incl. performanc

Short biography: Leon Lee holds an MSc in meteorology from Uppsala University. He joined Kjeller Vindteknikk in 2018 and works daily at the Swedish branch office with wind/icing analysis as well as energy yield assessments and other studies e.g. extreme weather, local wind climate, airport turbulence climate. He is currently working with the IceLoss 2.0 research project which aims to develop the next generation advanced calculation model for ice-related production losses. He also is a theory instructor on aviation meteorology at several flight training facilities since 2016 and a weather forecaster and presenter at Swedish TV4 since 2015.

R&D areas/s: Standardization

IEA Wind Task 19 – key results from 2016-2018 and future plans 2019-2021

Ville Lehtomäki, Kjeller Vindteknikk, FI

on behalf of IEA Wind Task 19 group

IEA Wind Task 19 ”Wind Energy in Cold Climates” is an international expert group with a mission to improve large scale deployment of cold climate wind power in a safe and economically feasible manner. The Task gathers and provides information about wind energy in cold climates while having standardization as a main cross cutting theme for most activities. Cold Climate areas are defined 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 works on a variety of topics, including: project development; operation and maintenance (O&M); health, safety and environment (HSE); operational experiences; and recent research.
This presentation summarizes the key findings and results from Task 19 work during 2016-2018 period as well as presents the future planned activities for 2019-2021.
During the working term 2016-2018, 11 countries participated in the Task work and VTT Technical Research Centre on Finland was the Operating Agent. Main reports and results from working period 2016-2018 are:

- Cold climate wind power market study update for 2015-2020 (published in WindPower Monthly magazine 2016)
- Cold climate aspects for international standard IEC 61400-15 ed1 “Site energy yield assessment” (2016, on going)
- International recommendations for Ice Fall and Ice Throw Risk Assessments (2018)
- Available Technologies for Wind Energy in Cold Climates, 2nd Edition (2018)
- Performance Warranty Guidelines for Wind Turbines in Icing Climates (2018)
- T19IceLossMethod free software v2.0 - validation & development (2017)

All reports are freely available here: https://community.ieawind.org/task19/home
Task 19 will continue working for a highly ambitions working period 2019-2021 with the following planned deliverables:

1. Update cold climate market study for 2020-2025
2. Icing forecast benefits fact sheet
3. Ice Protection System and retrofits presentation
4. Available Technologies wiki pages
5. Finalize cold climate aspects for international standard IEC 61400-15 ed1 “Site energy yield assessment”
6. T19IceLossMethod free software: for IPS
7. Performance warranty guidelines for IPS: testing details development
8. Performance evaluation guidelines for wind turbine ice detection systems
9. Best practices for testing icephobic surfaces
10. Recommended Practices report & fact sheet
11. International Recommendations for Ice Throw: uncertainty
12. Iced turbine sound emissions summary presentation

Web site: http://www.vindteknikk.fi

Short biography: Mr Lehtomäki has a Master’s degree in mechanical engineering (product development) from Helsinki University of Technology. Currently he works as Managing Director at Kjeller Vindteknikk Oy (Finnish office). In addition to managing the Finnish office’s commercial operations, his technical work today focuses on wind energy topics such as energy yield assessments, icing loss evaluations and wind measurement analyses. From 2009-2018 he worked at VTT Technical Research Centre of Finland Ltd in Wind Power team. At VTT, his work focused on coordinating and developing new projects and creating new technology innovations mainly in the field of wind energy. His main wind energy topics were ice assessment, iced wind turbine dynamics and icing effects on blades, icing wind tunnel experiment planning and aeroelastic wind turbine simulations. He is currently working on behalf of VTT as Operating Agent of International Energy Agency (IEA) Wind Task 19 “Wind Energy In Cold Climates” international expert group.
He is on a mission to unlock the potentials of cold climate to the wind industry.

R&D areas/s: 03. Pre-construction site assessment, measurements, models and standards, 04. Operational experiences incl. performance optimization, big data, production losses and repairs, 06. Wind turbine manufacturers – cold climate solutions, test centres, turbines

ENERCONs strategies for minimizing and assessing icing losses

Julian Schödler, ENERCON, DE

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As more projects are continuously being planned and built in regions where icing losses occur – it is crucial to include calculations on the losses, or rather, the added benefit of installing a proven system to mitigate these losses. Failure to account for this could result in double-digit losses for the project which could have severe consequences for the investor.
ENERCON is one of the leading companies in wind energy, with a worldwide capacity of 50 GW. Since its founding in 1984, ENERCON has provided the production, construction and maintenance of wind turbines. ENERCON focuses on research and development, always searching for new and improved solutions to the challenges of the wind industry. Among these challenges, we find sites with icing conditions. The energy potential is typically higher in the winter, caused by the higher density of the wind and the occurrences of higher wind speeds. At a site with significant icing conditions, the standstill times of the turbine due to icing can cause major energy losses.
In order to estimate production losses due to icing, ENERCON has used our experience in turbine control in cold climates to develop an in-house algorithm, where the icing losses are calculated based on SCADA data.
With an in-house developed ice detection system and the ENERCON rotor blade heating system based on hot air circulation inside of the blade, ENERCON has more than 20 years of experience in the field of ice detection and also de-icing. This combination of ice detection system and rotor blade heating system can reduce energy losses due to icing drastically and has been investigated and approved by the German certification company TÜV Nord.

Web site: https://www.enercon.de/en/home

Short biography: Julian Schödler works as a project leader and data analyst in the R&D department of ENERCON. His tasks are among others the estimation of icing-related losses, application of machine learning models on various topics, prototype programming and method and process optimization of the site assessment department. He holds a Master of Science degree in Physics from the Carl von Ossietzky University of Oldenburg.

R&D areas/s: 03. Pre-construction site assessment, measurements, models and standards, 08. Health, Safety and Environment (HSE) incl. noise, Mainly risk assessment combined with CFD for icefall simulations

State of the art risk reduction of wind power facilities

Daniel Swart, Lloyd's Register Consulting

Daniel Swart (Lloyds Register Consulting, NO)
Ane Kristiansen (Lloyds Register Consulting, NO)
Rolv Bredesen (Kjeller Vindteknikk, NO)

Wind turbines and other tall structures in cold areas are prone to ice accumulation, which constitutes hazards for people, animals, infrastructure and assets adjacent to the installation. An effective risk management system for monitoring and controlling the risks associated with the installation must be applied to ensure control of the risks.
The suggested method combines risk analysis and risk controlling barriers. The risk analysis can be used prior to construction or during operation and can be conducted with the help of simulations and barrier analysis. The barrier analysis supplements the simulations to visualise how preventive systems and technical barriers prevents and mitigates incidents.
The discussed method has been used for Tryvannsmasta, a 209-meter-tall broadcasting tower near Oslo, to investigate if the risk is at an acceptable level or not. It is key is to combine simulated data with technical barriers in an integrated approach to validate the safety and through design and the effectiveness of the barriers. The method applied for the case at Tryvannstårnet is aligned with the recently released guide from NVE (Norges Vassdrags- og Energidirektorat/The Norwegian Water Resources and Energy Directorate), Icefall from wind turbines [1].
The guideline approves that the focus must be on risk prevention and actions which reduces the probability of ice falling, as well as communication of the risks associated with the installations to encourage positive risk behaviour of the public which reduce their risk exposure.
Relevant best-practices from the Tryvann project will be made public including bow-tie diagrams of proactive and reactive barriers controlling the risk, assessment of the warning system, risk reduction factors and future recommendations for this site [2].
ref[1] https://www.nve.no/nytt-fra-nve/nyheter-konsesjon/ny-veileder-for-handtering-av-faren-for-iskast-fra-vindturbiner/
ref[2] Lloyd's Register - Update of risk analysis "Broadcast tower Tryvann" - To be published

Web site: https://www.lr.org/en/risk-management-1/

Short biography: Daniel Swart received his MSc in Technology and Safety in the High North from UiT - the Arctic University of Norway in 2017, with specialisation within risk and reliability. In Lloyd's Register, he has been working with risk management projects, amongst winterization projects, ice fall risk analysis, barrier strategy, reliability analysis amongst others. He is the focal point in cybersecurity in Lloyd's Register. He has operational and strategical experience in the Red Cross Search and Rescue corpse, both as discipline leader in avalanche safety and as leader of the contingency council.

R&D areas/s: 13. Other, Wind farm construction in cold climate

Construction of wind farms in cold climates areas – Owner's Engineer experiences

Joachim Binotsch, Ramboll, Germany

Tarkan Pulur, Ramboll DE, Jan Volmut Ramboll DE

As Owner's Engineer or a consultant, we always recommend to the possible extent to avoid major works to be executed during winter time, such as turbine foundation (concrete works), earth works, turbine components delivery and delivery of the heavy electrical components and turbine installation. In case, any of these activities must be carried out during the winter time, extra considerations and precautions have to be taken, to avoid any negative impact of the cold climate on the works and/or components. Specific solutions must be found and applied for excavation of foundation pits, concrete pouring, compacting of road construction materials, transport of main turbine components and turbine installation itself.
Also there are certain HSE risks related to the winter time / cold climate, which need extra attention, especially snowing, icing and ice throw and short daylight.
The presentation shows experience gained and solutions applied during construction of two major wind farms in Sweden and Norway

Web site: https://ramboll.com/services-and-sectors/energy/wind-energy

Short biography: Joachim Binotsch is working since 1995 in wind energy and is thus belonging to the "first generation" in onshore wind. He was general manager and shareholder of BBB Umwelttechnik GmbH until it became part of Ramboll in August 2016. Until 2003 he was responsible for the development of onshore wind farms in Spain, Germany and Hungary. Since then he specialized on technical due diligences (TDD) of onshore and offshore wind energy projects and Owner's Engineering. He has been leading the Owners Engineer teams for the wind farm Sidensjö in Sweden (144MW) and Raskiftet in Norway (112 MW)

R&D areas/s: 01. Forecasting, cloud physics and aerodynamics

Probabilistic forecasting of wind power production losses due to icing

Esbjörn Olsson, SMHI

Jennie Molinder (Uppsala University), Heiner Körnich (SMHI)

For planning, trading, and safely operating wind power in cold climates, reliable next-day forecasts of icing on wind turbines are needed. The modelling chain for icing and related production losses starts with a numerical weather prediction model. The forecasted meteorological parameters are used as input to the icing model and further into the production loss model. The production losses are estimated from the icing intensity and ice load with an empirical model. These forecasts are uncertain owing to errors in the meteorological initial conditions and model formulations, in the employed ice growth models, and in the production loss models. Probabilistic forecasting provides the statistically best forecast and its uncertainty, and therefore, it is valuable for decision-making for next-day forecasts of wind power production in cold climates.

Probabilistic forecasting accounting for uncertainties in different parts of the modelling chain has been studied. The mesoscale ensemble prediction system HarmonEPS, based on the numerical weather prediction model Harmonie/AROME was used for the meteorological parameters. The ensemble prediction system consists of 11 members and has been run for up to +42 hours for a two-week period in the winter 2011/2012 with a horizontal resolution of 2.5 km over a Swedish domain of 1100x1600 km2. For this period also a neighbourhood method was tested to account for representativeness errors. For two other winter periods, 10 weeks 2013/2014 and 14 weeks 2014/2015, we generated an ensemble forecast based on five uncertain parameters in the ice growth model formulations. The parameters were perturbed within the estimated range of uncertainty and a deterministic sampling method was used resulting in a nine-member multi-physics ice model ensemble. For this study the same numerical weather prediction model as described above was used for the meteorological parameters, but mainly only the deterministic forecast.

For verification of wind power production forecasts, it is important to have a high wind speed forecast skill. We have analysed the wind speed forecast skill for the different periods described above, and found that the wind speed bias differs for the different periods even though the same numerical weather prediction model is used. This could be because of model updates, but makes the verification and potential bias correction difficult.

The three different probabilistic forecasting methods have the benefit of both uncertainty estimations for each forecast and higher skill for the ensemble mean compared to a deterministic forecast. Combining different methods accounting for uncertainties in different parts of the modelling chain resulted in even better forecast skill and forecast uncertainty estimations.

Web site: http://www.smhi.se

Short biography: Meteorologist with many years of experience in atmospheric icing, both on wind power plants and aircrafts. Has a background as an aviation forecaster, both in SMHI and in the Swedish Air Force. Presently working with different projects concerning numerical weather prediction.

R&D areas/s: 01. Forecasting, cloud physics and aerodynamics

The effect of atmospheric aerosol particles on cloud icing rate

Antti Ruuskanen, Finnish Meteorological Institute, FI

Ari Leskinen (FMI, FI), Mika Komppula (FMI, FI), Sami Romakkaniemi (FMI, FI)

Icing is an atmospheric process where ice accumulates on surfaces of any kind. While couple of different icing processes exists, the most interesting related to atmospheric aerosol studies is in-cloud icing. This icing process can be caused either by liquid rain drops or cloud droplets. The most important differences between the two are droplet concentration and size.

Icing can cause damage to structures or financial losses. For example, wind energy power plants might have unplanned shutdown or flights might get delayed/cancelled. With well-structured forecasting models these kinds of unplanned events could be avoided.
Current forecasting models typically have simplified representation of droplets due to the lack of reliable measurement data for verifying the models (Makkonen et al., 2010). The size distributions with typical droplet size are the most important parameters that are needed for reliable icing forecasts.
We have studied cloud droplet properties and icing conditions for several years at the Puijo measurement station (306 m a.s.l. and 224 m above the surrounding lake level) located in Kuopio, Finland (Leskinen et al., 2009). In addition to Puijo measurement station, Finnish Meteorological Institute is running another measurement station, Vehmasmäki, which is focused for mast measurements. At the Vehmasmäki site there is a 318 m high mast equipped with meteorological instrumentation at various heights including icing measurements started in 2016 at two different levels (115 m and 272 m). The icing data can be linked to the meteorological conditions as well as the profile measurements of wind, aerosols and water vapour located on the site.
The main focus of the study is to investigate connection between aerosol particles and cloud microphysical properties, meteorology and icing rate. The study includes several icing detectors (on/off and accumulation speed), cloud droplet probe (CDP), aerosol size distributions, and meteorological instruments for air temperature and wind speed/direction. Beyond, cloud modelling tools with explicit description of aerosol and cloud microphysics will be employed to support the data analysis (Tonttila et al., 2017).
Preliminary results show interesting behaviour of cloud droplet properties before icing events: the size and number of cloud droplets has to increase to some level before icing begins. The size is linked to the inertia of the particles which plays great role when considering static structures and surfaces where ice accumulates. For example, we have seen that even though temperature and cloud number concentrations are clearly optimal for icing to happen, the event starts after cloud droplets have reached some threshold size. With cloud model we study the sensitivity of icing rate on the cloud droplet size distribution, and how this distribution depends on the background aerosol size distribution, in cloud turbulence and cloud height in the conditions similar to measurements at Vehmasmäki. Special attention will be given on how the formation of larger droplets and light drizzle within the cloud affects the estimated icing rate.
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Web site:

Short biography: Antti Ruuskanen earned M.Sc. (Tech.) from Aalto University in 2014 (major in Advanced Energy Systems) and started working at Finnish Meteorological Institute (FMI) shortly after. He began his Ph.D. studies in early 2015 at University of Eastern Finland with research topics including aerosol-cloud interaction, aerosol optical properties, and most recently, the effects of atmospheric aerosol particles on icing.

R&D areas/s: 03. Pre-construction site assessment, measurements, models and standards

Clear air in cold climates: performance of continuous-wave ground-based lidar

Wulstan Nixon, ZX Lidars

J Medley, C Slinger, M Pitter, S Wylie, A Glanville, M Harris

Most lidar systems used in the wind industry operate on the principle of coherent detection, and rely on signal backscattered from material suspended in the atmosphere such as water droplets, volcanic ash and pollution. In very cold climates, such as in Northern Canada and Scandinavia, low temperatures can lead to low moisture content and the levels of backscatter can become extremely low. Successful operation of a lidar under these conditions correspondingly requires very high sensitivity. Failure to achieve the required sensitivity has potential to impact the availability for campaigns in arctic conditions to the detriment of the overall resource assessment quality.

Here we quantify the sensitivity of a continuous-wave (CW) wind lidar (ZX300), allowing prediction of performance and availability in clear air (low backscatter) environments. CW lidars have the potential for better sensitivity than pulsed lidars by virtue of their higher photon flux and focusing of their laser power at each measurement height in sequence. This focusing ensures that optimum sensitivity is achieved at all heights.

The performance is analysed primarily for ground-based lidar operation and the resulting impact on resource assessment campaigns is investigated. Experience from deployments in different locations around the world are used to validate the conclusions. Although the analysis uses ground-based lidar data, the conclusions are relevant to any application where lidar data availability is important; for example, it may be a crucial factor for the effectiveness of lidar-assisted control employing turbine-mounted lidar systems.

ZX Lidars has access to a significant database of historical lidar data from the UK Remote Sensing Test Site (UK RSTS). By reprocessing this data with the algorithms used in the latest ZX300 lidar, the performance of the ZX300 can be predicted across a full range of conditions. The data have been analysed specifically to isolate clear-air conditions, in which the backscatter is consistently low at all measurement heights. The data availability and accuracy were investigated at both the 10-minute and 1-second level as a function of the measured values of backscatter. This analysis was then combined with results from campaigns in clear-air locations, to check for consistency between the behaviour in different geographical areas, and to predict ZX300 data availability in those regions.

The data indicate that high availability and accuracy are maintained for the very low levels of backscatter experienced in cold climates. Sensitivity of the ZX300 lidar conforms closely with behaviour predicted in a previous theoretical analysis.

In summary: the data have been used to quantify the risk of clear-air data drop-outs as a function of backscatter.

Web site: https://www.zxlidars.com/

Short biography: After leaving school in Malvern Wulstan worked for a German company making valves for breweries. He has now been at ZX Lidars for fours years working as part of the sales team.
When not ZephIR'ing (aka biking on the hills or drinking in the pub afterwards), Wulstan a member of an amateur drama group and helps run the local scout troop, although at the moment he's usually found trying to make the house he lives in a bit more inhabitable or make the kit car he's built drive beyond the front gate!

Abstract #: 34 (Oral), session 10_03

R&D areas/s: 02. De-/anti-icing including new technologies, ice detection & control incl. standards

Icing alleviation for wind turbines with no ice-protected blades

Masafumi Yamazaki, Kanagawa Institute of Technology

Shigeo Kimura(Kanagawa Institute of Technology, Japan), Paolo Rossi(ANEMOS MAKEDONIAS ENERGEIAKI S.A., Greek)

A new project for alleviation of ice accretion on wind turbine blades having no blade's ice protection system was initiated in 2017 in a Greek wind farm. The wind farm has been run by a Greek wind turbine operating company Anemos Makedonias (AM), the headquarters of which is located in Athens. AM has been running 34 Vestas-V52/850 wind turbines for 10 years. The nominal power of the total wind turbines was 28.9 MW. The wind farm is situated in Macedonia province in a north-western region of Greece and at an elevation of approximately 2100 m above sea level. Due to the high elevation and the mountainous geography, the turbines may be in danger of atmospheric icing in winter. In fact, it was reported that the electricity yield has been sometimes far less than that of expectation calculated from the designed power curve of the turbine and the measured wind speeds. Taking the situational conditions of the turbines into account, icing on blades could be prioritized as the most possible influential cause of this power reduction.
At the first stage of this project, an attempt of physicochemical method was made in 2017. This method can be identical to coating of icephobic paint to the blades of wind turbine. The paint of particular characteristics of low wettability, named as HIREC, was provide by a Japanese telecommunication company, NTT Advanced Technology Corporation. HIREC features its icephobic characteristics by following properties: superhydrophobicity of the contact angle above 150 degrees and very low ice adhesion strength. Coating work in situ for one wind turbine methodically selected out of 34 was implemented in September of 2017 before snow fall started.
One year after of the blades' coating, the data analysis of the power production and the observation of the blade surface conditions through the photo analysis were carried out in order to evaluate the effectiveness of coating application and consequently indicated some findings. Making the blade surfaces icephobic might increase the energy yield by larger than 10 %. This could be deduced from a supposition that separation of ice deposits from the blade could occur easily and then the period of blade with clean surfaces would be prolonged. Early separation of ice would lead to decreasing the risk of damages from the ice throw. The photo analysis has shown that erosion by impingement of supercooled minute water droplets occurred in the very limited area close to the leading edge of the blade as expected by the CFD analysis done previously. Therefore, the large portion of coated area still remains in the blade surfaces as it was. This suggests that the icephobically coated surfaces would exert the similar effect in the next icing season as they did the previous year.

Web site:

Short biography: Masafumi Yamazaki is currently a Master candidate at Kanagawa Institute of Technology, and has research experiences as a trainee in two institutions. His interests are in aerospace engineering and aerodynamics. He has contributed to solve icing problems of wind turbines, aircrafts, and anemometers through both of solo and global collaborative works. His previous and ongoing research subjects are shown below:

■Research Trainee, National Institute of Advanced Industrial Science and Technology, 2018-current

- Wind measurement in the cold environment
- UAV operations in disasters

■Research Trainee, Japan Aerospace Exploration Agency(JAXA), 2016-2018

- de-icing system for aircraft with low energy consumption
- visualization of a water droplet status on airfoils
- optical icing detector

R&D areas/s: 01. Forecasting, cloud physics and aerodynamics, 02. De-/anti-icing including new technologies, ice detection & control incl. standards, 04. Operational experiences incl. performance optimization, big data, production losses and repairs, 08. Health, Safet

A cross-comparison of the IceThrower database with 10 years of SCADA and meteorological forecast data - What can we learn?

Rolv Bredesen, Kjeller Vindteknikk, NO

Rolv Erlend Bredesen (KVT, NO)

To find an optimal operating strategy while maintaining safe operation is a challenge for wind turbines, especially when the publicly available background knowledge on relevant issues such as the risk of ice throw and related sensitivities is scarce or not quantified.
Ice risk assessments are especially sensitive on the operational mode of a turbine. During icing conditions, some turbines shut down early either intentionally, due to the control system or performance degradation. Other turbines, on the other hand, can operate with ice on the blade permitting repeated cycles of re-accretions and shedding for even a single icing episode. Most of the ice pieces collected in the IceThrower [0] database come from work by Dala Vind in one of their wind farms consisting of V90 turbines which were allowed to operate with ice on the blades. A cross-comparison of the considered turbine's SCADA data, long-term simulations of meteorological parameters, and cataloged ice debris data collected from 8 separate icing episodes is presented. Furthermore, the timing of field observations to modeled and observed icing events are inspected as well as the performance degradation of the turbine during icing periods. This extented [2][3] comparison is essential in increasing the precision of ice risk analysis in general, and to lower the uncertainties involved. Relevant icing statistics derived with KVT Meso is also presented for the site.
In this study we cross compare the impact locations from 8 episodes with risk maps calculated based on the 10 minute distribution of wind statistics for each of the episodes to get a better understanding of the uncertainties involved. Also the potential for detecting such icing episodes is scrutinized as the turbines performance penalty in terms of lost production was only minor even when ice pieces in the range of above 1 kg had been thrown. This marginal ice detection signal are employed for the 10 years of available scada data to long term adjust the number of relevant icing episodes and number of pieces thrown for this site. Based on the ice detection signal also the potential of the meteorological model KVT Meso ability to correctly detect and/or forecast the episodes is quantified using Receiver Operator Characteristics which includes miss rates and false positives.
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[1]
http://windren.se/WW2018/03_2_24_Bredesen_Norwegian_guidelines_regarding_the_risk_of_icethrow_for_the_public_Pub_v2_draft.pdf
[2] http://www.energimyndigheten.se/forskning-och-innovation/projektdatabas/sokresultat/?projectid=18386

Web site: http://www.vindteknikk.com

Short biography: Rolv Bredesen is Kjeller Vindteknikk's expert on IceRisk assessments and the current Norwegian representative in IEA Wind Task 19 - expert group on wind energy in cold climates. His considered safe hobbies are speed-riding, hang-gliding, motorcycling as well as rock climbing.

R&D areas/s: 02. De-/anti-icing including new technologies, ice detection & control incl. standards

Benchmark of four Blade-based Ice Detection Systems

Paul Froidevaux, Meteotest AG, CH

Saskia Bourgeois (Meteotest AG, CH), René Cattin (Meteotest AG, CH)

An optimized and efficient operation of wind parks under icing conditions has become a very important issue for the operators. To reach optimal performance, a turbine must be able to detect ice on the rotor blades immediately when it oc-curs. It must also provide an "ice-free" signal when normal operation can be re-sumed.
We present an independent field test of four blade-based ice detection systems. The study was initiated and financed by the VGB PowerTech. Four ice detection systems have been mounted on the same turbine located in a cold climate site in Sweden.
The project comprises the following steps and tasks:

- installation of four blade-based ice detection systems: Weidmüller BLADEcontrol, Eologix, fos4x fos4IceDetection, Wölfel IDD.Blade in par-allel on one turbine
- collection of data of all ice detection systems as well as SCADA data of the wind turbine
- camera images of the blades and on top of nacelle used as reference
- all data and camera images stored in a dedicated data base
- analysis and evaluation of performance of the four ice detections systems
- final report on observed differences between the four systems

The detailed measurement program as well as the list of questions to be answered was defined by Meteotest in close collaboration with the project advisory board and the ice detection system manufacturers.
We will report on experiences from this first benchmark on blade-based ice de-tection systems.

Web site: https://meteotest.ch/en/division/icing

Short biography: Paul Froidevaux holds a PhD in Climate Sciences. He joined Meteotest four years ago, working primarily in the wind energy department. He is also responsible for operational weather models at Meteotest. In the context of wind energy and cold climate, Paul is an expert regarding icing forecasts and the analysis of SCADA data from wind turbines located in cold climate.
Paul couldn't live without at least three bicycles and spending a lot of time on them.

R&D areas/s: 03. Pre-construction site assessment, measurements, models and standards

On the formation of an icing atlas in Austria

Heimo Truhetz, Wegener Center for Climate and Global Change (WEGC), University of Graz, Austria

Clemens Wienerroither (WEGC, AT), Armin Leuprecht (WEGC, AT), Heimo Truhetz (WEGC, AT), Andreas Krenn (ernergiewerkstatt, AT)

Icing is one of the limiting factors in exploiting wind energy resources in cold climates. Due to the complexity of icing processes that range from meteorological/climatological to microphysical scales and show high variability in space and time, icing on wind turbines is difficult to measure and to model – especially in mountainous regions. The more difficult becomes an estimation of its far reaching impacts in long-term wind farm planning.

In the framework of the research project "R.Ice" (www.eisatlas.at/rice-en), funded by the Austrian Research Promotion Agency (FFG) through the Klima- und Energiefonds (project ID 853629), we have generated an icing atlas for the Austrian territory. The methodological approach unifies latest meteorological modelling techniques with a sophisticated icing model. In detail, we drive the well-known Makkonen icing model with long-term (period 1989 to 2015) meteorological reconstructions from the models CCLM and WRF that were operated on convection-permitting scales. By doing so, we receive long-term time series of ice masses for the Austrian domain in a high spatial (3 km grid spacing) and temporal (hourly time steps) resolution. These modelled ice masses are statistically analysed and a climatological icing atlas (average number of icing events and durations) is derived and compared with observed instrumental icing from multi-annual wind measurements as well as the results of a survey among Austrian wind turbine supervisors.

In our contribution to the conference we introduce the icing atlas, discuss the results of its evaluation, and elaborate on the differences between CCLM and WRF.

Web site: http://wegcenter.uni-graz.at

Short biography: Academic education and professional development:
2005-2010 Ph.D. student (Uni Graz) in the field of dynamical downscaling with emphasis on near surface wind. Ph.D. (Natural Sciences) degree in Physics: April 2010.
1995-2000 Studies of Environmental System Sciences with emphasis on Physics, Uni Graz. M.Sc. degree in Physics: June 2000.
1990-1995 Studies of Technical Physics, Technical University of Graz, Austria
2011-2017 PostDoc (staff scientist track) at Uni Graz, WEGC, Austria
since 2017 Senior Scientist at Uni Graz, WEGC, Austria
since 2010 Vice and Interim Head of Reloclim at WEGC, Austria
2011-2014 Coordinator of the CLM Community Working Group "Convection-Resolving Climate Simulations" (CRCS) (www.clm-community.eu)
since 2005 Lecturer at Uni Graz; supervision/co-supervision of master/PhD students and PostDocs
2003-2005 Büro ecowatt, Graz, (self-employed), Wind atlas for Styria
2001 Environmental Software & Services GmbH, Gumpoldskirchen, Austria
Main research areas & project specific qualifications: Regional climate modelling and model evaluation in complex terrain; analysis of climate processes and climate change in the Alpine region; statistical downscaling and bias correction

R&D areas/s: 04. Operational experiences incl. performance optimization, big data, production losses and repairs

Using 1Hz data to monitor turbine integrity

Carla Ribeiro, DNV GL

Francesco Vanni (DNV GL), Thomas Van Delft (DNV GL), Chris Hansford (DNV GL)

Keywords
Onshore wind, offshore wind, data analysis, fault detection, monitoring systems

1. General summary
Owners and Operators (OOs) seek ways to improve the performance of their wind turbines, reduce downtime and service and maintenance cost, increase operational efficiency, extend the life of their assets and, overall, reduce the Levelised Cost of Energy (LCoE).
While the potential hidden within operational data, available for free from the turbines' SCADA systems, is clear, traditional desktop-based studies have generally been too expensive to be a viable investment for OOs. It is only recently, with the advent of affordable online digital analysis platforms, that operational data started to be routinely mined to identify any performance issues or trends that could be indicative of potential failures.
These types of services normally focus on 10-minute SCADA data, however many modern turbine models also provide good quality data at 1Hz through their OPC and IEC interfaces. The analysis of this type of "higher-frequency" data is beginning to be explored.
We have developed a structural integrity monitor, which makes use of 1Hz data to identify and track some of the main structural frequencies of a turbine and to highlight any significant changes over time or across turbines, which may be indicative of existing issues or incipient failure modes.
In this presentation we will provide details of the algorothm and we will present the results of two case studies, one focussing on monitoring of foundation integrity, the second focussing on the detection of blade pitch misalignment.
2. Method
The algorithm we developed combines frequency domain analysis on 1Hz data and convolution filtering to identify the frequencies and energy content of the main structural modes and track them over time. Data acquisition rates above 1Hz permit the identification of the 1st tower mode and of the rotor frequency (1P). These can be monitored over time to spot unexpected changes in frequency or energy which may be indicative of foundation issues, rotor mass or aerodynamic imbalance, etc.
3. Results
We provide from two case studies. In the first, a wind farm experienced issues with degradation of the turbine foundations. These are visible when analysing the tower frequency, extracted from the 1Hz data, and show that ongoing monitoring based on such analysis would have identified the issue well before it became apparent through cracks and inspection results.
In the second case study we show how analysis of 1Hz data resulted in the identification of blade misalignment, an issue which is seldom looked at due to the difficulty in identifying it and discerning it from other power curve performance problems.
4. Conclusions
Our results show that 1Hz data can be a valuable input to condition monitoring, and enable the identifciation of issues such as foundation degradation and pitch misalignment that cannot be addressed through analysis of 10-minute SCADA data.
The algorithm we propose can be used to generate automatic alerts that will warn OOs when any of these potential issues are detected so that they can be avoided, or corrected, or that their impact can be mitigated.
5. Learning Objectives
While many turbine models nominally provide access to 1Hz data, in reality a significant proportion of these generates data at 1Hz by supersampling data at lower frequencies. This has resulted in some widespread skepticism towards the use of 1Hz data for condition monitoring analysis.
Our aim is to demonstrate the value of regular analysis of 1Hz data and to motivate the industry to move towards improved quality and frequency of turbine data outputs.

Web site:

R&D areas/s: 04. Operational experiences incl. performance optimization, big data, production losses and repairs

Short biography: Wind resource assessment expert with more than 13 years of experience, working in various regions across the world. Joined legacy Garrad Hassan in 2008 and has had a number of roles within the company since, both in technical and managerial capacities. She is now Head of Department, Renewable Energy Analytics, managing a team of more than 40 engineers to deliver services in the project development and operational stage of both wind (onshore and offshore) and solar projects. These include pre and post-construction energy assessments, site meteorological conditions, resource panorama (online meteorological data management), short term forecasting, performance monitoring of operational assets, among others. Her background is in Environmental Engineering, Climate Physics and Renewable Energy, all obtained with first class honours equivalent. She is also member of the IEA task 19 for the development of wind projects in cold climate.

R&D areas/s: 07. Laboratory and full-scale testing, small wind turbines, Comparison of numerical and experimental icing simulations

Industrial research on the design of wind turbines for icing conditions

Inken Knop, Technische Universität Braunschweig, DE

Stephan Bansmer (Technische Universität Braunschweig, DE), Khalid Abdellaoui (Wobben Research and Development GmbH, DE), Muhanad Mahmoud (Wobben Research and Development GmbH, DE), Andree Altmikus (Wobben Research and Development GmbH, DE)

In the research project „Industrial research on the design of wind turbines for icing conditions" funded by the Federal Ministry for Economic Affairs and Energy the process of icing and de-icing of rotor blades was examined numerically and experimentally by the Technische Universität Braunschweig (TU BS) and Enercon.
At the beginning of the project, TU BS upgraded its icing wind tunnel in the Institute of Fluid Mechanics to reproduce the icing conditions of the ground-level atmosphere. For this purpose a new spray system has been developed, enabling experiments with low liquid water contents (LWC<0.5g/m^3) at low wind speeds (<40m/s) and with small droplets (MVD<50μm) [1]. With well instrumented models, which correspond to the typical structure of rotor blades in the outer form and the inner layer structure, a large number of experiments were conducted in the icing wind tunnel. Thereby, the icing on a non-heated airfoil as well as the possibilities for anti-icing and de-icing with a heated model have been investigated. Additional investigations on the influence of different ice shapes on lift and drag were carried out.
Another aim of the experiments in the wind tunnel of the TU BS was to validate computational tools for the prediction of ice accretion. Numerical codes (TAUICE [2] and LEWICE [3]) based on the Messinger balance [4] have been primarily used for predicting aircraft icing. So far they have also been validated more or less only for this application [5,6]. But since the use of numerical tools represents an increasingly used option in wind turbine icing research [7,8], there exists a need for a comparison of the results of experimental and numerical icing simulation for the typical wind turbine icing boundary conditions. Several results of this comparison show that the numerics predict the limits of the iced area well in glaze and rime ice conditions. Furthermore, there are relatively good similarities of the ice thickness distribution between experiment and simulation in the rough ice range. In glaze ice conditions, however, larger deviations occur, similar to those described in [5].

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Web site:

Short biography: Since November 2015 Inken Knop is a PhD student in Fluid Mechanics at Technische Universität Braunschweig. She has a Bachelor's degree on mechanical engineering and a Master's degree on Renewable Energies from Technische Universität Hamburg. In Braunschweig she focuses on the

R&D areas/s: 07. Laboratory and full-scale testing, small wind turbines, Comparison of numerical and experimental icing simulations

investigation of different droplet measurement techniques in additions to the research on wind turbine icing and de-icing. Her favorite task is the experimental work in the icing wind tunnel.

R&D areas/s: 04. Operational experiences incl. performance optimization, big data, production losses and repairs, 06. Wind turbine manufacturers – cold climate solutions, test centres, turbines and components

Technology retrofit and service approach for performance optimisation in cold climates

Ulrik Rydstroem, Siemens Gamesa Renewable Energy

This is a commercial presentation and not a technical paper

Siemens Gamesa has a long history and vast experience in cold climate turbine installations around the world and has been a first mover in bringing to market new technologies for improving the performance of turbines in these conditions. In particular, in Sweden, Siemens Gamesa has over 1,8 GW installed or under construction and over 300 turbines in operation with de-icing and/or Operation with Ice (OWI). This presentation illustrates some examples where technology retrofit has delivered true value to customers as well as a holistic view of the knowledge and expertise SGRE bring to operating a wind farm in cold climates

Web site: https://www.siemensgamesa.com/en-int

Short biography: Ulrik Rydstroem is currently the Head of Service for Siemens Gamesa in Sweden, Finland and Lithuania. Since graduating as a Mechanical Engineer, he has further supplemented his education with studies in Marketing, Economics and Industrial Environmental Engineering. Ulrik started in wind power when he joined Service at Siemens AB in 2012, bringing with him a well-developed acumen in developing operational efficiency and in productivity as well as profitability improvement, in addition to his rich experience in engineering and project management. In his career over the last 23 years, Ulrik has developed senior management experience having had the overall responsibility for managing, operating and developing a number of departments in construction and engineering businesses. Ulrik's specialty is to develop positive results, for customers as well as for his own company.

R&D areas/s: 03. Pre-construction site assessment, measurements, models and standards

Wind-farm-scale blockage in stable regime associated with cold climates

Till Beckford, DNV GL, Netherlands

Christiane Montavon (DNV GL, Netherlands), James Bleeg (DNV GL, UK)

General summary
When modelling turbine interactions within arrays, the wind industry usually only considers wake losses, whereby a specific turbine only affects turbines located downstream of its position. In practice, turbine interactions also include lateral as well as up- and downstream interactions, which altogether contribute to the resistance (aka blockage) that the wind farm induces on the background flow, deflecting some of the flow above and around the wind farm. A consequence of this is that the turbines operating on the upstream edge of the wind farm are exposed to wind speeds which are slightly different (usually reduced) from the so-called freestream conditions, as measured by a mast before the wind farm is in operation. Computational fluid dynamics (CFD) simulations, modelling turbines via actuator disks, can account for the two-way interactions between flow and turbines. By comparing simulations results with and without the turbines operating, we can quantify the changes in the upstream wind speed seen by the turbines on the upstream edge of the wind farm, and therefore calculate the associated bias in energy production when such a blockage is ignored.
In this contribution, we analyse the sensitivity of wind-farm-scale blockage to atmospheric conditions particularly relevant for cold climate regions, by varying the upstream profiles and surface stability conditions of a set of CFD simulations.

Method
For a specific wind farm, we carry out two sets of CFD simulations with and without the turbines operating. The turbines are modelled via an actuator disk model. The blockage effect is quantified from both sets of simulations, comparing the energy produced by the turbines on the upstream edge to what they would produce in isolation. Since blockage is not easily quantifiable from direct data (wind farm operators don't tend to willingly operate turbines in isolation!), a validation of the blockage seen at the wind farm is attempted by comparing the measured and simulated non-uniform pattern of production of leading turbines. Earlier work suggests that the magnitude of blockage is sensitive to the turbine density, turbine hub height to rotor diameter ratio, as well as to the prevailing atmospheric stability conditions. The current contribution focuses on the latter, by calculating the magnitude of the blockage loss for a range of conditions, from neutral to very stable surface stability conditions, as well as by investigating its sensitivity to the thickness of the boundary layer height.

Results
Early results on the sensitivity tests suggest that the magnitude of the blockage is increased as the surface stability conditions become more stable. For a couple of complex terrain, forested wind farm sites in Scandinavia, the simulated blockage loss (in energy term) increased by 50% to 70% when the surface stability conditions changed from near neutral ($L \sim 1000$m) to moderately stable ($L \sim 200$m). Investigations on another site also showed that the blockage loss increases as the boundary layer becomes thinner, as is relevant for sites with frequent low-level jet conditions such as seen in the Baltic Sea.
A conclusion from the analysis carried out is that wind-farm-scale blockage is likely to lead to non-negligible losses for wind farms developed in climates with frequently occurring stable surface conditions.

Web site: https://www.dnvgl.com/energy/services/index.html

Short biography: Till Beckford has been working in the renewable energy sector with DNV GL since 2012. Working in the Renewable Energy Analytics department, Till focuses on undertaking analyses of wind farms throughout their life cycle – from project development through to operational analyses. In his current role, Till leads a team of engineers serving the Nordics & Baltics markets and is the technical lead for DNV GL's pre-construction services. Till has worked on some of the largest wind farms in northern Europe and has extensive experience in Cold Climate projects. Till has a Masters in Mechanical Engineering from the University of Bath.

R&D areas/s: 02. De-/anti-icing including new technologies, ice detection & control incl. standards

Presenting ice detector research results from wind turbine field tests and icing wind tunnel tests

Tatu Muukkonen, Labkotec Oy, FI

Jarkko Latonen, Labkotec Oy, FI

Labkotec is presenting ice detector research results from wind turbine field tests and from VTT icing wind tunnel tests. Wind turbine and icing wind tunnel test results are needed to finalize the development of blade-mounted ice detector. Both nacelle-mounted ice detectors and blade-mounted ice detectors have been studied during the field tests and VTT icing wind tunnel tests as well as simulations.
Blade-mounted ice detector is based on direct measurement on blade surface and is going for production after years of intensive research and development phase. The very first blade-mounted ice detector prototype by Labko was installed to a wind turbine blade already in 1994. It was integrated to wind turbine to optimize blade heating and to minimize ice accumulation on the blades.
Labkotec is also developing solutions around the current LID-3300IP ice detector. New solutions include e.g. updated LID-3300IP Type 2 ice detector, surge protection cabinet for ice detector control unit and ice warning light system. Functional safety level of LID-3300IP Type 2 ice detector has been improved from PL b to PL d to provide even more reliable use in wind turbines. Surge protection cabinet is guarding the ice detector against overvoltage from e.g. lightning strikes. Ice warning lights are designed to inform public and personnel of icing conditions to avoid possible accidents due to falling ice.

Web site: http://www.labkotec.fi/en

Short biography: Working on ice detection R&D and customer related applications for about seven years as Project Manager and about four years as Product Manager. My life has been very exciting lately as I'm teaching my son to drive.

R&D areas/s: 03. Pre-construction site assessment, measurements, models and standards

Verification of numerical weather model predictions and wind turbine production-loss due to ice using ceilometer measurements

Niklas Sondell, Modern Energy, Sweden

Niklas Sondell (Modern Energy, SWE), Rolf-Erik Keck (Modern Energy, SWE), Måns Håkansson (Statkraft AS, NOR), Espen Hagström (Statkraft AS, NOR)

Modern Energy has developed a method for assessing the production loss due to ice at the pre-construction stage of wind farm development. The method is based on time series input of local atmospheric conditions such as temperature, wind speed, wind direction and liquid cloud water content (LWC) of the local air mass. These time series can be obtained through on-site measurements, but the most common approach is to generate this data by conducting high-resolution simulations of local weather using WRF. In a subsequent step we simulate the performance degradation of the ice-affected turbines. This includes the main processes which simulate the ice-accession (melting, sublimation and mechanical sheading), as well as a set of turbine specific parameters which govern the sensitivity to ice, the efficiency of the de-icing system and the trigger points in the control system for ice-affected operations.

The accuracy of the simulated weather input is the most important aspect to achieve high quality ice-loss predictions. While most of the input parameters can be satisfactorily verified against met-mast measurements, e.g. wind speed and temperature, it is more uncommon to have measurements of LWC. In this work we present a verification of the LWC in a set of WRF simulations in complex terrain. The LWC signal in the simulations has been verified using an onsite ceilometer, a laser-based device which can measurement visibility and cloud height in a vertical column. Measurements and field data analysis have been undertaken by Statkraft AS for three sites: a costal site in Norway and two inland sites in Sweden.

Web site: http://www.mewind.se/

Short biography: Karlstad Modern Energy AB is a boutique consultancy firm founded and operated by Niklas Sondell and Rolf-Erik Keck. Together Niklas and Rolf-Erik have 25 years´ experience of technical calculations from the wind industry ranging from turbine performance & profile aerodynamics to full wind farm optimization & post-construction analysis. For more information about us visit: http://www.mewind.se/about-us/

Abstract #: 45 (Oral and poster), session 07_04 (13_15)

R&D areas/s: 02. De-/anti-icing including new technologies, ice detection & control incl. standards

Increased turbine efficiency during icing conditions by means of pre-emptive blade heating control

Michael Moser, eologix sensor technolocy gmbh, AT

Theresa Loss (Graz University of Technology, AT), Michael Moser (eologix, AT), Thomas Schlegl (eologix, AT)

Nowadays, wind turbines in icing conditions are more and more being equipped with anti-icing and/or de-icing equipment. These devices consist of either a hot air fan which circulates air within the blade structure and have a high latency or consist of conductive elements in the blade which can heat up fast. Both system designs are typically lacking a sophisticated control algorithm, often relying on a small number of temperature sensors at the blade root. Especially the de-icing regime requires the turbine to stand still or be idling, thus being unproductive. Furthermore, heating power is often fixed and de-icing run times are calculated using no more than ambient temperature and/or just by quasi-empiric values from experience.

Based on data collected on heated turbines, we present an approach to effectively control turbine heaters by means of multiple icing and temperature sensors which deliver data from heated areas of the blades. This allows for efficiency increase in at least the following ways:

1. unnecessary blade heating can be avoided (e.g. during positive temperatures and free surfaces)
2. unnecessarily high blade surface temperatures can be avoided (e.g. temperature does not exceed +10°C), allowing for less mechanical stress, smaller temperature gradient over the blade, less heating energy consumption and earlier restart, thus reducing downtime)
3. by anticipation of icing events (combinations of low temperatures and the distribution of the presence of humidity)

In the full paper, we will show use cases, measurement data of events and a data comparison of approx. 20 turbines under similar conditions, controlled by a pre-emptive blade heater control system based on distributed sensors.

Web site: http://www.eologix.com

Short biography: Michael Moser studied Electrical Engineering and Sound Engineering at University of Music and Performing Arts Graz and Graz University of Technology. Between 2007 and 2013, he was a research assistant at the latter, where in 2013 he completed his PhD thesis focusing on energy harvesting and icing detection on electrical power transmission lines. Since 2014, he is managing director of eologix sensor technology. When he finds time, he still likes to play the piano.

R&D areas/s: 02. De-/anti-icing including new technologies, ice detection & control incl. standards, 06. Wind turbine manufacturers – cold climate solutions, test centres, turbines and components, 07. Laboratory and full-scale testing, small wind turbines

To heat or not to heat ?

Xavier VANWIJCK, XANT, Belgium

Xavier VANWIJCK (XANT, BE), Pieter-Jan JORDAENS (OWI-Lab, BE)

For mid-power wind turbines in cold climate conditions, the costs of the anti-/de-icing strategies can become problematic since the solutions currently proposed on the market can quickly represent a few percentages of the wind turbine costs. To reduce the downtime due to iced blades, XANT made a multi-criteria analysis of the available options and finally selected to blow hot air within the blades of its 100 kW machines.
But since XANT provides wind turbines in remote regions with limited equipment, the selected solutions had to be tested in advance; that's why XANT used the climatic chamber facilities operated by the OWI-Lab in the Port of Antwerp (Belgium). This test allowed XANT to anticipate problems coming from the cold conditions.
Since then, XANT installed two 100 kW wind turbines in Alaska where the selected solutions have been challenged in real conditions.

Web site: http://www.XANT.com

Short biography: Xavier Vanwijck joined 3E's wind turbine technology team as a structural engineer in March 2009 and joined XANT in 2013. He contributes to in-house technological developments in wind energy and is also specialised in technical due diligence and turbine inspection services. Xavier also develops tools for the review of contracts (supply and O&M) and financial models from a technical point of view.
After working for Samtech as a finite element software developer, Xavier worked for the Office National d'Etudes et de Recherches en Aérospatiale (ONERA) in Paris as a specialist in space surveillance and environmental monitoring.
Xavier Vanwijck graduated from the University of Liège (Belgium) with a degree in Electrical and Mechanical Engineering in 1998.

Xavier is now the Chief Technical Officer of XANT.

R&D areas/s: 02. De-/anti-icing including new technologies, ice detection & control incl. standards

Blade based ice detection – knowledge base for efficient operation in cold climate conditions

Timo Klaas, Wölfel Wind Systems GmbH

Timo Klaas

Since the efficiency of wind turbines (WT) is primarily reflected in their possibility to produce energy at any time, the down times of WTs due to "conventional" inspections for damage or ice detection are costly and unwelcome for WT investors.
Especially the danger of ice throw from rotor Blades has to be avoided for personal safety reasons. Furthermore, the ice on rotor blades can cause severe damage to the wind turbine itself. Not only to the rotor blades, but also other parts of the structure, e.g. gear box and the tower are more affected by higher loads and imbalances.
For this reason the Wölfel Group has developed a wide product line-up with vibration-based SHM systems for damage and ice detection in rotor blades, foundation and tower monitoring (onshore and offshore), load monitoring, vibration reduction systems, etc., to give wind turbine operators the opportunity to reduce the number of WT inspections and increase availability and yield.
The centerpiece of this paper is the presentation of the latest innovations and developments around SHM systems:
In this context the following will be presented:

- The importance of ice and damage detection on rotor blades
- New hardware concept: Have a look into the future
- Additional blade monitoring features such as damage detection, rotor blade imbalance and pitch angle monitoring
- Increase of energy output: summer vs winter operation
- Smart data: How to use advanced data analytics to gain new findings

Web site: https://www.woelfel.de/en/home.html

Short biography: Timo Klaas is educated as an industrial engineer (B. Eng), 33 years old and lives in Hamburg. He is working for Wölfel Engineering and is leading the sales department for all systems related to wind energy.

R&D areas/s: 06. Wind turbine manufacturers – cold climate solutions, test centres, turbines and components

Nabralift Tower: Challenges of Icing Conditions in Open Tower Structures

Emilio Rodriguez Saiz, Nabrawind Technologies, Spain

Arantxa Esparza (NBTECH, Spain), Emilio Rodríguez (NBTECH, Spain)

Nabralift wind turbine tower is a solution that fits perfectly in Scandinavian market, that is currently under way on installing bigger and taller wind turbines.
Its three monopile based foundation let to undertake its implementation in every season. This is possible also in winter time since the excavation as well as concrete pouring and curing is carried out under zero level where the temperature keeps warm all the year. This foundation type reduces the quantity of concrete in more than 95% comparing with a standard foundation based in reinforced concrete footings.
Nabralift structure is based on three column jacket type identical modules. This simplifies logistics enormously since all the components of each module can be transported to site in conventional trucks, and only a special convoy is required for transition piece parts.
In addition the robustness of the self erection system, in which the structure is fully guided, let complete the process with an ten-minute mean wind speed up to 15 m/s. This advantage speeds up the assembly process even also in winter time when Scandinavian area registers highest wind speeds in year.
The impact in the wind turbine loads and in the WT dynamics due to ice buildup and low temperatures have been studied and solved resulting in a new low temperatures version that will be launched in Winter Wind 2019.
This Nabralift LT version let install the tower in IEA Ice Class 3 sites.

Web site: http://www.nabrawind.com

Short biography: M Sc in Materials Engineering at Bilbao University from 1999.
Worked in the Aerospace Industry until 2007 in different aircraft and helicopter projects (Boeing 787 and 747, Embraer 145, Sikorsky S-92).
Worked from 2007 in wind turbine design and development at Gamesa (SGRE) in different wind turbines (3.3 MW and 5Mw platforms); in relation with cold climate was project leader for the development of a Blade de-icing system in cooperation with VTT and has several years of experience with wind turbines operating in Finland including Lapland.
Working from 2016 as Materials and Processes Engineering Manager at Nabrawind Technologies.

R&D areas/s: 05. Onshore turbines, aerodynamics, loads and control

Load monitoring and lifetime assessment for wind turbine towers

Carsten Ebert, Wölfel Wind Systems GmbH, Germany

Manuel Eckstein, Wölfel Wind Systems, Germany

Wind turbine (WT) towers are exposed to various loads such as high wind, additional loads due to pitch angle errors and incorrect operational modes. These loads affect the operating costs as well as the lifetime of the components. Nevertheless, the majority of all existing wind turbines have large – but unknown – reserves with respect to their lifetime.
With a simple and intelligent monitoring concept these loads can easily be recorded and analyzed with respect to operational mode, lifetime and predictive maintenance. An accelerometer combined with a numerical model is used to measure the vibrations and to derive the loads in any segment of the tower.
It can be shown that the fatigue loads differ in different operating modes. In particular, special conditions - such as power failure, icing conditions, imbalances - lead to higher loads that reduce the service life. Through permanent monitoring, the effects - e.g. by rotor icing – are objectively recorded and analyzed. The mode of operation can be optimized and the lifetime maximized.
In a research survey, this concept has been investigated with respect to validity and precision. With additionally installed strain gauges, the mathematically derived loads are compared and evaluated with respect to the loads measured by the strain gauges directly. It is shown that the concept is very suitable for lifetime prediction and various load analyses (e.g. influence of retrofitted components).
In this context, the following will be presented: sensor and monitoring concept; insight in mathematical method; research survey: evaluation and comparison of loads; lifetime prediction; predictive maintenance.

Web site: https://www.woelfel.de/en/home.html

Short biography: Carsten Ebert is civil engineer (Dr.-Ing.) and 42 years old. He has been working for Wölfel Wind Systems since 2008 and is Engineering Director for the wind energy and the structural dynamics departments. He has an extensive knowledge in structural dynamics, especially in the field of structural health monitoring based on vibration measurements. At Wölfel, he is responsible for the development of products for the structural monitoring of rotor blades, towers and foundations. Since 2013, he is a member on advisory board of VDI-Guideline 4551, a German guideline for the condition monitoring of offshore wind foundation structures.

R&D areas/s: 06. Wind turbine manufacturers – cold climate solutions, test centres, turbines and components, 07. Laboratory and full-scale testing, small wind turbines

EFAFLU test case: cold start-up validation of transformer pumps by the use of a large climatic test chamber

Daniele Brandolisio, OWI-Lab, BE

Daniele Brandolisio (OWI-Lab, BE), Pieter Jan Jordaens (OWi-Lab, BE), Joao Pinto (EFAFLU, PT), Benedita Ferreira (EFAFLU, PT)

The new trend in the installation of wind turbines is the choice of remote areas, where wind conditions are very often optimal leading to new investments for the implementation of wind energy parks. On the other hand, such locations have to deal with extreme inhospitable climatic conditions: extreme cold and/or hot temperatures, strong winds and gusts, high humidity, ice and/or snow, salty environment (in case of the offshore market). These harsh locations form a huge challenge for the machine itself and maintenance and repairs works in such circumstances can be challenging. In some cases repair works have to be postponed because of bad environmental conditions and thereby noticeably affects the turbine availability and its business case. For this reason, wind turbines and its components need to be designed and validated to meet the capability of surviving and operating in such extreme conditions. OEM's and component suppliers are more and more aware of the need to perform advanced validation tests in order to substantiate confidence in its designs, and to increase the reliability and robustness of their products in such inhospitable environments.
EFAFLU is a Portuguese company entirely dedicated to development, manufacture, marketing, technical support as well as after-sales service of pumps, pumping systems and fans. With the increase in the demand of wind turbine installation in harsh environments, EFAFLU recognized the need to validate one of its leading typology of product (oil pumps for transformers) performing cold start-up tests in extreme cold temperatures. For this, EFAFLU teamed up with OWI-Lab. OWI-Lab is specialized in testing and verification of wind turbine components and full integrated systems as gearboxes, generators, liquid filled and cast resin transformers, power converters, hydraulic systems, etc. in extreme climatic conditions, thanks to its own climatic test chamber – one of the largest of Europe – able to range the temperature from -60°C to +60°C. A specific focus of the climatic test lab is in to test cold-start-up sequences, cold climate / winterization effects, and icing conditions on large electro-mechanical equipment.
According to EN 50216-7 standard – "Power transformer and reactor fittings; Part 7: Electric pumps for transformer oil", pumps are required to perform a cold start-up test at -25°C. During the test the pump shall reach full running speed following the conditions of minimum voltage with oil at minimum temperature and without overheating or other adverse observations. Besides the standard specifications, the intention of EFAFLU was to extend the standard requirements to a more severe scenario of: -45°C. A tailor-made test setup has been designed and implemented by EFAFLU, able to accommodate different pump models and sensors for measurements at specific locations.
The potential risks which lead to failures related to start-up in extreme cold temperatures are:

- Lubricants become viscous and too stiff due to extreme cold, putting exceptional load on the pump;
- Rotating elements in the pump can be at risk because of insufficient lubrication and/or differential thermal expansion of sub components;
- Due to difficulty of the cold start-up, the pump motor can experience overheating problems caused by high current demand;
- Low temperatures effect materials (plastics, metals, rubbers) and cause brittle fracture of materials (sealings, cables, gears,…)

Therefore, the validation in a controlled environment of systems and components to be installed in areas where extreme conditions represent a risk of potential failures is crucial to guarantee the correct operation of the component and to assess the design choices which influence the lifetime.

Web site: http://www.owi-lab.be/

Short biography: Beginning 2018, Daniele joined the OWI-Lab team, the wind energy RD&I initiative implemented and coordinated by Sirris. His main focus and expertise can be found within the domain of lab testing and R&D field measurements. As application engineer 'wind energy' he supports and performs either onshore and offshore R&D measurement campaigns, and ongoing RD&I projects for the industry.

R&D areas/s: 06. Wind turbine manufacturers – cold climate solutions, test centres, turbines and components, 07. Laboratory and full-scale testing, small wind turbines

Moreover, he develops and performs test campaign in the Climatic Test facility of OWI-Lab together with the other OWI-Lab team members and research partners as VUB and UGent.
After achieving a master degree in Mechanical Engineering at the University of Udine (Italy), Daniele started his career first in the condition monitoring field in the steel industry at Danieli (Italy); in 2011 he joined the Noise and Vibration group in the Mechanical Engineering Department of KU Leuven (Belgium), first as researcher and then as test engineer, where he strengthened his knowledge in vibration testing either in the lab (6 DOF shaker table) as in the field. He obtained expertise knowledge on modal analysis and has experience with setting up measurement campaigns. Daniele has been involved in several research projects; he also worked at Siemens Industry with a secondment contract in the framework of EU projects.
His interest towards renewable energy comes from his passion for the outdoors. With climbing as his main activity, he found in the wind energy sector an opportunity to combine his interest with his professional skills.

R&D areas/s: 06. Wind turbine manufacturers – cold climate solutions, test centres, turbines and components, 07. Laboratory and full-scale testing, small wind turbines

Siemens Gamesa test case: extreme cold start-up validation of a wind turbine gearbox by the use of a large climatic test chamber

Pieter Jan Jordaens, OWI-Lab

Daniele Brandolisio (OWI-Lab, BE), Pieter Jan Jordaens (OWI-Lab, BE), Mikel Ochoa Oronoz (Siemens Gamesa, ES), Inaki Ruiz De Ocenda Ortiz De Guzman (Siemens Gamesa, ES)

Wind turbines are more frequently installed in remote areas, where very often profitable wind conditions makes those sites attractive to implement wind energy parks. On the other hand, such locations have to deal with extreme inhospitable climatic conditions: extreme cold and/ or hot temperatures, strong winds and gusts, high humidity, ice and/or snow, salty environment (in case of the offshore market). These inhospitable locations form a huge challenge for the machine itself and maintenance and repairs works in such circumstances can be challenging. In some cases repair works have to be postponed because of bad environmental conditions and thereby noticeably affects the turbine availability and its business case. For this reason, wind turbines and its components need to be designed and validated to meet the capability of surviving and operating in such extreme conditions. OEM's and component suppliers are more and more aware of the need to perform advanced validation tests in order to substantiate confidence in its designs, and to increase the reliability and robustness of their products in such inhospitable environments.
Siemens Gamesa, a leading manufacturer of multi-MW wind turbine gearboxes is also aware of the benefit of a dedicated validation processes. For the part of extreme cold temperatures and hot climate validation tests it teamed up with OWI-Lab. This Belgian R&D Initiative houses one of Europe's largest climatic test chamber, specifically designed to validate wind turbine components in extreme climatic conditions. A dedicated test-rig has been designed to perform cold-start up gearbox tests under extreme temperatures (-40°C to +60°C). The test bench is used to verify the capability of the gearbox to withstand a shutdown event and subsequent return into service in extreme cold climate conditions (cold soak test). The same test bench can also be used to validate the cooling performance of the gearbox in hot climatic conditions.
Potential failure modes of a gearbox at extreme cold or hot temperatures include:

- Lubricants become viscous and too stiff due to extreme cold, putting exceptional load on the pumping equipment and other auxiliaries mounted on a wind turbine gearbox system.
- Rotating elements in the gearbox can be at risk because of insufficient lubrication and/or differential thermal expansion of sub components.
- Lubricants can become more or less viscous which effects the oil flow in bearings and raceways.
- Cooling system can experience overheating problems during extreme heat.
- Long cold start-up runs and its negative effect on energy yield.
- Low temperatures effect materials (plastics, metals, rubbers) and cause brittle fracture of materials (sealings, cables, gears,…)

The potential failure modes illustrate the requirement for qualitative engineering of the lubrication mechanism, thermal management system and appropriate control strategy in case of (extreme) cold start-up events. Validating these systems in a controlled environment has been performed by Siemens Gamesa together with OWI-Lab.

Web site: http://www.owi-lab.be/

Short biography: Pieter Jan Jordaens joined Sirris (Belgian technology center – www.sirris.be) in 2010 as a project leader. Since then he has been responsible to built-up and roll-out 'OWI-Lab' (www.owi-lab.be) which is the Belgian research, development and innovation lab for wind energy. This platform is supporting innovation within the full value chain of wind energy but is focusing on the emerging sector of offshore wind energy and wind energy in harsh environments as 'cold climate wind energy'. The aim is to reduce investment and O&M costs, and make the technology efficient and reliable as possible to compete with traditional energy sources .
Pieter Jan focused on developing the innovation and test services of the lab as business developer. Specifically on topics as 'climate chamber testing' of wind turbine components for offshore, cold, hot, and tropical climates the OWI-Lab team has built-up international recognition. One of the largest climatic test facilities in Europe was built up in the port of Antwerp to test and demonstrate the ability of wind turbine machinery to operate in harsh conditions worldwide in which they are currently installed. In cooperation

R&D areas/s: 06. Wind turbine manufacturers – cold climate solutions, test centres, turbines and components, 07. Laboratory and full-scale testing, small wind turbines

with the university of Brussel (VUB) also an RD&I trajectory was set-up on the topic of structural health monitoring (SHM), structural integrity and the use of big data for (offshore) wind turbine applications. OWI-Lab has been one of the first actors in the offshore wind energy value chain in addressing the SHM topic. Also a spin-out company was set-up as a valorization result of the R&D trajectory.
Before joining Sirris, Pieter Jan obtained a Master's degree in Electro-Mechanical Engineering at the International University College Group T (now KUL) in Leuven. After that he studied the International Postgraduate Programme in Entrepreneurial Engineering.

R&D areas/s: 07. Laboratory and full-scale testing, small wind turbines

Cold climate test center in Sweden

Martin de Maré, RISE Research Institues of Sweden

Martin de Maré (RISE)

Full scale test and validation for the wind industry
Owners and operators want to purchase proven products so suppliers need to prove the suitability of their products in cold climate conditions. The full scale test center in Arjeplog municipality will provide the right conditions to get ahead of things in this aspect. Besides it also offers possibilities to develop safe routines for installation, operation and maintenance in harsh conditions. The cold climate wind community will also have increased possibility to influence and be part of the development of standards and regulations in this area.
Sensor technology development, improved models and simulation, improvement of forecasting, enhanced operation and remote tools is also being welcomed at the test center.

Web site: http://coldclimatetest.com/

Short biography: Project manager with experience from both establishment projects and research projects in wind power. International network within wind power in cold climate.

R&D areas/s: 06. Wind turbine manufacturers – cold climate solutions, test centres, turbines and components

Vestas Cold Climate Solutions

Brian Daugbjerg Nielsen, Denmark

Brian Daugbjerg Nielsen, Karl Gregory

Vestas will present the cold climate solutions package, the Low temperature which have been installed since the kW platform, the journey to Anti-icing, why it was selected, how it was designed, how it have been tested to a commercial product. Field testing and latest learnings will presented, and what the focus will be in the short term. Vestas furthermore offers icing forecasting, and it will be elaborated what learnings have been from this, and how this correspond to field data, and what considerations Vestas is doing.
Furthermore Vestas is expanding its cold climate program in terms of:
- Ice Detection
- Integration of Ice Detection in Anti-icing to run in a more safe based operation
- Maturing Anti-icing product to the be ready for the market

Web site: https://www.vestas.com/en/campaignsites/coldclimate/home

Short biography: Holds a master from Copenhagen Business School in Economics
Worked in Vestas since 2006
Been in the cold climate field since 2012, as responsible for the cold climate road map
Personal interest: Active running and fiction novels

R&D areas/s: 01. Forecasting, cloud physics and aerodynamics

Icing Predictions for the Canadian Wind Energy Industry

Simon-Philippe Breton, Environnement et Changement Climatique Canada (ECCC), Canada

Simon-Philippe Breton (ECCC, Canada), Franco Petrucci(ECCC, Canada), Marilys Clément(Nergica, Canada), Nigel Swytink-Binnema(Nergica, Canada)

Icing is known to be an important problem for the wind turbine industry in cold climates. It is among other things associated to a reduction in power production, as ice accretion on turbine blades affects their aerodynamic properties, thereby reducing their efficiency. It can also be associated to increased fatigue loads on the blades, and can cause ice throw.
It is therefore very useful for wind farm operators to accurately forecast icing and the associated power losses. This can help in forecasting how much electricity will be fed into the grid. Accurate icing forecasts can also inform about when to use anti-icing systems, as well as better plan maintenance activities.
This project focuses on power production losses associated to icing in order to develop tools that can help the wind energy industry deal with this problem. It brings together a multidisciplinary team of experts from Nergica and the Meteorological Service of Canada (MSC).
MSC uses the numerical weather prediction model called GEM-LAM to perform high resolution (2.5 km) operational weather forecasts for the whole of Canada, four times a day. At MSC, we have direct access to the real-time output from this model, which is continuously improved and known to perform world-class leading edge high fidelity weather predictions. In this project, various meteorological variables output from the GEM-LAM model every six hours are interpolated at chosen locations at a high vertical resolution. They are then used by Nergica in an icing model, GPEO, inspired by the work from Yang et al. [1] to model icing. GPEO models ice accretion on a fixed cylinder. Turbine-dependent transfer functions are then developed by Nergica to translate the ice accumulation into power loss on a wind turbine. This icing and power loss forecast is performed operationally (continuously in time) as the forecast data from MSC become available.
Nergica is the owner of an experimental test site in cold climate that includes two commercial 2-MW instrumented wind turbines as well as two meteorological masts, and it has access to met mast data measured at different locations. The instruments include various types of ice detectors as well as cameras continuously taking pictures of a cylinder for which an image analysis is performed to detect and qualify icing.
The icing and power loss forecasts performed by GPEO are compared to available experimental data from Nergica's experimental site for validation purposes and to refine the icing model. Findings from these comparisons and from further analysis of the available observations can also contribute to improving the outputs from the MSC meteorological forecasts related to icing.
Preliminary results have shown to be very promising. Work is currently being done to improve GPEO to better represent ice ablation. Emphasis is also put on improving the versatility and accuracy of the transfer functions, and to provide confidence intervals for the forecasts provided.
An overview of the numerical method used at MSC to perform its forecasts and of the algorithms used to model icing will be provided. The available experimental data used for validation will also be presented. The latest results obtained from this project will be shown and discussed, and steps for a second phase to this project will be outlined. For example, artificial intelligence is being considered in transfer functions development.
References
[1] J. Yang, W. Yu, J. Choisnard, A. Forcione and S. Antic, Coupled Atmospheric-Ice Load Model for Evaluation of Wind Plant Power Loss. J. Appl. Meteor. Climatol., vol. 54, pp. 1142-1161, 2015.

Web site:

Short biography: Simon-Philippe Breton is a physicist and holds a Ph.D. in wind turbine aerodynamics from the Norwegian University of Science and Technology in Trondheim, Norway. He completed a post-doctorate at the École de technologie supérieure in Montréal, Canada, where he focused on analysing the wake development downstream of wind turbine rotors. He was later Associate Professor in the Department of Earth Sciences at Uppsala University in Sweden, in the wind energy research group. As part of this group, he taught various wind energy topics at the Wind Power Project Management Master's Program offered at Uppsala University. He later acted as a project manager, research and innovation, at

R&D areas/s: 01. Forecasting, cloud physics and aerodynamics

Nergica (formerly the TechnoCentre éolien) where he worked on various applied research projects in wind energy related among other things to icing.
His studies and work have allowed him to carry out various research trips abroad, including in Germany, Denmark, Spain, Norway and Sweden. He has experience in developing collaborations and partnerships between academia and industry, and in the identification and funding of key research topics. He joined Environment and Climate Change Canada in September 2018 where he is now working on a wind project in collaboration with Nergica and the University of New Brunswick, whose goal is to improve icing and wind ramps forecasts, which are two phenomena that can significantly affect wind generation.