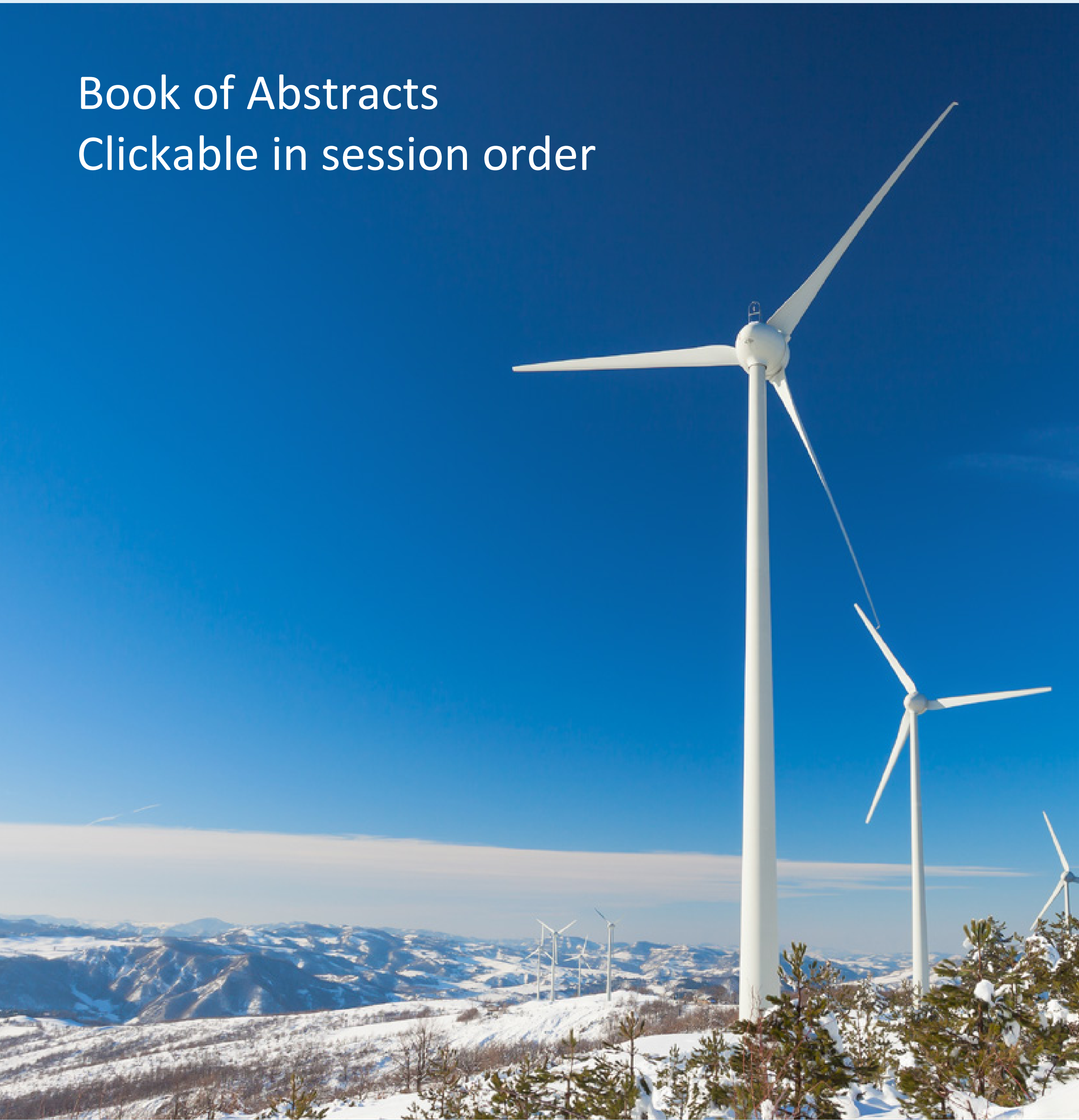
Winterwind

INTERNATIONAL WIND ENERGY CONFERENCE

10th year ANNIVERSARY

Book of Abstracts

Clickable in session order



Winterwind 2018 • Åre • Feb 5-7

INTERNATIONAL WIND ENERGY CONFERENCE

MONDAY

	FIELD TRIP DAY
10:00	Bus departs from Hotel Holiday Club, Åre
10:00-15:30	Field trip
15:30	Back in Åre
16:00-20:00	Registration and access to exhibition hall

TUESDAY

	Arenan	Solskog *(2:nd floor)*	Snöljus *(2:nd floor)*
08:30-10:30	Registration and Exhibition	Workshop - Ice throw *Bengt Göransson and Rolv Bredestad* *Risk Area Reduction for Ice Throw, Bengt Göransson, Pöyry Sweden AB (58)*	

10:30-12:00

OPENING SESSION WINTERWIND 2018

Chairs: Johanna Olesen and Göran Ronsten

Welcome
Ulla Hedman Andrén
Director of Operations Swedish Windpower Association

Onshore wind - Why is it so challenging being the word's most competitive energy technology?
Christian Kjaer, Danish Wind Turbine Owners' Association (55)

How to achieve the goals in practice?
Lars Andersson, Swedish Energy Agency (56)

Bright new ideas - Innovation pitches
Coach: Johanna Olesen
Raul Prieto, VTT (FI), Tanja Tränkle, RISE (SE), Esa Peltola, VTT (FI), René Cattin, Meteotest (CH)

12.00-13.00 **Lunch**

12:30-12:55 **Poster presentations**

- Overview about the icing research at the Institute of Composite Structures and Adaptive Systems (German Aerospace Center) – Transfer to wind energy in cold climate possible? *Christian Mendig, German Aerospace Center (DLR), GER (37)*
- Measurements of cloud droplet size and concentration related to icing *Mika Komppula, Finnish Meteorological Institute (34)*
- Development of a reliable modeling system for the calculation of rime ice loads on overhead transmission lines *Øyvind Byrkjedal, Kjeller Vindteknikk, NO (44)*
- SINTEF's crash test of a potentially dangerous frozen wet-snow cylinder at the Structural Impact Laboratory *Rolv Erlend Bredesen, Kjeller Vindteknikk (23)*

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13:00-14:30

Pre-construction site assessment, measurements, models and standards
Chairs: Jenny Longworth and Ville Lehtomäki

From icing loss to production loss – a comprehensive comparison of today's tools
Daniel Lindholm, EMD International A/S (35)

Open Data sets from Cold Climate Wind Farms in Finland
Simo Rissanen, VTT, FI (13)

Understanding Icing in the Nordics and North America
Till Beckford, DNV GL (16)

Modelled vs observed LWC – where do we stand?
Magnus Baltscheffsky, WeatherTech Scandinavia AB (21)

Health, Safety and Environment (HSE) incl. ice throw and noise
Chairs: Olivia Andrén and René Cattin

Making ice fall and throw predictions for wind turbines more reliable
Sten Barup, ENERCON, SE (7)

Norwegian guidelines regarding the risk of icethrow for the public
Rolv Erlend Bredesen, Kjeller Vindteknikk, NO (24)

Numerical simulation of ice-throw from wind turbines in cold climate
Hamid Sarlak, DTU, DK (25)

Health & Safety Best Practices for Wind Farm O&M in Cold Climate
Charles Godreau, TechnoCentre éolien, Canada (31)

Forecasting and cloud physics
Chairs: Tanja Tränkle and Greg Thompson

Forecasting ice accretion on rotor blades: validation against webcam and ice detectors
Saskia Bourgeois, Meteotest, Switzerland (28)

Verification of high-resolution probabilistic forecasts of icing in Germany for the winter 2016/17
Lukas Strauss, University of Vienna (17)

Addressing forecast uncertainty of wind turbine icing with deterministic sampling
Jennie Molinder, Uppsala Universitet, SWE (38)

Turbine-specific ice loss assessment - accuracy and advantages
Mark Žagar, Vestas, DK (15)

14.30-15.30

Break

15:00-15:55

Poster presentations

Making life easy – over 100 turbines in field under active fos4X rotor ice control
Bernd Kuhnle, fos4X, Germany (40)

Acoustic Condition Monitoring of wind turbines
Timo Mämmelä, APL Systems Oy (47)

IEA Ice class detection with a mesoscale modeling stream and big data support
Abel Tortosa, Vortex (33)

15:30-17:00

Pre-construction site assessment, measurements, models and standards
Chairs: Helena Wickman and Stefan Ivarsson

Site-assessment and icing impact - using ERA5 assimilation data
Morten Lybech Thøgersen, EMD International A/S (EMD), DK (39)

Sensitivity of icing losses. Terrain versus elevation – a case study
Rickard Klinkert, Kjeller Vindteknikk, SE (42)

Operational experiences incl. performance optimization, big data and production losses
Chairs: Jennie Molinder and Matthias Rapp

Benchmark SCADA analysis of 5 different wind turbine Ice Protection Systems
Ville Lehtomäki, VTT Technical Research Centre of Finland Ltd (9)

Retrofitting a de-icing system on turbines affected by extreme icing: Our experience
Sebastien Trudel, EDF EN Canada (1)

Wind turbine manufacturers – cold climate solutions
Chairs: Saskia Burgeois and Sven-Erik Thor

Nordex advanced Anti-Icing System for N149/4.0-4.5
Konrad Sachse, Nordex Energy GmbH, Germany (2)

Leveraging insight from operational data to optimize performance in cold climate
Per Egedal, Siemens Gamesa Renewable Energy, SE (10)

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The use of CFD to post-process wind speed data from remote sensing devices in complex terrain
Wulstan Nixon, ZephIR Lidar, UK (46)

Development of numerical models for ice accretion predictions
Johan Revstedt, Lunds Universitet, SE (36)

Retrofitting anti-icing blade heating on installed wind turbines
Petteri Antikainen, Wicetec, Finland (32)

Ice Protection System Performance Assessment Methodology
Matthew Wadham-Gagnon, TechnoCentre éolien (30)

Vestas Cold Climate Solutions and next steps
Brian Daugbjerg Niesen, Vestas Wind Systems A/S (20)

More than 20 years of experience – Retrospect and outlook of ENERCON's cold climate technologies
Sten Barup, ENERCON, SE (52)

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

19:30- **Dinner and entertainment**

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WEDNESDAY

Arenan	Solskog	Snöljus

08:30-10:00

Wind turbine manufacturers – cold climate solutions (technical)
Moderators: Jeanette Lindeblad and Christian Kjaer

Task 19 – Ice Protection System Warranty Guidelines
Jenny Longworth, Vattenfall AB, Sweden (48)

Requirements on wind turbines in cold climates
Jonas Sundström, Skellefteå Kraft (50)

Panel discussion with manufacturers: Offering production warranties in cold climates - is it even possible?
Enercon - Claes Jeppsson
Nordex - Nils Lehming
Siemens Gamesa - Per Egedal
Vestas - Brian Daugbjerg Niesen

10.00-10:30 **Break, Poster presentations**

First 3D accelerometer based measurements at the blade tip: what's the benefit of the data?
Michael Moser, eologix sensor technology gmbh (43)

Wind Turbine Power Output for Different Cold Climate Conditions
Dimitar Stoyanov, Coventry University, UK (27)

Method for early detection of damage in conductive blade heat systems
Greger Nilsson, Blade Solutions AB (5)

Innovations and developments of ice and damage detection for rotor blades
Timo Klaas, Wölfel Engineering GmbH & Co. KG (41)

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10.30-12:00

De-/anti-icing, ice detection & control including standards

Chairs: Liselotte Aldén and Daniel Lindholm

The importance of accurate detection for turbine ice prevention systems
André Bégin-Drolet, Université Laval (26)

Standardizing ice detector tests in icing wind tunnel - final results
Timo Karlsson, VTT Technical Research Centre of Finland, FI (12)

ICE CONTROL: Potential of innovative icing measurements and icing forecasts to optimize the operation of wind farms during icing conditions
Thomas Burchhart, VERBUND Hydro Power GmbH (11)

Variability in Ice Protection System efficiency
Stefan Söderberg, WeatherTech Scandinavia AB (18)

Laboratory and full scale testing, test centers

Chairs: Inga-Lill Olsson and Matthew Wadham-Gagnon

Atmospheric stability consideration for cold climates
Hanna Vollan, Prevailing Ltd, UK (19)

Use of LIDAR for power curve measurements in Nordic climate
Martin Grønsleth, Kjeller Vindteknikk AS, NO (45)

Cold Climate testcenter in Sweden,
Stefan Ivarsson, RISE (Research Institutes of Sweden) (3)

Ice Release and Erosion Resistant Materials for Turbine Blades
Wei Zhang, Ice Release Materials LLC/Polymer Exploration Group LLC (53)

12:00-13:15

Lunch

12:45-13:10

Poster presentations

Ice detector research results from wind turbine field tests and from icing wind tunnel tests
Tatu Muukkonen, Labkotec Oy, FI (14))

Local effects on icing for wind power in cold climate
Esbjörn Olsson, SMHI (54))

Evaluation of Anti-Icing behaviour in terms of EIROS-project
Björn Speckmann, Fraunhofer IFAM, Germany (4)

Lessons learned from ice ablation tests in icing wind tunnel
Raul Prieto, VTT Technical Research Centre of Finland (6)

13:15-15:00

Grand finale - Past and future

Moderators: Åsa Elmqvist and Jos Beurskens

Towards the improvement of icing forecasts using the AROME/HIRLAM model,
Gregory Thompson, NCAR (51)

Don't look back in anger – a retrospective look on wind energy in cold climate
René Cattin, Meteotest (22)

Panel discussion:
Christian Kjaer, René Cattin, Greg Thomson and Jonas Sundström

14:40-14:50 **Summary of Conference**

14:50-15:00 **Final words**
Ulla Hedman Andrén

R&D areas/s: 14. Workshops - Owners' experiencies, Future technologies

Risk Area Reduction for Ice Throw

Bengt Göransson, Pöyry Sweden AB

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A study of the risks with ice throw from wind turbines in winter climate has been performed in the project ICETHROWER within the frame research program “Cold Climate" co-financed by Energimyndigheten 2013-2017.
Project participants were Pöyry Sweden, Dala Vind, Programografik, Skellefteå Kraft and Vattenfall R&D. More than 500 observations of ice throws were analysed. As a conclusion from the study the project group proposes that the commonly used safety distance with respect to ice throw from wind turbines can be reduced from 1.5 x (D+H) to D+H, where D is the rotor diameter and H the hub height. Additionally we propose that the same equation can be used regardless of turbine status.
The conclusion is based on the observations and that the risk of injury at the distance D+H is lower than other risk levels accepted in society.

Web site:

Short biography: Bengt has 35 years of wind technology experience. Was project leader of the Icethrower study.

R&D areas/s: 10. Market potential, insurance, finance - risk assessment and mitigation

Onshore wind - Why is it so challenging being the word's most competitive energy technology?

Christian Kjaer, Danish Wind Turbine Owners' Association

Christian Kjaer (DWTOA, DK)

Within the past two years, wind energy on land has become the most cost-competitive power production technology in large parts of the world, including in Sweden. Nevertheless, it seems that wind energy in Scandinavia - predominantly in Sweden and Denmark - is still facing many challenges and barriers to reaching its full potential. This presentation seeks to provide answers to why onshore wind is still facing challenges, despite being the world's most affordable power technology. The focus will be on Sweden and Denmark and will include a.o. perspectives on financing, planning, innovation and standards.

Web site: http://dkvind.dk

Short biography: Christian Kjaer has been working in the wind energy sector since 1998. He has served as CEO of the Danish Wind Turbine Owners' Association since August 2016.
In 2006 he was appointed CEO of WindEurope (formerly European Wind Energy Association, EWEA) in Brussels, after serving four years as the organisation's policy director. During his tenure as CEO, EWEA grew from 15 to 60 staff and an annaual turnover of €15 million.
After resigning from EWEA in April 2013, he founded Faraday Consult, a Brussels-based public affairs consultancy. In February 2015 he was appointed Head of Unit at the International Renewable Energy Agency (IRENA), in Abu Dhabi, United Arab Emirates.
Christian sat on the Board of Directors at the Global Wind Energy Council (GWEC) from 2006 to 2013. In the same period, he served on the Board of the European Renewable Energy Council (EREC) in Brussels. In 2012 he was ranked eighth in leading trade magazine Windpower Monthly's annual ranking of the 30 most influential people in the global wind energy industry. He worked as an economist and policy advisor for the Danish Wind Industry Association in Copenhagen, Denmark from 1998 to 2002. Before that, Christian worked as a journalist at the political desk of main Danish daily newspaper, Berlingske Tidende. Christian Kjaer has been a member of the Board of Trustees of the charity, Renewable World in London, and was a member of the Board of 'CECELIA 2050' – an initiative on EU renewable energy policy options towards 2050.
Christian was Expert Reviewer on the IPCC's 4th and 5th Assessment Reports on Climate Change (2007 and 2014) and Review Editor on the IPCC's Special Report on Renewable Energy Sources (2011).
He holds a Masters' Degree in International Economics and Business Administration from Copenhagen Business School and the Graduate School of International Economics and Finance at Brandeis University, Boston, USA (1997). He is a journalist and member of the Danish Federation of Journalists.

R&D areas/s: 13. National strategies, research programs, grid access and new developments

How to achieve the goals in practice?

Lars Andersson, Swedish Energy Agency

Sweden has a long history in renewable energy and hydro power has been the backbone of the system. During the latest 20-30 years has biomass gone from a marginal energy source to be the predominant source of energy in Sweden. Last year we had a political agreement aiming for 100% renewable energy in 2040. To be able to reach this wind power needs to increase dramatically from 16 TWh today to considerably more than 50 TWh. This will need research, investments and efficient work from state agencies on a new scale.

Web site: http://www.energimyndigheten.se/en/

Short biography: Long background in working with energy policy in different roles in the Governmental Office and other state bodies like Swedish Energy Agency.

R&D areas/s:

Bright new ideas

Inovation pitches,

Raul Prieto, VTT (FI), Tanja Tränkle, RISE (SE), Esa Peltola, VTT (FI), René Cattin, Meteotest (CH)

Web site:

Short biography:

R&D areas/s: 02. De-/anti-icing including ice detection & control

Overview about the icing research at the Institute of Composite Structures and Adaptive Systems (German Aerospace Center) – Transfer to wind energy in cold climate possible?

Christian Mendig, German Aerospace Center (DLR), GER

Alexander Pototzky (DLR, GER)

In Braunschweig, the DLR works on ice protection systems (IPS) with lower energy consumption than the thermal bleed air IPS, which is state of the art in most passenger aircrafts with jet engines. The focus lies on electrical driven IPS, like the electro-thermal IPS, made from CFRP and which is weight-bearing due to its integration into the airplane structure. Another IPS is an electro-mechanical one, which is based on structural vibrations of the unstiffened sections of an airplane structure. A partner in the development of new IPS is the Technical University Braunschweig. Both are using facilities like icing wind tunnel, centrifuge and (in future) an icing whirl tower to assess the IPS. Regarding the assessment if and when an IPS has to be started and stopped, DLR also works on Ice Detection Systems which are measuring an ice layer or the process of icing both direct on the structure where the icing occurs. The speech aims for a discussion with the auditorium to answer the questions if a technology transfer to wind energy in cold climate is possible or not and which requirements has to be met.

Web site: http://www.dlr.de/fa/en/desktopdefault.aspx

Short biography: In University: Studie of Mechatronics; since 2012 research associate in DLR in the field of aircraft icing within the fields of ice protection and ice detection systems and the according test facilities; Working on the dissertation text with the content of direct ice detection. Personal interest is to juggle job and young familiy.

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

Measurements of cloud droplet size and concentration related to icing

Mika Komppula, Finnish Meteorological Institute

Mika Komppula (FMI, FI), Ari Leskinen (FMI, FI), Antti Ruuskanen (FMI, FI) and Sami Romakkaniemi (FMI, FI)

In-cloud icing can be caused either by liquid rain drops or cloud droplets, with their main difference in droplet size and typical concentration in the cloud. In the current forecasting models the representation of droplets is highly simplified, and typically in the models only five different hydrometeor classes are forecast without information on the droplet size distribution (e.g. Makkonen et al., 2010, Nygaard et al., 2011, Seity et al. 2011). Thus the information of the most crucial parameter, the droplet size, is missing (Homola et al., 2010). On top of that the probability for icing conditions is more likely to increase than decrease in the warming Arctic hence understanding the driving mechanisms through real observations is a prerequisite.

We will provide the missing information related to cloud droplet properties through our in-situ instrument setup. Finnish Meteorological Institute hosts two research stations measuring icing among other atmospheric component including cloud droplet size distribution. These stations provide us with a perfect opportunity to study the connection between cloud microphysical properties, meteorological parameters and icing rate. Altogether, the measurement setup presented is unique, but this far underutilized in cold conditions.

The two measurement stations Puijo and Vehmasmäki both locate in Kuopio in Central Finland. At the Puijo observation station, located on a 74m tall tower, we measure in situ the properties of liquid and ice clouds, and mixtures of both with extensive instrumentation. We have almost ten years of data on aerosol and cloud properties, especially the cloud droplet size distribution in different meteorological conditions. This data set will now be utilized in icing studies. Icing measurements at Puijo have been running since 2009 with multiple sensors. At the Vehmasmäki site we have a 318m high mast equipped with meteorological instrumentation at various heights including icing measurements started in 2016 at two different levels (115 m and 272 m). This icing data can be linked to the meteorological conditions as well as the profile measurements located on the site. Here we present the results after the first winter of continuous measurements at both locations, and analyze how the estimated cloud droplet number concentration and measurement altitude in the cloud is affecting the icing rate.

References

Homola, M. C., Virk, M. S., Wallenius, T., Nicklasson, P. J., Sundsbø, P. A. Effect of atmospheric tem-perature and droplet size variation on ice accretion of wind turbine blades. Journal of Wind Engineering and Industrial Aerodynamics, 98, p.724-729, 2010.

Makkonen, L., Laakso, T., Marjaniemi, M., Finstad, K. J. Modelling and prevention of ice accretion on wind turbines. Wind Engineering, 25:3-21, 2001.

Nygaard, B. E. K., J. E. Kristjansson, L. Makkonen: Prediction of in-cloud icing conditions at ground level using the WRF model. J. Appl. Meteor. Climatol., 50, 2445–2459, 2011.

Seity, Y., Brousseau, P., Malardel, S., Hello, G., Bénard, P., Bouttier, F., Masson, V.: The AROME-France convective-scale operational model. Monthly Weather Review, 139(3), 976-991, 2011.

Web site: http://en.ilmatieteenlaitos.fi/atmospheric-research-centre-of-eastern-finland

Short biography: Mika Komppula is leading the Atmospheric Measurements -group at Finnish Meteorological Institute (FMI) in Kuopio (since 2008). He has been working at FMI since 2001 and earned his doctoral degree on Atmospheric Physics in 2005 from the University of Helsinki. His research topics include atmospheric aerosols and their interaction with clouds using a wide range of instrumentation including in-situ and remote sensing (e.g. lidars) instruments. One of the most recent topics of the group is icing related to aviation and wind energy sector.

R&D areas/s: 01. Forecasting and cloud physics, 03. Pre-construction site assessment, measurements, models and standards

Development of a reliable modeling system for the calculation of rime ice loads on overhead transmission lines

Øyvind Byrkjedal, Kjeller Vindteknikk, NO

Bjørn Egil Nygaard (KVT, NO), Øyvind Welgaard (Statnett, NO), Igor Gutman (STRI, SE), Timo Karlsson (VTT, FI), Muhammad Virk (UiT, NO), Harold McInnes (MET, NO), Emilie Iversen (KVT, NO), Hálfdán Ágústsson (KVT, NO)

The development and validation of a model-based system for calculation and prediction of rime ice loads on overhead transmission lines is presented. The work is carried out within the frame of the FRonTLINES research project, and is motivated by recent mechanical failures of transmission lines in Norway caused by extensive ice loads, particularly in the areas exposed to in-cloud icing. The comprehensive modeling is developed in order to improve the calculation of design ice loads as well as for monitoring of lines under operation, including forecasting of potentially critical weather events.
The project comprises mesoscale numerical weather predictions (NWP), field measurements, laboratory tests, and ice accretion modeling including CFD simulations. The NWP model with an optimized setup is used to simulate the local atmospheric conditions and time development of the relevant atmospheric variables, i.e. wind field, temperature, supercooled atmospheric water content, air humidity, etc. The predicted variables are validated using measurements from three different project test sites specially selected within the project and located in exposed mountainous regions of Norway.
To verify the results of calculations, in addition to measurements of standard weather parameters, the following instrumentation has been installed at the test sites:
- A recently developed ice load sensor (Ice-Troll)
- A heated web camera system for reliable ice monitoring
- Real-time ice load measurements in overhead line test spans and in operational high voltage transmission lines

Modeling the time dependent accumulation of rime ice is based on the theory of collision between droplets and cylinders (ISO12494 / Finstad et al. 1988). Initial results of the FRonTLINES project indicated that the readily available formulae for calculation of collision efficiency were inadequate for the large icing diameters often observed at the test sites.
In order to collect empirical data on the collision efficiency for large cylindrical objects, laboratory experiments were designed and carried out at the icing wind tunnel at VTT Technical Research Centre of Finland. Similar experiments were also carried out utilizing a CFD model including droplet trajectory calculations. These calculations were conducted by The Arctic University of Norway (UiT), using the CFD simulation tool ANSYS FENSAP-ICE.
The results show that the icing predictions based on the improved modeling system correspond very well to the measurements in terms of ice accumulation on test spans and operational transmission lines. Maximum ice loads obtained over long time periods are however sensitive to ice shedding events which are somewhat less predictable. Measurements also show that the relative difference between the maximum ice loads on single conductors and maximum ice loads on bundled conductors increase with increased ice load, and that the difference is mainly explained by more frequent ice shedding from bundled conductors.

Web site: http://vindteknikk.se

Short biography: Byrkjedal has been working in Kjeller Vindteknikk since 2007, and has currently the position of R&D manager in the company. Byrkjedal has a background as a meteorologist and holds a phd in meteorology from the University of Bergen, Norway.
He has been working in the field of meteorological icing during the past 11 years, and has lead the development of the Norwegian wind- and icing atlases and has also created wind and icing atlases for Sweden and Finland. Byrkjedal has also developed the IceLoss methodology to estimate power losses due to icing based on operational power data from several Swedish wind farms. He is currently the leader of the Nordic research project FRonTLINES, which is aimed at developing tools for the prediction of icing for overhead power lines.

R&D areas/s: 01. Forecasting and cloud physics, 03. Pre-construction site assessment, measurements, models and standards

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

SINTEF's crash test of a potentially dangerous frozen wet-snow cylinder at the Structural Impact Laboratory

Rolv Erlend Bredesen, Kjeller Vindteknikk

Gaute Gruben (SINTEF, NO)

We present the results from an 76.4 J impact test of frozen wet-snow performed using the kicking machine at the Structural Impact Laboratory at NTNU in Trondheim, Norway. The impact test was performed in order to study the risk relevance of frozen wet-snow impacts on the human body. Using the laboratory's pendulum impactor (kicking machine) a controlled impact velocity of 20 m/s was reached and the associated impulse (force-time curve) was obtained using 4 strain gauges on a steel measurement device attached to a 150 ton reaction wall. The result from a cylinder shaped sample weighing 0.382 kg with a diameter 94.4 cm, a length of 11.4 cm, a density of 500 kg/m3, and a momentum of 7.64 Ns is presented together with the associated video from a high speed camera. The 3 ms (milliseconds) duration average force (normalized by the momentum) was 2.452 kN which translates to an average resultant acceleration of 50 g for a 5 kg stiff object (coarse human head/neck representation). Based on the conservative considerations the associated risk is not considered life-threatening (below 5 % probability of a life threatening injury, associated with a skull fracture, according to the Wayne State Tolerance Curve and the Head Injury Criterion).
In addition we present the results for unfrozen snow cylinder with an impact energy of 40 J from an Abaqus simulation based on the snow hardening law in Haehnel and Shoop (2004). The simulation showed a peak force of 2 kN after 0.5 ms with a triangular signal for the timeduration of 4 ms (velocity of 20 m/s, energy of 40 J, momentum of 4 Ns, a 200 gram unfrozen snow cylinder with a fixed diameter of 80 mm and density of 500 kg/m3).
For the unfrozen snow-cylinder the probability of a concussion is estimated at 20 % using logistic regressions curves presented by Laurel et al. (2017) in Frontiers in Neurology. For the frozen wet snow cylinder of 80 J, the probability of concussion is estimated at 60-80 %.

Web site: http://www.vindteknikk.no

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: 03. Pre-construction site assessment, measurements, models and standards

From icing loss to production loss – a comprehensive comparison of today's tools

Daniel Lindholm, EMD International A/S

Wiebke Lanreder

As a consultant or developer, the endeavor of evaluating the expected production losses due to icing in an energy calculation offers a smorgasbord of different methods and techniques and during the last years a range of different approaches has emerged.
The aim of this paper is to compare the different processes and quantify uncertainties related to the process.
When stepping through the different phases involved in estimating icing losses three major sources of uncertainty can be identified.
Firstly, there is a large variety of different sources of how to determine icing periods.
In pre-construction phase you normally have access to a measurement mast, from which you can draw conclusion about instrumental icing. Additionally, there is a number of icing maps available, e.g. from Kjeller Vindteknikk [1], [2], [3], Wice [4], and lately also our new icing tool.
Using the extensive EMD data base with tall measurement masts across Scandinavia, we evaluated and compared the known maps against actual instrumental icing from these site measurements to find out what kind of differences a consultant/developer should be prepared for.
Secondly, the instrumental icing has to be translated into production loss, which is connected to significant uncertainty due to its sensitivity to the control settings of the WTG.
The most common practice would be to apply a factor which represents the relationship from instrumental icing to expected icing loss in that particular position. In our work we compare the findings from DNV/GL [5], the IEA recommendation [6] including the validation study from Cattin [7], [8], the translation proposed by Kjeller [9] and our own analysis of production data.
We will illustrate the range of results coming from the different methodologies, also in comparison with older publications which can give an indication to what extent different control ´strategies have an influence on the losses [10].
Finally, the inter-annual variations of icing occurrences from the different sources will be evaluated.
The reader will learn about the range of uncertainties from all three contributors.
[1] "Icing Map of Sweden," Kjeller Vindtekknik, http://www.vindteknikk.com/_extension/media/83/orig/KVT_OB_2012_R076_Icingmap_Sweden.pdf, 2012.
[2] "Icing Map of Norway," Kjeller Vindtekknik, https://www.nve.no/Media/3759/kartbok3a_4143.pdf, 2009.
[3] "Icing Map of Finland," Kjeller Vindtekknik, http://www.vindteknikk.com/services/analyses/wind-power/pre-construction/icing-map, 2012
[4] WIceAtlas (VTT) More or less global coverage; http://virtual.vtt.fi/virtual/wiceatla/
[5] DNV-GL – Sweden… 17_WindEurope2016-Icinglosses-Whatcanwelearnfromproductionandmeteorologicaldata.pdf
[6] IEA, 13. Wind Energy Projects in Cold Climate, Expert Group Study on Recommended Practice, 2017.
[7] Rene Cattin, on behalf of IEA Task 19: Blind Icing map Validation, Winterwind 2015, http://winterwind.se/wp-content/uploads/2015/08/7_2_09_Cattin_IEA_Task_19_-_Blind_icing_map_validation_Pub_v2-6.pdf
[8] Rene Cattin, on behalf of IEA Task 19: Validation of the IEA Task 19 Ice Classification, Winterwind 2016, http://winterwind.se/wp-content/uploads/2016/02/3_3_3_Cattin_Validation_of_the_IEA_Task_19_ice_site_classification.pdf
[9] Ø. Byrkjedal, Estimating Wind Power Production Loss due to Icing, Kjeller Vindtekknik, IWAIS XII, Andermatt, 2009
[10] T.Duncan et al., GH: Understanding Icing Loasses and Risk of Ice Thorw at Operating Wind Farms, Winterwind 2008, http://www.winterwind.se/2008/presentationer/08_Landberg_Winterwind_2008.pdf

Web site: http://www.emd.dk

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

Short biography: Employed as Wind Energy Consultant at EMD International for seven years and have during that period estimated the energy production for well over 100 Swedish sites. If Im not evaluating icing, I like to dive and refit my new sail boat.

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

Open Data sets from Cold Climate Wind Farms in Finland

Simo Rissanen, VTT, FI

Simo Rissanen (VTT, FI)
Esa Peltola (VTT, FI)

Cold climate wind energy grows globally 12 GW/a thus holding a large market potential. For this large business opportunity, there is a large need from research and industry communities in the cold climate wind energy value chain to have access to climate and turbine data of cold climate sites, in order to

- better understand site specific pre-construction production assessment in icing conditions
- develop full scale turbine site testing methods (assessment method development, benchmark heating systems, system validation, prototype testing, sensor tests) [1].
- support standardization and model development

In order to overcome the needs above, VTT publishes a unique open access dataset for EERA JP Wind Research Community. The data includes open access meteorological mast data and operational data of multiple turbines over five (5) years from two sites in Finland, and simultaneous and longer-term monthly time series in icing conditions for reference. The two sites for the data sets represent in this context a) an easy site both in terms of icing and terrain complexity, and b) a site with severe icing and terrain complexity.

The dataset includes data from

- Olos in Northern Finland (met mast + 5 turbines) , being a site with severe icing and complex terrain,
- Pori on the western coast (met mast + data from 1 turbine out of four in the same part of the wind farm), being a site with less icing and terrain complexity, and
- Longer-term time series on icing conditions on the same sites from the global WIceAtlas data.

Presentation provides an overview to project and published data. This project was funded by an EU IRPWIND project.

[1] EERA JP Wind SB Cold Climate Wind, Plan for 2017, presentation for EERA JP Wind SC November 2016, compiled by Ville Lehtomäki

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

Short biography: Simo Rissanen has been a Research Scientist at VTT Technical Research Centre of Finland between 2003 and 2006 and again since 2011. His work focuses on wind power in cold and icing climate and dynamic modelling and simulation of wind turbines. He has worked on several R&D projects related especially to ice mapping, ice assessment, wind turbine modelling and icing effects on wind turbines.

R&D areas/s: 03. Pre-construction site assessment, measurements, models and standards, 04. Operational experiences incl. performance optimization, big data and production losses

Understanding Icing in the Nordics and North America

Till Beckford, DNV GL

Adnan Shah (DNV GL, USA), Julien Haize (DNV GL, GB), Carla Ribeiro (DNV GL , GB)

A major challenge for wind energy developments in cold climates is to understand the magnitude of energy losses caused by blade icing. The magnitude has been seen to exceed 50% during winter months, and surpass 10% over the course of a year. Such information is paramount to ensure the financial success of individual projects and indeed for the cold climate wind industry as a whole.

Exacerbating the risk that icing poses to potential wind farms in cold climates is the difficulty in accurately predicting the energy losses at a pre-construction stage. To solve this critical issue, DNV GL has been building its database of knowledge from both operational projects and pre-construction meteorological masts throughout the world, and feeding the findings from this back into its methodologies.

Analysis of data from the Nordics has shown a strong trend with elevation, the importance of cloud base height, the high variability of wind farm icing and the ability to minimise loss through the turbine's control strategy. These findings have been presented at numerous Winterwind conferences over the past years.

At this conference, DNV GL shall expand the research undertaken to North America, and present a comparison between the characteristics of wind turbine and anemometer icing in the Nordics and North America, in order to show what similarities exist and how the regions differ. This comparison offers an interesting insight to industry players looking to expand into either market, whilst providing the scientific community with the results of real data and observations to further their understanding of the processes at play.

DNV GL has analysed operational data from over 30 wind farms and 80 meteorological masts in the Nordic region, together with a broad spectrum of data in North America. The resulting dataset is analysed and trends with respect to geography (elevation above sea level, height above ground, distance to coastline, latitude and longitude), operational mode, turbine layout and manufacturer are assessed, along with a comparison of the annual variability. Furthermore, the importance of humidity, temperature and cloud base height is discussed.

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

Short biography: Till has been working at DNV GL for the past 5 years since graduating from university. At DNV GL Till has been part of the Project Development department focusing on the Scandinavian and Finnish markets and undertaking pre-construction and operational energy assessments. In conjunction with this work, Till has taken a leading role in developing DNV GL's understanding of icing in cold climates and the methods used to predict these losses. Till made his Winterwind presenting debut at the 2015 conference and in his spare time enjoys music and sports.

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

Modelled vs observed LWC – where do we stand?

Magnus Baltscheffsky, WeatherTech Scandinavia AB

Magnus Baltscheffsky (WeatherTech Scandinavia AB, SE), Stefan Söderberg (WeatherTech Scandinavia AB, SE), Timo Arstila (University of Oulu, FI), Ville Kaikkonen (University of Oulu, FI)

In pre-construction site assessments results from Numerical Weather Prediction models (NWP's) are often used to estimate the site-specific icing climate. The very nature of the problem studied introduces a number of uncertainties such as: How well are the models predicting wind and temperature? How many years are needed to get an understanding of the icing climate? How well are the clouds modelled? All these parameters and more are entered to models that estimate ice accretion on structures.
It has previously been concluded that evaluating NWP performance using ice load measurements is hard since the reliability in measured ice loads can be questioned and also involves uncertainties in the ice accretion models. To make improvements and reduce uncertainties in modelled icing climates, trustworthy measurements of Liquid Cloud Water (LWC), Median Volume Diameter (MVD), and Droplet Size Distribution (DSD) are needed.
Several efforts to develop instruments for measuring LWC, MVD and DSD have been carried out over the years. A new promising instrument is the ICEMET-sensor (www.oulu.fi/icemet) developed at the Optoelectronics and Measurement Techniques Unit at the University Oulu. The ICEMET-sensor detects and measures cloud droplets in the air that cause icing of structures at freezing temperatures. The instrument is able to determine LWC, MVD and DSD over a volume of air utilizing a computational imaging method. The sensor has been verified (NIST-tracable) in the laboratory and tested in an icing wind tunnel. The ICEMET-sensor can be installed in masts, wind turbines, power lines etc. The first sensor system has now been measuring on the nacelle of a wind turbine in eastern Finland since February 2017.
In the present study, data from the ICEMET-sensor has been used and analysed together with NWP data from high resolution WRF model runs (www.mmm.ucar.edu/wrf-model-general). The focus in the evaluation lie on the amount of predicted LWC and timing of the icing events.

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

Short biography: Magnus Baltscheffsky is currently a model developer and consultant at WeatherTech Scandinavia where he has worked for the past 7 years with atmospheric modelling and issues related to the icing climate. He holds an M.Sc. in Meteorology from Uppsala University.

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

Making ice fall and throw predictions for wind turbines more reliable

Sten Barup, ENERCON, SE

Monelle Comeau (ENERCON, CA), Uta Zwölfer-Dorau (ENERCON, DE), Wojciech Martko (ENERCON, DE), Nina Weber (ENERCON, DE), Hector Rodriguez (ENERCON, DE)

With increased demand for risk assessments regarding ice fall and throw from wind turbines a new discipline emerges. Calculation methods in these investigations should be highly reliable, ensuring their results actually increase the public safety. Based on this notion, ENERCON has built the largest databases of ice fall and throw measurement campaigns (Meteotest, 2017) and, using this data, has developed a validated ice fall and throw prediction tool (DWG, 2017).

The ice piece collection campaign was performed at a high icing-intensity wind farm in the Czech Republic. Four ENERCON turbines, operating in different heating and operation modes, were monitored over three icing seasons and more than 25 000 ice pieces were collected. In combination with the operational data from the turbines (SCADA data) and on-site meteorological measurements this database allows a precise representation of icing characteristics for a specific icing site, turbine type and several heating and operation modes. These characteristics are the foundation of a newly developed tool for calculating the probability of ice fall and ice throw in the vicinity of a wind farm. The trajectory model of the tool is based on well-established equations of motion for comparable trajectories as described in (Biswas, Tylor and Salmon, 2011). The innovation at hand is the precise representation of ice piece parameters, as well as the amount of ice pieces expected for each operating and heating mode, turbine type and site specific icing conditions. This precision was confirmed during the validation process of the tool.

A base number of pieces expected per year for a specific scenario and scaling factors for operational and heating modes, icing intensity and rotor diameter has been developed. Furthermore a representative distribution of the ice piece properties mass and area was established. During the validation it was proven that the modelled results at the location of the measurements are representative.

As more turbines are built in cold climate or icing conditions, an increased demand for ice fall risk assessment, as well as the need for safe operation under those conditions, have arisen. As a result, it is necessary to spark development in the field of ice throw and fall risk investigations. Our work shows that it is possible to get precise results from ice fall calculations if the assumptions on ice piece properties and numbers are accurate. This proves that it is important to do more specific research on the ice piece landing positions, numbers and characteristics depending on turbine types and operating modes. The authors aim to speed up the process by demonstrating the success of the project at hand.

Delegates will learn that it is possible to reach precise results when modelling the probability of ice fall and ice throw from wind turbines, obtaining a reliable assessment of the associated risk. Their attention will be brought to the crucial importance of including turbine and operating mode specific icing parameters in the calculation, to achieve this goal. Additionally it will be made clear that a general increase in accuracy can best be put into effect by extending the ice throw and ice fall observation databases available in the industry and developing a common standard for calculations (as currently underway in IEA Wind Task 19: Standardization of input parameters for ice throw / ice fall risk assessments, also supported by the authors).

References

Biswas, S., Taylor, P., & Salmon, J. (2011): A model of ice throw trajectories from wind turbines, in: WIND ENERGY, vol. 15, no. 7, pp. 889-901.

Meteotest (2017): Ice throw data collection – Meteotest's expert opinion on ENERCON's ice throw data collections, Version 2.

WindGuard Certification (2017): Certification Report – Software Ice Fall Tool, Version 01.

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

Short biography: Sten Barup has been working with icing related research and site suitability assessments at ENERCON Wind Farm Engineering since 2011. The R&D tasks have included icing and ice throw measurement programmes as well as the development and validation of ENERCON's ice throw risk assessment methodology. He holds a Master's degree in mechanical engineering and is currently delegate for the IEA Task 19 subcommittee working on the first international guidelines for ice fall and throw risk

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

assessment. Besides enjoying time with family in his leisure time, he also likes horses, tractors and carpentry.

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

Norwegian guidelines regarding the risk of icethrow for the public

Rolv Erlend Bredesen, Kjeller Vindteknikk, NO

Roger Flage (IRIS, NO), Bushra Butt (NVE, NO)

The Norwegian guidelines gives advice on the possible consequences of ice throw from wind turbines for the public (third persons). The guideline is the result of an internal project at the Norwegian Water Resource and Energy Directorate (NVE), with external contributions from Roger Flage at IRIS (International Research Institute of Stavanger), and Rolv E. Bredesen from Kjeller Vindteknikk.
The background for R&D project is that all wind farms in Norway to various degrees are exposed to icing conditions enabling the hazard ice throw and ice fall from the blades of wind turbines onto the surrounding areas. The resulting risk of injury is a topic for interested stakeholders and proper communication of this risk is a challenge, which may result in that the risk of being hit by ice debris originating from wind turbines sometimes are exaggerated. Therefore NVE has actuated the current Research and Development project regarding ice throw and ice fall which focuses on how the risk should be managed and communicated based on currently available documentation, best practices and research. The goal of the project is to prepare easily understood and relevant advise for wind farm concessionaires (owners/operators) and to the general public:
1) How to communicate the risk of injury and damage to the general public caused by ice throw and ice fall.
2) Relevant measures handling the risk of injury and damage.
3) Clarify the criminal and compensatory liability for incidents involving injury.
The Norwegian Guideline is meant as a supplement to the IEA Wind Task 19's internationally harmonized guidelines regarding ice throw risk assessments. However, the health and safety issue related to wind farm working personnel is not considered in this project.
There is a requirement from NVE to evaluate the extent of icing and to assess the risk of ice throw/ice fall when applying for a wind farm license in Norway. An evaluation shall be sent to NVE before operating the wind-power stations.
A recommended list of the most important items in such an evaluation is presented together with short guidance on how to perform said work, including how to describe the related uncertainties and strength of knowledge regarding key assumptions in a risk assessment.

Web site: http://www.vindteknikk.com/news/icerisk-state-of-the-art-article-about-ice-shedding

Short biography: Rolv E. Bredesen is the current Norwegian member of IEA Wind Task 19's expert group on wind energy in cold climates. He is the Norwegian consultant company Kjeller Vindteknikk's expert on ice risk assessments.
Dr. Roger Flage is an asistant professor and was newly elected as the General Secretary of ESRA (European Safety and Reliability Association)
Bushra Butt has previously worked as head of communication at NORWEA, The Norwegian Wind Energy Association which is the voice of the Norwegian wind and ocean energy industry. She is currently working at The Norwegian Water Resource and Energy Directorate (NVE) and leads the ministry's work regarding the upcoming Norwegian guidelines regarding the risk of ice throw for the public.

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

Numerical simulation of ice-throw from wind turbines in cold climate

Hamid Sarlak, DTU, DK

Jens Nørkær Sørensen (Professor, DTU Wind Energy)

Recently, a research project was conducted at DTU Wind Energy with the aim of computing trajectories of the detached fragments – including the whole or part of a blade in case of a wind turbine accident and/or ice throw from wind turbines in cold climate. The trajectories of thrown objects are attained using the solution to equations of motion and rotation (6-DOF), taking into account aerodynamic lift, drag and moment coefficients. The in-house numerical tool, Savbal, takes dynamic stall and wind variations due to shear into account and investigates different scenarios of throw including the throw of an accumulated ice piece on the blade.
This presentation aims to disseminate the findings of ice-throw calculations using the code, Savbal. During computations, a maximum throw distances of approximately 100 and 600 m are obtained for standstill and normal operating conditions of a typical wind turbine, respectively, with the ice pieces weighing between 0.4 to 6.5 kg. These simulations can be useful for revision of wind turbine setback standards, especially when combined with risk assessment studies. Upon request, Savbal is freely available to interested researchers.
Best regards,

Web site: https://sarlakportfolio.wordpress.com/research1/

Short biography: I am an aerodynamics and turbulence modelling researcher. I have worked on CFD simulations (implementation and application) in areas of atmospheric boundary layers (ABL) and wind farms and flow past airfoils using LES and RANS modelling. I have also been involved in ice-throw computations of wind turbines. Besides numerical work, I have been involved in low-speed wind tunnel experiments to characterise the behaviour of a number of aerofoils at low and moderate Reynolds numbers. Throughout my PhD and postdoc research at the Technical University of Denmark (DTU) I collaborated with various international R&D institutions including Statkraft (Norway), the Johns Hopkins University (USA), Centre de Recherche en Aeronautique (Belgium), as well as Cranfield University (UK). I am a member of a number of scientific organizations including the American Institute of Aeronautics and Astronautics (AIAA) and Danish Society for Industrial Fluid Dynamics (DANSIS).

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

Health & Safety Best Practices for Wind Farm O&M in Cold Climate

Charles Godreau, TechnoCentre éolien, Canada

Nicolas Jolin (TCE, CA), Matthew Wadham-Gagnon (TCE, CA), Bruno Boucher (TCE, CA), (other collaborators to come)

Canada's wind industry faces some unique challenges related to operation and maintenance (O&M) in cold climate regions. There are a number of safety hazards on a wind farm related to cold climate. Historically original equipment manufacturers (OEMs), operators, and independent service providers have developed their own procedures and best practices for cold climate health & safety. A consensus on industry best practices is essential, not only to provide a safe and healthy workplace for wind industry employees and the public but also to reduce the industry's main preoccupations regarding O&M in Canadian cold climate regions.

A best practices guide for O&M health and safety of wind farms in cold climate was created upon an initiative by the Canadian Wind Energy Association's (CanWEA) O&M caucus Subcommittee on Icing and Cold Climate Safety. These best practices come from a consensus of the Canadian wind industry's practices, up-to-date and reliable literature, and federal regulatory requirements.

The guide consists of a 35 page document split in to 5 sections; basic definitions, physical conditions, hazards, best practices, and best practices decision tree. A summary of the guide will be presented.

Web site: http://www.eolien.qc.ca

Short biography: Charles Godreau is a research analyst at the TechnoCentre Éolien (TCE) since 2014. He has a Master's degree in Energy and Computational Fluid Dynamics from Polytechnique Montréal. M. Godreau is specialized in ice detection methods including image analysis, double anemometry and specialized sensors. He also works on cold climate related projects such as ice protection systems evaluation and behavior of wind turbines in icing climate.

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

Verification of high-resolution probabilistic forecasts of icing in Germany for the winter 2016/17

Lukas Strauss, University of Vienna

Lukas Strauss, Stefano Serafin, Manfred Dorninger (University of Vienna, AUT), Saskia Bourgeois (Meteotest, CH), Thomas Burchhart (VERBUND Hydro Power, AUT)

In the past years, probabilistic prediction of wind speed for wind energy power production has received significant attention. The ICE CONTROL project, introduced at Winterwind 2017, aims to extend the probabilistic approach towards the forecasting of icing conditions, responsible for significant losses of power production at cold climate sites. ICE CONTROL includes an experimental field phase, consisting of two measurement campaigns at a wind farm located in hilly terrain in Rhineland-Palatinate, Germany, during the winters 2016/17 and 2017/18. The comprehensive measurement data allow to verify probabilistic icing forecasts, assessing their value for wind energy producers.

In this contribution, we present verification results from the first winter campaign for the period Nov 2016 to Feb 2017, during which a few severe and a number of lighter icing cases occurred at the wind farm. To predict meteorological icing conditions, the Weather Research and Forecasting (WRF) model is used at resolutions of 12.5 km (outer domain) and 2.5 km (inner domain covering Germany). Two 10-member mesoscale model ensembles, both coupled to global ensemble forecasts by the European Centre for Medium-Range Weather Forecasts (ECMWF EPS) are compared to one another: (i) a dynamically downscaled (DD) ensemble, making use of only one WRF physics configuration, and (ii) a multi-physics (MP) ensemble, taking advantage of 10 different WRF configurations.

The ensemble model verification of temperature, humidity, wind speed, ice rate and ice load (as derived using the Makkonen icing model) shows an encouraging skill of both the DD and MP ensembles to predict icing conditions in the 48-h time frame. However, at a model resolution of 12.5 km, both ensembles are underdispersive (i.e., do not fully capture the observational variability of temperature etc.). The MP ensemble generally shows greater sensitivity (i.e., a higher hit rate) to detecting icing conditions than the DD ensemble, albeit at a somewhat higher rate of false alarms. Simulations at 2.5 km resolution are currently under way and results will be presented.

The probabilistic forecasting approach allows to select application-specific optimal ratios of hit rate and false alarm rate for turbine operators (cost/loss analysis). A by-product of this work is the assessment of different individual WRF physics configurations potentially useful for deterministic forecasts of icing, which are used by the majority of icing forecast providers today.

Web site: http://imgw.univie.ac.at/en/research/amk/projects/ice_control

Short biography: Lukas Strauss is a Postdoc scientist at the Department of Meteorology and Geophysics, University of Vienna. Before joining the ICE CONTROL project, Lukas did a PhD in mountain meteorology. He has worked with measurement data from Doppler lidars, met masts, and research aircraft and has built experience in probabilistic meteorological forecasting recently. Lukas has never skied in Sweden.

R&D areas/s: 01. Forecasting and cloud physics, 03. Pre-construction site assessment, measurements, models and standards, 06. Wind turbine manufacturers – cold climate solutions, 10. Market potential, insurance, finance - risk assessment and mitigation

Turbine-specific ice loss assessment - accuracy and advantages

Mark Žagar, Vestas, DK

Mark Zagar (Vestas, DK), Neil Davis (DTU, DK)

Constant increase of understanding the weather and climate forecasting problematics, especially the issues of concern to the wind energy sector, has enabled many new techniques and strategies in planning, constructing, operating, and maintaining the wind power plants. In our work, presented in this paper, we focused on improving the prediction and life-time assessment of wind turbine icing. Besides presenting the improvement in prediction of ice affected loss of production in cold climates, we also illuminate the potentials and opportunities which follow from more accurate icing prediction.
The main difference in the improved ice loss assessment method, presented in this paper is that it is explicitly addressing pad-level and turbine specific loss of production due to ice build-up, and its impact on the power performance of the wind turbine. This has important consequences for the whole value chain and throughout the lifetime of a wind plant:
- More precise siting of individual wind turbines with respect to expected icing impact is enabled
- A commercially most suitable wind turbine variant can be selected
- In some circumstances the construction schedule is affected by ice even down to the individual turbine level and can profit from turbine specific ice regime assessment
- Operational strategies of individual turbines in a wind plant can account for ice impact by for example selecting turbines for curtailment and other operational regimes
- Choice of de-icing and anti-icing equipment can be made for individual wind turbines
- Life-time loads can be more accurately calculated for individual turbines, which again enables new and advanced operational strategies and more accurate service cost forecast
We also address the accuracy requirement for a successful ice loss assessment and ice forecast, in order to maximize the financial benefits of a wind project. This can for example refer to warranties for specific levels of availability, production, or even revenue.
Results from applying the pad-level ice loss assessment on several wind farms in Scandinavia will be presented. The skill has been found equal or superior to the park-level assessment, meaning that the prediction of variability of production loss between individual wind turbines in a farm has been at least as accurate as that between the wind farms. The absolute accuracy of the ice loss assessment has also been found quite satisfactory.
The improved and more precise ice loss assessment presented in this paper is based on previous work performed in the project Icewind, and also captures some learnings and tools developed through the IAE Task 19 initiative.

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

Short biography: Mark Žagar holds a PhD in meteorology and has both academic and public weather service background. He has over 20 years of experience in numerical weather prediction and atmospheric modeling with focus on the boundary layer and mesoscale processes, of which last 9 years in the wind energy business. Mark is a senior specialist in Data, Simulations & Modelling department of Vestas Wind Systems A/S in Denmark. His primary role is to drive development and integration of quality assured modelled data using mesoscale and microscale models into resource reliability, variability, and predictability estimation, wind turbine and power plant performance optimization, and risk analysis.

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

Forecasting ice accretion on rotor blades: validation against webcam and ice detectors

Saskia Bourgeois, Meteotest, Switzerland

Paul Froidevaux (Meteotest, CH),
Thomas Burchhart, Martin Fink (VERBUND Hydro Power, AUT),
Lukas Strauss, Stefano Serafin, Manfred Dorninger (University of Vienna, AUT),
Alexander Beck, Christoph Wittmann, Florian Weidle (Zentralanstalt für Meteorologie u

Ice accretion on rotor blades causes production losses due to power curve degradation and eventually a forced shut down of wind turbines. Icing can also cause damages to the mechanics and represents safety risks for passers-by and service personnel. Reliable forecasts of blade icing several hours or days in advance would therefore be valuable for the operation of wind parks in cold climates. Not only the duration of icing conditions but also the amount of accreted ice effects turbine operation. Therefore, a concrete need for quantitative forecasts of ice load exists.
During the winter seasons 2016/17 and 2017/18, we ran a numerical weather prediction model coupled with an ice accretion model. We produced daily forecasts of ice growth and ice load for a wind park in Germany. We also monitored effective icing on one of the turbines thanks to webcams and ice detectors placed on the nacelle. The ice detectors allowed us to directly measure ice loads in addition to the relevant meteorological parameters.
This work was done within the framework of the research project ICE CONTROL and in collaboration with the University of Vienna, the "Zentralanstalt für Meteorologie und Geodynamik" in Austria and the park operator VERBUND.
The presentation focuses on the main challenges regarding both observations and forecasting. We also address the sensitivity of the ice accretion model to different atmospheric parameters and its impact on the uncertainty of the forecasts.
The project ICE CONTROL aims at providing park operators with an assessment of the feasibility of ice load forecasts for wind parks in moderate complex terrain in central Europe. More specifically, we try to determine the major sources of uncertainty of our ice load model and identify possible improvements of our model chain (WRF and Makkonnen models). The combination of webcams and ice detectors on the nacelle provide a valuable data base for the validation of icing forecasts.

Web site: https://meteotest.ch/

Short biography: Saskia Bourgeois has studied Earth Sciences at ETH Zurich and did a PhD in Climatology measuring solar radiation and reflectance on the ice sheet of Greenland.
In 2006, Saskia joined Meteotest. First, she was a project manager, focusing on wind site assessments in complex terrain and cold climate.
Since 2011 Saskia is heading the Wind Energy group at Meteotest.
Currently, Saskia is involved in three different long term research projects dealing with ice detectors, icing prediction and production losses due to icing. Personal insterest: one big and three small little wild boys.

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

Addressing forecast uncertainty of wind turbine icing with deterministic sampling

Jennie Molinder, Uppsala Universitet, SWE

Heiner Körnich (SMHI, SWE), Esbjörn Olsson (SMHI, SWE), Peter Hessling (KapAB, SWE)

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 when using next-day forecasts of wind power production in cold climates.

Here the focus lies on the uncertainties in the ice growth model formulations. The impact of these uncertainties on the icing and production loss result are examined by using a method of Uncertainty Quantification, namely deterministic sampling. As a first step, five parameters were identified as highly uncertain in the icing model by performing a literature study. These parameters are then perturbed within the estimated range of uncertainty. This generates an ensemble of icing forecasts with the benefit of both uncertainty estimations for each forecast and higher skill for the ensemble mean compared to a deterministic forecast. The method of deterministic sampling is also compared to random sampling. In random sampling tens of thousands model runs are conducted, however with deterministic sampling only a few model runs are needed to get similar performance of the ensemble.

The performance of the setup is examined for the winter 2013/14 where wind turbine observations are available from four sites in Sweden. The mesoscale numerical weather prediction model HARMONIE-AROME is used for the meteorological parameters. Forecasts has been run for up to +42 hours for a ten week period in the winter 2013/14 with a horizontal resolution of 2.5 km over a Swedish domain of 1100x1600 km2. The validation demonstrates that using deterministic sampling for the uncertainty of the icing model leads to improved icing and related production loss forecasts.

Web site: http://www.geo.uu.se/research/luval/disciplines/Meteorology/ongoing-research/wind-energy/

Short biography: PhD student in Meteorology at Uppsala University focusing on probabilistic forecasting of wind power in cold climate

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

Making life easy – over 100 turbines in field under active fos4X rotor ice control

Bernd Kuhnle, fos4X, Germany

Bernd Kuhnle (fos4X,GER)

Reliable and accurate ice detection is absolutely necessary for safety relevant sites with restrictions for the operation under icing conditions, such as wind turbines near roads and on parking lots. The relevant measurement of ice accretion directly on the blades, where it is most important, leads to effective mitigation of ice throw risks. Furthermore, the availability is increased and effort in operation is decreased due to certified automatic restart capabilities. The system is therefore not only increasing safety, but also an economically viable solution, which amortizes after a short period. However, also for other risk class areas, ice detection provides various benefits. The heating cycles can be optimized and the operational parameters, such as reduced operation modes can be triggered.
This presentation will allow the audience to answer important questions about ice detection:

- What are the benefits of using ice detection on restricted sites?
- What is the advantage of rotor blade ice detection over others for the operation in unrestricted areas?
- What is the difference of rotor ice control regarding ice detection on different turbine types?

The presentation will feature measured field data on the currently installed basis of several hundreds of MW and give an insight into the functionality and efficiency of rotor ice control.
fos4X provides its ice detection, consisting of its fiber-optic rotor blade sensing standard hardware platform and the software algorithm rotor ice control for various manufacturers and turbine types. With its full integration into the turbine control, it offers real advantages over standard ice detections and facilitates the optimization for the operators. With several decades of accumulated field experience, the system has proven its reliability and quality, also in comparison with other existing solutions on the market.
In addition, ice detection is only of various features, which can be realized with vibration measurements in rotor blades. An example of detected damage in rotor blades with the software application turbine integrity control is also part of the presentation.

Web site: http://www.fos4x.de

Short biography: Bernd Kuhnle is CCO and leads the key account, business development and sales activities at fos4X.
Together with his team, he is dedicated to ensure close customer relations and the development of the world-wide market of fiber-optic sensors in rotor blades for monitoring and control purposes. Before joining fos4X in 2013 he worked as a researcher in the area of rotor blade loads, aero-elasticity and load mitigating controls for wind turbines.

R&D areas/s: 02. De-/anti-icing including ice detection & control, 08. Health, Safety and Environment (HSE) incl. ice throw and noise, 09. Inspection, maintenance, repair and decommissioning, 12. Environmental Impact Assessments (EIA)

Acoustic Condition Monitoring of wind turbines

Timo Mämmelä, APL Systems Oy

Roy Hjort (APL Systems, FI), Antti Leskinen (APL Systems, FI)

Acoustic blade condition monitoring has proven to be difficult task. Better understand the changes in blade condition, whether it is change in blade properties or ice buildup, have been a demanding task. Also, the cold conditions present in Nordic and high altitudes exposes the blades to more wear and tear compared to milder conditions. Comprehensive way to monitor blades is difficult. Acoustic condition monitoring is based on online monitoring and analysis of acoustic data collected from wind turbine. This is comprehensive method that continuously monitors all wind turbine blades and can detect changes on them. Automatic online analysis combined with trend analysis and 3D evaluation of acoustic spectrum of individual wind turbine produces a clear picture on individual blade condition. Based on online monitoring, changes in blade condition can be detected which helps to target maintenance operations can be to correct wind turbines. Online acoustic condition monitoring also generate complete compliance data in different seasons and over wide range of weather conditions. Changes in the sound spectrum, that also includes low frequency sound, can be identified readily, which also adds acceptance to wind energy in the local communities. AuresSound™ acoustic monitoring platform has been developed by APL Systems in cooperation with Wärtsilä Finland and is has been tested in harshest of conditions.

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

Short biography: Timo Mämmelä has been involved with sound and noise monitoring since 2011. Timo has a background in environmental analysis and R&D work in Pharmaceutical industry. Timo has been involved in developing online maintenance and ice detection system for wind industry from the beginning. Presently he is Vice President and head of sales and business development in APL Systems ltd.

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

IEA Ice class detection with a mesoscale modeling stream and big data support

Abel Tortosa, Vortex

Pau Casso (Vortex), Gil Lizcano (Vortex), Pep Moreno (Vortex), Oriol Lacave (Vortex)

Mesoscale model technology has employed for icing characterization for wind industry applications for many years now. Results notably encourage the atmospheric modeling approach but there is still a gap for absolute values characterization of icing events.
Lack of validation exercises and the own complexity of phase transition phenomena make the pure mesoscale modeling path still useful for preliminary assessment but limited for complete icing class identification, when decision are more critical regarding the wind turbine site adaptation.
The current work assesses a merge statistical and dynamical approach for icing events characterization. WRF mesoscale model time series with two level of resolution, pre-greyzone, 3Km, and, post-greyzone, 100m, were employed to provide a complete meteorological database of atmospheric variables which fed a statistical remodeling stream. Remodeling stream is built on a multi-model approach combining different machine learning tools.
Measurement data from 3 sites in Quebec, Canada, were employed to train and validate the results of the combined mesoscale and statistical modeling approach. The measurements were curated and processed by TechnoCentre Eolien (TCE) , and include more than 100 icing events characterization for the three sites using GEM-LAM-Jones-Makkonen (GLJM) model [1].
We present the results of the analysis of the performance of the mesoscale +statistical model for the 3 sites, for both level of resolution. We have also tested a cross-site statistical modeling technique to infer a standardized bias correction.
The results show that more than 80% of the icing occurrence are identified and derived icing classes match the semi-empirical assessment made by TCE. We acknowledge, however, that conclusion on the site-characterization is constrained by the limited number of independent locations considered in the analysis.
The combination of mesoscale modeling stream with big-data analytics opens a windows for better and automatic icing characterization. Now, the question remains on the validation and the learning from more case analysis.
We thanks TEC for made available the data and documentation for the empirical foundation of this work.
[1] Development and Validation of an Ice Prediction Model for Wind Farms , Marilys Clément, Charles Godreau, Nigel Swytink-Binnema, Kossivi Tete, 2017, https://www.eolien.qc.ca/en/documentation-en/studies/item/developpement-et-validation-d-un-modele-de-prevision-du-givre-pour-les-parcs-eoliens.html

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

Short biography: Abel Tortosa has background in Physics and Astrophysics. He has been working in the wind industry for over 10 years, mostly on the wind resources modeling and forecasting areas. He joined in Vortex in 2013 where he is the lead developer of the statistical modeling skeleton behind Vortex mesoscale technology. Prior to Vortex, Abel worked at True Power for 4 years.

R&D areas/s: 01. Forecasting and cloud physics, 03. Pre-construction site assessment, measurements, models and standards

Site-assessment and icing impact - using ERA5 assimilation data

Morten Lybech Thøgersen, EMD International A/S (EMD), DK

Lasse Svenningsen (EMD, DK), Daniel Lindholm (EMD, DK)

ABSTRACT:
The first batch with 7 years of data from the long awaited ERA5 global assimilation dataset was released from ECMWF during summer 2017 [1]. A data review by EMD comparing raw wind speeds from the ERA5 datasets to wind speeds from tall masts around the globe showed excellent correlation when comparing to the widely used reanalysis MERRA2, ERA-Interim and CFSR [2]. This indicates that ERA5 brings increased accuracy into the atmospheric flow modelling chain. The improved correlation is explained by various improvements in ERA5: improved data assimilation model and data sources as well as increased temporal and spatial resolution (i.e. hourly and ~31 km). This study evaluates icing intensities derived from various data sources, to assess if the ERA5 data can improve icing estimates. We utilize an implementation of the ISO 12494 (Makkonen) icing model, where the icing model parameters are estimated using comparable WRF mesoscale configurations - but driven by different global assimilation sources: MERRA, ERA-Interim, CFSR and the newly released ERA5. Model results are compared to icing data from 10 sites in Scandinavia.

REFERENCES:
[1] ECMWF: ERA5 data documentation, available online:
https://software.ecmwf.int/wiki/display/CKB/ERA5+data+documentation (accessed 2017-10-16)
[2] EMD: ERA5 data documentation, available online:
http://help.emd.dk/mediawiki/index.php?title=ERA5_Data

Web site: http://www.emd.dk

Short biography: Morten Lybech Thøgersen is the head of the Wind R&D Department at EMD International A/S – and is currently leading team of 5 R&D specialists - along with being the project manager for a number of external and internal R&D projects. He has specialist knowledge within topics like MCP, wakes, turbulence, IEC classification and probabilistic methods. Morten oversees the high-performance computing efforts at EMD. Morten came to EMD in early 2001 and he has been working with software development, consultancy services and R&D. Prior to that, Morten was employed as a scientist at Risø National Laboratory (now DTU Wind Energy). His interests are within probabilistic methods and wind modelling as well as project management using Agile methods. At home, he enjoys the time with his family - and to sail, scuba-dive and snowboard.

R&D areas/s: 03. Pre-construction site assessment, measurements, models and standards, 04. Operational experiences incl. performance optimization, big data and production losses

Sensitivity of icing losses. Terrain versus elevation – a case study.

Rickard Klinkert, Kjeller Vindteknikk, SE

Johan Hansson, Kjeller Vindteknikk (now Arise), SE

In cold climate, production loss due to icing is an important parameter in the planning of wind farms. Disregarding turbine control strategies in icing condition, a rough estimate of the expected losses due to icing can be estimated from turbine elevation but other parameters may also influence.
In a recent commercial project we found, using a numerical weather prediction model to feed our icing model, two nearby wind farms (60 km part) with similar turbine elevation to generate quite different losses due to icing. In this study we investigate the reasons for the discrepancy in the icing losses between the farms. We show that the differences mainly can be attributed to the local terrain and to the upstream flow characteristics during icing events rather than the elevation.
In addition we will show examples of icing losses from operational wind farms and have a closer look on how the production losses due to icing varies internally in the wind farm. Among other things we will discuss the indication that the most upstream turbines (during icing conditions) are associated with larger losses due to icing than those downstream, although the downstream turbines have higher elevation.

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

Short biography: Background:
Rickard Klinkert holds a Master of Science degree in Physics and has many years of experience with the modelling and solving of different physical problems. Since 2012 he has been working at Kjeller Vindteknikk, analyzing wind a climate conditions for wind energy. He is also head of the Swedish and Finnish markets for Kjeller Vindteknikk.
Experience in cold climate:
Rickard has been involved in a large number of assessments for wind farms in the Nordics. The majority of these being located in cold climate. On daily basis he is calculating wind farm production, icing conditions and losses due to icing using state-of-the-art methods developed by Kjeller Vindteknikk. Rickard has also been involved in other close connected fields such as mapping of icing conditions and calculation of ice-throw.
Personal interests:
Rickard has been singing in choirs for 25 years running. He also runs marathons and loves food of all kinds.

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

The use of CFD to post-process wind speed data from remote sensing devices in complex terrain

Wulstan Nixon, ZephIR Lidar, UK

Alan Derrick (RES, UK), Iain Campbell (RES, UK), Alex Woodward (ZephIR Lidar, UK)

Data from remote sensing devices (RSD) are widely considered as being bankable for use in many aspects of wind resource assessment campaigns. They offer considerable opportunities in producing high quality, cost reduced wind measurements where the use of conventional meteorological masts are technically or financially challenging. Once installed, both the position and height of conventional anemometry such as cups are fixed, limiting their measurements to certain turbine locations and dimensions. Other benefits from RSD include:

• Measurements up to and exceeding standard hub heights;
• Wind climate characterisation across the full rotor diameter;
• Easy installation in difficult to access sites and climatic conditions;
• Enhanced used in forested sites requiring less tree clearance than for mast installations; and
• Lower risk operation in climates subject to structural icing.

Ground-based vertically-scanning RSD, whether based on sodar or lidar technology, calculate the mean wind speed based on measurements taken from the circumference of a scanned volume. This process relies on the assumption that the line-of-sight velocities measured around the scan are representative of the wind speed at the scan centre. It is possible for this assumption to break down in strongly non-uniform flow, which can lead to possible differences between the volumetric measurements of RSD and the point measurements obtained from conventional anemometry. Hence, in areas of terrain induced flow complexity, there may be a need to convert the volume measurements taken by a RSD at each height into a point equivalent measurement more representative of what a cup anemometer sited on a collocated mast would measure at that height.

Conversion of wind speed data from RSD are possible in certain inhomogeneous flow situations based on high resolution Computational Fluid Dynamics (CFD) modelling, which are used to derive the flow geometry throughout the measurement volume. This process is key to ensuring continued project financing based on data from stand-alone remote sensing devices, whilst reducing the uncertainty between a RSD and conventional anemometry in complex terrain. Whereas prior studies have focused on only a few test cases with a specific CFD model, this study brings together validations of CFD applied at many co-located mast and lidar pairs on a wide range of sites. Furthermore, the data conversions have been derived and compared using two different CFD models for each site (Meteodyn WT and Ventos). From this suite of results, an estimate of the uncertainty in the resultant CFD converted wind speed can be made. The benefits provided by this work can help to reduce overall project development risks and secure more favourable investment from the use of RSD in future wind energy developments.

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

Short biography: Scott has been involved with wind energy research and development for 10 years, and is currently working as a wind engineer at ZephIR Lidar. He studied Electronic & Electrical Engineering at Loughborough University and completed his PhD at the Centre for Renewable Energy Systems Technology (CREST) where he focused on the use of Computational Fluid Dynamics (CFD) in modelling wind flow and forest interactions. Since then he has worked within the small to medium scale wind industry and his current role at ZephIR focuses on the development of lidar technologies for wind resource and energy assessment.

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

Development of numerical models for ice accretion predictions

Johan Revstedt, Lunds Universitet, SE

Matilda Ronnfors (LU, SE), Antoine Dubille (LU,SE/ISAE-ENSMA,FR), Robert-Zoltan Szasz (LU,SE), Johan Revstedt (LU,SE)

Numerical modeling of ice accretion on wind turbine blades is a promising tool which can complement experimental campaigns to improve the understanding of the involved physical processes. Beside being often economically more advantageous compared to experiments, numerical computations offer a better control of the involved physical parameters. As a result, individual parameters are easier to separate, thus, numerical simulations are well suited for parametric studies. Nevertheless, due to the large number of parameters and broad range of scales which need to be modeled, numerical modelling of ice accretion is still not straightforward and one often needs to develop new models or find a balance between accuracy and required computing power.
We propose to present the numerical modeling carried out recently at the Div. of Fluid Mechanics, Lund University, which was focusing on three development routes.
First, the existing ice accretion model based on Lagrangian Particle Tracking (LPT), initially implemented in the in-house CFD solver at the division, has been implemented in the open-source library OpenFOAM [1]. The main advantage of implementing the model in OpenFOAM is the availability of a significantly larger physical models already in the library. Furthermore, the OpenFOAM implementation has the potential to reach a broader community.
Second, the ice accretion model implemented in the in-house solver, suitable to model rime-ice conditions, has been extended to model glaze ice conditions as well. The model implemented so far is simplified, offering faster computations but lower accuracy. Further improvement of the model is planned as a future work.
The third development aimed to create a tool to extrapolate data obtained for two-dimensional airfoil cross sections to three-dimensional turbine blades. The reason is that both in experiments and computations often only 2D data is available. Although a tool based on extrapolation cannot compete in the description of the physics with full-3D simulations, it can be a good alternative when results are needed in a short time or with low computing resources.
1. www.openfoam.org

Web site: http://www.fm.energy.lth.se/english/

Short biography: R.Szasz received his PhD at Lund University, Sweden in 2004, the topic of the thesis being "Numerical modeling of flows related to gas turbine combustors". Since 2004 he is working at the Department of Energy Sciences, Lund University, currently as researcher, the main topics of interest being isothermal and reacting swirling flows, acoustics and flows related to wind turbines.

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

Benchmark SCADA analysis of 5 different wind turbine Ice Protection Systems

Ville Lehtomäki, VTT Technical Research Centre of Finland Ltd

Timo Karlsson (VTT, FI), Simo Rissanen (VTT, FI), Esa Peltola (VTT, FI)

Cold climate markets are expected to grow +12GW/a between 2016-2020 making it the largest "special" climate market in wind energy today (IEA Wind Task 19, 2016). Several turbine manufacturers have also seen this growing market and offer today a variety of different blade Ice Protection Systems (anti- and de-icing systems) to mitigate icing challenges on wind turbines. However, publically available analyses on different Ice Protection System's (IPS) performance, efficiency, and technical maturity, are missing. Since WinterWind 2015, there has been a public cry-out for performance guarantees from owner/operators regarding turbines equipped with IPS. As a summary, there is a large need for more 3rd party assessments of the performance and system maturity of different turbines equipped with IPS available on the market. At the moment it stands that a joint industry, shared benefit project between Vattenfall AB, BlaikenVind AB, Taaleri Energia Operations Oy and VTT has been formed and VTT is set to analyse historical SCADA data from Enercon, Vestas, Siemens-Gamesa, Nordex-Acciona and Dongfang wind turbines all equipped with IPS and located in Scandinavia and Central Europe. The main goals are to evaluate a) production losses due to icing for turbines equipped with IPS; b) gain of production from use of active heating IPS compared to turbines without IPS; and c) IPS reliability from O&M perspective by calculating the IPS technical availability. Historical SCADA data will be analysed and a unified method to evaluate icing losses, IPS gains and IPS reliability assessment of all turbine types will be developed and used together with project partners. The assessment of a) will be performed with Task 19 open-source code T19IceLossMethod, and for b) VTT WIceAtlas will be used as a source of non-heated turbine icing losses. The results of this project will contribute as well to the accomplishment of the goals defined in the IEA Wind Task 19 "Ice Protection System Warranty Guidelines" related to the harmonization of full scale wind turbine testing methods in cold climate conditions. In this presentation, some first intermediate results will be presented regarding icing losses, production gain and technical availability from the five different IPS systems.

References

IEA Wind Task 19. (2016, July 29). Emerging from the cold. (WindPower Monthly) Retrieved August 22, 2016, from http://www.windpowermonthly.com/article/1403504/emerging-cold

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

Short biography: Mr. Lehtomäki has been part of VTT Technical Research Centre of Finland Ltd since 2009. He has a Master's degree on mechanical engineering on product development from Helsinki University of Technology. Currently as Senior Scientist, his everyday work focuses on coordinating and developing new projects and technology innovations mainly in the field of cold climate wind power. He specializes in icing effects on blades, iced wind turbine dynamics, ice detection and pre-construction icing loss assessments. He is the Operating Agent of International Energy Agency (IEA) Wind Task 19 "Wind Energy in Cold Climates". He is the coordinator of European Energy Research Alliance Joint Program Wind (EERA JP WIND) Sub Program on Cold Climate focused on medium to long-term research needs. He is the coordinator of cold climate sub-committee in the revision of IEC 61400-1 ed3->ed4 "Design requirements for wind turbines" standard. He is also working with IEC 61400-15 ed1 "Energy yield assessment" standard regarding cold climate effects.
He is on a mission to transform cold climate wind power into a mainstream market.

R&D areas/s: 02. De-/anti-icing including ice detection & control

Retrofitting a de-icing system on turbines affected by extreme icing: Our experience

Sebastien Trudel, EDF EN Canada

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EDF EN has been operating more than 500 wind turbines since 2012 in the harsh icing environment of Québec in Eastern Canada. While most turbine OEMs now offer active ice protection systems on new turbines, EDF EN faces the challenge of retrofitting solutions to minimise icing losses on existing turbines having no anti-icing or de-icing system.
Starting in 2015, EDF EN worked with East Coast Wind, an independent service provider based out of Maria, Quebec, and Wicetec, a Finnish product provider based in Helsinki, to implement the de-icing system developed by Wicetec, the Wicetec Ice Protection System (WIPS) on some turbines of Lac Alfred. The Wicetec Ice Protection System is an active electrothermal system that can be retrofitted onto an existing wind turbine by laminating a conductive carbon fiber under the blades leading edge surface. While the idea looks simple, there are many technical challenges to overcome: bringing the rotor down, setting up a temporary blade surfacing facility, as well as increasing the power transmission to the hub. Over the first winter, after the commissioning of two prototypes in December 2016, the TechnoCentre éolien conducted an independent performance assessment of the retrofitted ice protection system. This analysis includes a quantification of the reduction of the icing losses from operating the system as well an assessment of its performance in severe icing conditions.
In our presentation, we will describe the challenges and obstacles encountered to realise this important project, and solutions developed to overcome them. We will also discuss about the promising results obtained over the first winter of operation.

Web site: https://www.edf-en.ca/about/edf-en-canada-glance/

Short biography: I have always been driven by the environmental science field of science. After completing an engineering degree in civil and environmental engineering, I worked for a few years in the industrial cleaning and hazardous waste business. I returned to school to complete a master in environmental science, working on a thesis assessing renewable energy potentials.
In 2004, I started working on wind resources assessment as a consultant for 5 years. In 2009, I moved on with EDF EN Canada, a wind project developer, where I have been a key member of the internal wind resource assessment team. Two years ago, I was promoted to Manager of the measurement team in charge of the installation and maintenance of our development and permanent met tower fleet in Canada and the US, which represents about 200 active towers, as well as all of the power performance tests we perform.
At EDF EN, I have also been in charge of all the R&D efforts related to icing since 2011. We currently have 9 projects with more than 733 turbines under operation in Canada, facing medium to extreme icing conditions. I have been involved on multiple R&D tests, reviews and analysis on ice detectors, anti-icing coatings, de-icing systems, ice-throw models as well as optimisation of ice operation algorithms.

R&D areas/s: 02. De-/anti-icing including ice detection & control

Retrofitting anti-icing blade heating on installed wind turbines

Petteri Antikainen, Wicetec, Finland

Steven Fugere, Eacst Coast Wind, Canada

To author's knowledge, for the first time in the cold climate wind industry, a fully functional and reliable technical solution for retrofitting blade heating on a wind turbine has been tested successfully over a one year test period.
The Ice Prevention technology used in this retrofit test project, has earlier been applied for wind turbines for more than 700 MW, almost 300 turbines over 20 years with an increasing pace. All this has been done for new projects, installed at blade and turbine factories in co-operation with turbine OEMs.
This time, the technology was adapted for existing turbines, retrofitting, a standalone system without the OEM. The owner of wind farm took responsibilities which OEMs had carried in previous projects.
First, as a test, two turbines for winter 2016-2017 were retrofitted. After this successful test winter, the next step, ten more, were installed for winter 2017-2018 to gain experience for serial production.
There has been technical and practical challenges to tackle: power supply to hub, cabling to blades, blade handling, setting up local work shop, just to name few of challenges. In this presentation, solutions to enable retrofit as well as results are presented.
This presentation will tie in and be complementary to IPS performance methodology by Technocentre Eolien and EDF EN Canada's Operator experience of the project. This presentation will provide a perspective from the Technology provider and installation point of view.

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

Short biography: Petteri, who holds M.Sc. in Technical Physics, has 20 years' experience in cold climate wind power. For example he has developed an icing wind tunnel, testing methods and participated in National and International standardisation committees, SESKO and IEC MT12-1. He has also been a board member for the Finnish Wind Power Association. Petteri has worked as Team Leader and Principal Scientist at VTT, Technical Research Centre of Finland, where ice prevention system technology was originally developed. In 2014 Petteri co-founded Wicetec, a company supplying ice prevention systems for wind turbines.
Personal interest: wintersports

R&D areas/s: 04. Operational experiences incl. performance optimization, big data and production losses, 14. Workshops - Owners' experiencies, Future technologies

Ice Protection System Performance Assessment Methodology

Matthew Wadham-Gagnon, TechnoCentre éolien

Charles Godreau (TCE, CA), Nigel Swytink-Binnema (TCE, CA), Gabriel Rosso (TCE, CA)

A methodology for the performance assessment of ice protection systems (IPS) for wind turbines will be presented. The complete method requires a reference turbine and a turbine equipped with an IPS system. The analysis looks at availability and faults, total production, total expected production based on the ice-free reference power curve, and the total expected production based on the iced reference power curve. These values are compared with the total production of the reference turbine to evaluate the potential gain provided by the ice protection system. This methodology has been developed over time and applied to several types of IPSs (hot air, electrothermal, icephobic) installed on turbines from different OEMs. This method was applied namely to assess the performance of a retrofitted electrothermal system tested by EDF EN Canada. Results from this analysis will be presented by Sébastien Trudel in another presentation submitted to WinterWind.

Web site: http://www.eolien.qc.ca

Short biography: Both in Quebec and internationally, Matthew Wadham-Gagnon is recognized by his peers as an industry authority in wind energy in cold climates. As Project Manager and Business Development Coordinator, Matthew stands out as a pioneering figure when it comes to incorporating best practices for harnessing the wind resource at cold climate sites.
In spite of what might appear to be a strong conformist bias, Matthew is in reality the standard bearer of an innovation-oriented industry. With over ten years of experience in engineering, project management, applied research, technical assistance, business development and international engagements as speaker, panelist or conference chair, Matthew has come to acquire leading-edge expertise in his field.
With a Master's degree in mechanical engineering from McGill University, he represents Canada in the International Energy Agency's Task 19 working group on wind energy in cold climates.

R&D areas/s: 06. Wind turbine manufacturers – cold climate solutions

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

Konrad Sachse, Nordex Energy GmbH, Germany

Ines Runge (Nordex Energy GmbH), Konrad Sachse (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 will do the next step, which is introducing the further advanced AIS for the N149/4.0-4.5.
The advanced system offers a strong 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. Another step is the further optimization of the control system and power supply. The nominal power is increased to cover a larger surface area without decreasing the heating power per square meter.
The system has therefore a high reliability and good maintainability which will lead to a high availability of the AIS.
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 new technology has been tested with various prototypes since 2013.
The components of the advanced AIS have been intensively tested and qualified regarding the heat distribution as well as the lightning protection system. A brief overview of test results and field experiences will be presented.

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

Short biography: Danela Jacob works as a development engineer at Nordex Energy GmbH since 2014. She has been working on the Anti-Icing System in the blade engineering department since 2013. She holds a B. Eng. in mechanical engineering and a M. Eng. in renewable energy systems.

R&D areas/s: 06. Wind turbine manufacturers – cold climate solutions

Leveraging insight from operational data to optimize performance in cold climate

Per Egedal, Siemens Gamesa Renewable Energy, SE

Chief Control And Monitoring Engineer

Siemens Gamesa has over 4 GW of wind turbines installed throughout the northern hemisphere, in the harsh cold climates of Canada, Norway, Sweden and Finland, and over 300 turbines in operation with de-icing technology. With decades of operational data, our scientists and engineers have gained reliable insight to turbine operation under cold weather and icing conditions. Harnessing the power of this data, Siemens Gamesa has developed Operation with Ice. When icing conditions and formation of ice on the blades are detected, this turbine controller functionality optimizes the performance of the turbine through periods of icing to minimize losses and prevent costly shutdowns. Furthermore, the knowledge gained from analyzing the huge volume of operational data is used to determine which type of technology the site in evaluation would benefit most from, and which degree of icing makes the investment worthwhile to ensure smooth operation and maximization of returns in the harshest of climates.

Web site: http://siemensgamesa.com/en/

Short biography: Per Egedal is Chief Engineer in Siemens Gamesa Renewable Energy Technology Department for Control and Monitoring features. He has more than 15 years of experience with design of control features for wind turbines, condition monitoring and safety system.

R&D areas/s: 06. Wind turbine manufacturers – cold climate solutions

Vestas Cold Climate Solutions and next steps

Brian Daugbjerg Niesen, Vestas Wind Systems A/S

Brian Daugbjerg Nielsen (Vestas Wind Systems A/S, DK)

The cold climate technologies are maturing and the industry is on the right journey. Vestas will elaborate on the market requirements, the new trending requirement and what solutions which can be offered on the short term and what the next steps could look like.
- Ice assessment; how to evaluate the risk and what mitigations to take
- Ice removal technology; how to operate the turbines pending ice class
- Ice detection technology; how to operate the turbine in a safe manner
- Cold climate turbine; mixing the features to create the right match
- Commercial commitment; creating business case certainty

Vestas will go through these items and elaborate on each of the items and here among go through the further opportunities for developments and what is needed from a industry innovation point of view.

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

Short biography: Senior Product Manager at Vestas. Responsible for product options: Commercial leading and managing options, drive road map and Go to Market plans.
Been in Vestas since 2006. Started out in Sourcing based in Lem, From 2007-2009 expat in R&D facility, UK Isle of Wight to integrate sourcing into blade development programs in an early stage. Moved back to DK in 2009 working with category management for sourcing. Moved to Aarhus in 2012, and started as a product manager, working from the Vestas HQ. Been heavily involved with cold climate developing De-icing system.
Holds an MSc in Industrial Marketing & Purchasing from Copenhagen Business School.
38 years, Married and have 2 boys aged 1,5 and 3 Years respectively.
Hobbies: Sport in terms of running, and back yard fitness, then family allows it. Movies and TV shows on netflix. Reading books before sleep is a must do.

R&D areas/s: 06. Wind turbine manufacturers – cold climate solutions

More than 20 years of experience – Retrospect and outlook of ENERCON's cold climate technologies

Sten Barup, ENERCON, SE

Katharina Roloff (ENERCON, DE)

The 10th year anniversary of Winterwind is a good occasion to look back in the past developments and innovations concerning the ENERCON cold climate technologies. The presentation will give a retrospect of icing related research within two decades covering ground-breaking innovations, field studies at cold climate sites and third party investigations ending with an outlook about ideas for the future.
ENERCON launched the first rotor blade heating system on an E-40 turbine back in 1996. Since then several challenges had to be tackled, e.g. adapting the technology to larger and even two section rotor blades. Today the system can be activated manually or automatically and operated in anti-icing or de-icing mode. ENERCON has installed more than 3 000 rotor blade heating systems in 21 countries covering everything from severe icing climates in Canada, Austria and Sweden to regions with less and milder icing events in Western Europe.
The ENERCON standard ice detection system uses characteristic control curves in order to detect changes in the aerodynamic properties of the rotor blades. It was patented in 2004 and certified by TÜV Nord. Every ENERCON turbine around the world is equipped with this system ensuring a safe operation even at sites where icing events are very rare. To meet potential safety concerns and requirements from building permits, ENERCON offers redundant ice detection system and several ice mitigation strategies such as nacelle alignment during icing conditions, wind farm ice detection triggered by single turbines or warning lights when meteorological conditions could lead to ice fall in the wind farm.
The Cold Climate Package option from ENERCON significantly increases power production for low temperature sites, operating with rated power down to temperatures of -30°C, and further on with decreased maximum power output down to -40°C. More than 600 cold climate package turbines have been built in alpine regions of Austria, in Canada and in Scandinavia.
ENERCON's drive and commitment to continuously improve our systems have led to new solutions and increased reliability, persistently optimising the production and the safety for our customer's cold and icing climate sites.

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

Short biography: Sten Barup has been working with icing related research and site suitability assessments at ENERCON Wind Farm Engineering since 2011. The R&D tasks have included icing and ice throw measurement programmes as well as the development and validation of ENERCON's ice throw risk assessment methodology. He holds a Master's degree in mechanical engineering and is currently delegate for the IEA Task 19 subcommittee working on the first international guidelines for ice fall and throw risk assessment. Besides enjoying time with family in his leisure time, he also likes horses, tractors and carpentry.

R&D areas/s: 06. Wind turbine manufacturers – cold climate solutions

Task 19 – Ice Protection System Warranty Guidelines

Jenny Longworth, Vattenfall AB, Sweden

Ville Lehtomäki (VTT), Carla Ribeiro (DNVGL)

Presenting a Task 19 report that will be published that sets out some guidelines for wind farm Developers, Consultants and Wind Turbine Generator (WTG) Suppliers operating in cold climate areas, where there is risk for icing. One of the largest production risks when developing wind farms in cold climate is due to ice build up on the blades leading to aerodynamically changed blade profiles or stand still of the turbines and consequently loss of production. A number of turbine manufacturers have developed ice protection systems that should prevent or remove any ice that builds up on the blades and therefore prevent the majority of the icing losses. The losses due to cold climate will never be zero, however with time, systems should become increasingly efficient.
The aim of these guidelines are to set out possibilities for how such systems can be warranted and tested and enable the wind industry to develop cold climate sites further. Task19 has considered different alternatives that could provide a basis for a performance warranty for the IPS system.

Web site: https://www.ieawind.org/task_19.html

Short biography: Jenny Longworth has a Master of Mechanical Engineering with a MSc in Renewable Energy Systems and has eleven years of experience within the wind analysis field, working at different companies, both developers and consultancies. After a number of years heading up the Solna based wind resource team at Vattenfall she is now working as a Wind Project Procurement Manager with WTG procurement, also for Vattenfall. Jenny has been a member of Task 19 for nearly two years.

R&D areas/s: 06. Wind turbine manufacturers – cold climate solutions, 14. Workshops - Owners' experiencies, Future technologies

Asset manager

Jonas Sundström, Skellefteå Kraft AB, Sweden

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Ice is one problem for windpower in Cold climate however not the only.
Skellefteå Kraft AB have used AIS based on carbon fibre since our first fullscale Project Uljabuouda.
We can see differencies between the systems used both between different suppliers and also frome different times.
Experiences says it is getting better but I believe we still have a long way to walk before we have reached the end with a perfect product

Web site:

Short biography: Raised in a small village in sweden, North of the Arctic circle, Porjus. I started to work as technichian in hydro. I moved down to Skellefteå 1998 were istarted to work on our dispatch center, before I took the step out to the unknown 2010/11, then I started to work with windpower in Skellefteå Kraft. This is the faremost interesting thing I have done in my career, to get the oportunity to work with something that is not finished and that have so many inprovements ahead is great. I feel joy everytime I go home from work and knows I have learned something new and that new is helping us to get a more carbon neutral energy production.

R&D areas/s: 02. De-/anti-icing including ice detection & control

First 3D accelerometer based measurements at the blade tip: what's the benefit of the data?

Michael Moser, eologix sensor technology gmbh

Thomas Schlegl (eologix, AT), Michael Moser (eologix, AT)

Measurement of rotor blade Eigen frequencies and their alteration due to physical changes of the blade (such as deterioration of structural integrity, mass changes such as ice accretion and blade temperature) is a common principle for rotor blade damage detection as well as for blade-based icing detection. Typically, accelerometers can not be positioned over the entire blade length and on any position due to restrictions in accessibility (in retrofit applications) and by design limitations (during blade manufacturing), as well as due to the concern of additional lightning issues.

This problem can be overcome by making acceleration sensing wireless. Microelectromechanical system (MEMS) based accelerometers have been on the market for years, are approved technology and since they are often designed for mobile applications, the power demand is reasonably low.

Typical measurement ranges are e.g. 2g, but ranges of up to 200g can be achieved. Also, the resolutions are sufficient for smart signal analysis and sampling rates can exceed 1000 Hz.

Wireless acceleration sensing however comes at the price of a limited energy budget. Therefore, all parameters concerning the measurement (e.g. sampling rates) must be carefully chosen and raw data must be preprocessed accordingly before wireless transmission.

Due to the high flexibility in the choice of mounting positions, all critical points of the blade structure from root to tip (yet not limited to the blades but implemented in one system) can be continuously monitored in order to allow for predictive maintenance throughout the lifetime of the turbine.

In our presentation, we will show measurement data from the surface of a blade tip on a turbine under icing conditions. We will demonstrate the relationship between the oscillation behaviour obtained from a blade tip and icing behaviour of a turbine.

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

Short biography: Michael Moser studied Electrical Engineering and Sound Engineering at Graz University of Technology (TU Graz) and University of Music and Performing Arts Graz. He was a research assistant at the Institute of Electrical Measurement and Measurement Signal Processing (TU Graz), where in 2013 he completed his PhD thesis focusing on energy harvesting and icing detection on electrical power transmission lines. In 2013, he was one of three founders of eologix and has been focusing on icing detection on wind turbines since then.

His personal interests include but are not limited to playing the piano.

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

Wind Turbine Power Output for Different Cold Climate Conditions

Dimitar Stoyanov, Coventry University, UK

Hamid Sarlak (Technical University of Denmark, Denmark), Jonathan Nixon (Coventry University, United Kingdom)

The viability of wind turbine projects in mountainous and sub-arctic regions is often negatively affected by the presence of ice. Ice builds on wind turbine rotor blades and reduces their aerodynamic efficiency, which leads to degraded power output. Previous numerical ice modelling research on wind turbines has had a tendency to focus on ice profiles formed under specific condition and during a finite period of time. This study investigates how a wind turbine's power output varies during a typical day in different cold climate regions. Different wind turbine sizes and aerodynamic profiles are also considered.
This is achieved using a modified Messinger model to obtain 2D ice shapes and XFoil to determine aerodynamic characteristics. The wind turbine power performance is obtained using Blade Element Momentum Theory. A model is developed in MATLAB and applied to evaluate the modelling capability of low computationally intensive tools and the ice losses variation due to wind turbine size and location. Typical Cold Climate locations and horozontal axis wind turbines are examined that are find in the literature.
The results will help to inform manufactures on potential wind turbine sites and the outlined methodology can be adopted by other research developing project viability and ice predictive tools.

Web site: https://www.linkedin.com/in/dimitar-stoyanov-a87762106

Short biography: My name is Dimitar Borisov Stoyanov and I am currently a PhD candidate in Coventry University. I have received my bachelor diploma from Technical University of Sofia in Aircraft Maintenance and Operation in 2015 and my master diploma from Coventry University in Aerospace Engineering in 2016, both with distinction. After my master diploma, I successfully passed an interview and was given the chance to undertake a Wind Turbine Icing Prediction and Evaluation project, which I have been working on since 26th of September 2016.
My academic experience helped to obtain skills in computational fluid dynamics simulations and modelling using openFOAM software, applied numerical and analytical modelling, experimental analysis using Altair ObtiSctruct software, aerodynamics and flight dynamics and MATLAB modelling. Currently I improve my knowledge on ice numerical modelling and the complex simulation of ice accretion with the consequent evaluation of power degradation.
I am interested in renewable energy, aircraft advances in electrical engines and gliders, wind turbine industry development and novel techniques of optimizing wind energy harvesting. As part of my PhD project I follow the recent advances in ice modelling, anti/de-icing modelling, performance modelling both numerical and statistical. Regularly I check reports from IEA and REN21.

R&D areas/s: 09. Inspection, maintenance, repair and decommissioning

Method for early detection of damage in conductive blade heat systems

Greger Nilsson, Blade Solutions AB

No co-authors

Deicing- and anti-icing systems are important for sub-arctic climate wind power production. Regular blade heat systems are either based on circulating hot air within the blade or conduction type systems applied to the blade surfaces. The most commonly used conduction type systems use heating elements consisting of electrified carbon fiber heat mats. Such mats cover exposed areas of the blade, that is, on or near the blade's outer half's leading edge. These systems are, therefore, energy efficient since the heated areas only constitute a fraction of the total blade area. Unfortunately, the same areas are also the most exposed to impact damage, for instance, from falling ice. Additionally, the conductive heat system itself acts as a lightning rod, increasing the likelihood of lightning strikes. Damages from physical impacts or lightning strikes are therefore common. Damages reroute the electrical currents causing local hotspots, often forcing temperatures to exceed the epoxy matrix pyrolysis temperature, in turn, causing the damage to grow. Large damages may jeopardize the structural integrity of the blade and increase risks of catastrophic blade failure. Furthermore, repairing large damages are complex and exceedingly expensive. Large damage repairs often require cranes and even replacing the blade, which prolongs the turbine downtime. Early state detection and repair will reduce downtime, needs of expensive cranes, and blade replacement or failure risks.

This presentation will present a two-stage method for early defect detection.

The first stage consists of inspection using ground-based, long-range thermal cameras. The second inspection stage includes an up-tower inspection to evaluate the hot-spot gravity if the ground-based thermal camera inspection had indicated heat system defects. The up-tower inspection gives informations about exact hot spot temperatures and upcoming blade heat system repair set up.

The proposed method is fast compared to one step up-tower inspection method. First ground-based inspection is performed within the hour, thereby allowing regular inspection of even large wind farms, involving the second stage only when the first stage has indicated problems. Regular, rapid detection of hotspots may reduce the operational costs of sub-arctic wind farms considerably.

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

Short biography: Owner and developer at Blade Solutions. Worked twenty years whit composite material science. Now focusing on developments and repair methods of cabon fibre based blade heat systems. Personal interests: Downhill skiing and multihull sailing.

R&D areas/s: 02. De-/anti-icing including ice detection & control, 04. Operational experiences incl. performance optimization, big data and production losses

Innovations and developments of ice and damage detection for rotor blades

Timo Klaas, Wölfel Engineering GmbH & Co. KG

Dr.-Ing. Carsten Ebert (Wölfel Engineering GmbH & Co. KG)

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
- System robustness based on more than 500 systems running in the field
- Additional blade monitoring features such as damage detection, rotor blade imbalance and pitch angle monitoring
- Lightning protection: Use of latest Fibre-optical technology in rotor blades
- Industry 4.0: Connected systems lead to efficiency - Monitoring Intelligence Center MIC.Windenergy
- Smart data: How to use advanced data analytics to gain new findings

Web site: https://www.woelfel.de

Short biography: Timo Klaas studied as an industrial engineer (B. Eng), 32 years old and lives in Hamburg.
He has been working in the sales department for Lufthansa Technik before he joined Wölfel Enigineering.
He is now leading the sales department at Wölfel Group for all systems related to wind energy.

R&D areas/s: 02. De-/anti-icing including ice detection & control

The importance of accurate detection for turbine ice prevention systems

André Bégin-Drolet, Université Laval

André Bégin-Drolet (UL, CA), Jean Ruel (UL, CA), Jean Lemay (UL, CA), Jonathan Ouellet (Boralex, CA)

It is now recognized that ice prevention system (IPS) can improve wind power production in cold climate. Many wind turbine manufacturers such as Enercon, Vestas, Siemens and Senvion nowadays offer cold climate package and ice prevention system to cope with the adverse effect of atmospheric icing. Even though these systems offer the opportunity for wind farm operators to increase the annual energy output for a given site, the operation of IPS needs to be carefully controlled. These systems need a substantial amount of energy to be operated and losses incurred during inadequate heating periods can offset the gains obtained for heating when it is necessary. Moreover, under severe icing events, the limited heating capacity of IPS cannot ensure an ice free operation. To cope with all those issues, proper ice detection is needed to operate IPS for wind turbine. The Meteorological Conditions Monitoring System (MCMS), developed at Université Laval in Canada, and installed on several wind test sites is a new measurement tool that can be very useful to assess and control IPS. A collaboration between Université Laval and Boralex led to the installation of a MCMS on an Enercon wind turbine operated by Boralex in eastern Canada. Historical data from 4 nearby wind turbines were analyzed to assess the benefit of using a MCMS as a central unit for the control of the turbine IPS. Preliminary results showed that this management technique can yield significant gains.

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

Short biography: André Bégin-Drolet is a professor of mechanical engineering at Université Laval. Pr. Bégin-Drolet research focuses on designing mechatronic systems used as sustainable development tools and a large portion of his work is oriented toward improving wind power production in cold climate where atmospheric icing is prevalent. His research led him to the design of a smart sensor adapted to measure 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 sailor who loves to perform in both inshore and offshore regattas.

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

Standardizing ice detector tests in icing wind tunnel - final results

Timo Karlsson, VTT Technical Research Centre of Finland, FI

Tuomas Jokela (VTT, FI), Mikko Tiihonen (VTT, FI)

Cold climate wind today is the largest "special" climate in wind power industry. Reliable, repeatable ice detection is essential for operation in cold climate conditions. Laboratory testing of instruments and subsystems is common and accepted practice in wind power industry in other areas (e.g. turbine subsystems, weather instruments other than ice detectors). For most of these wind turbine subsystems there are standards and industry best practices for laboratory testing. However, no standards exist for performance testing of ice detection instruments. Common practice in the cold climate wind community is to test instruments in real sites in real conditions. While these real world tests are valuable, they are slow, expensive and at the mercy of often unpredictable weather conditions. Because of these reasons, wind tunnel testing is very beneficial especially for R&D purposes.
In order to bring ice detector testing closer to par with testing of other instruments, VTT has been working together with industry partners Vattenfall, Statkraft and Labkotec on a set of standardized test conditions for icing wind tunnel testing of ice detectors.
The goal of the project was to develop a set of standard testing conditions that emulate real-life icing conditions and a set of common Key Performance Indicators (KPIs) that can be used to evaluate both the detector performance and the suitability of an ice detection method for a given purpose. KPIs were chosen to represent different phases of an icing event in order to produce a comprehensive view of detector performance.
Tests were performed in VTT icing wind tunnel in 2016-2017. Test conditions were selected to represent real-life in-cloud icing conditions. Different test cases represented different icing severities in order to capture how sensor can cope with various conditions. Conditions were defined by selecting air temperature, wind speed, icing time and liquid water content of air. The following sensors were tested:
• ISO 12494 standard rotating cylinder Ø3cm L=50cm
• Labkotec LID-3300ID ice detector
• Vaisala relative humidity sensor
• Vaisala shaft heated cup anemometer
• Vector unheated cup anemometer
• Vector wind vane
• Combitech ice monitor
The greatest benefit of testing is the ability to have reproducible tests in rapid succession. When doing full-scale tests outdoors in real conditions wait times can be very long. Standardized tests in wind tunnel can help accelerate testing for ice detector manufacturers significantly. Standardizing the test conditions also makes it easier to compare different generations of sensor to each other, helping accelerate R&D cycles for ice detector manufacturers.
An end user will also benefit greatly from standardized testing: when test conditions and KPIs are same for different kinds of sensors it is easier to evaluate different ice detection methods and pick the one best suited for any particular application.
Test protocol and KPIs will be presented along with relevant results for all tested instruments. Project and some preliminary results were presented at Winterwind 2017.
The results will be used as part of IEA WIND Task 19 work and implemented to Task 19 Recommended Practices 2019 revision.

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

Short biography: Timo Received his M.Sc. degree form Aalto University in 2012, from the School of electrical engineering, with speciality in automation and control engineering. He has been employed at VTT since 2011 working as a research scientist in VTT Wind power technologies group. During his time at VTT Timo has been working on numerous R&D projects related especially to wind power in cold climates. These include ice detection method development, ice assessment, production data analysis and ice prevention system development.

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

R&D areas/s: 02. De-/anti-icing including ice detection & control, 04. Operational experiences incl. performance optimization, big data and production losses

ICE CONTROL: Potential of innovative icing measurements and icing forecasts to optimize the operation of wind farms during icing conditions

Thomas Burchhart, VERBUND Hydro Power GmbH

Thomas Burchhart, Martin Fink (VERBUND Hydro Power, AUT),
Lukas Strauss, Stefano Serafin, Manfred Dorninger (University of Vienna, AUT), Alexander Beck, Christoph Wittmann, Florian Weidle (Zentralanstalt für Meteorologie und Geodynamik (ZAMG), AUT), Saski

Icing on rotor blades causes unplanned production losses and downtimes and may represent a significant risk for third parties and service technicians. The operator is confronted with severe balancing energy costs, electricity costs for blade heating and additional personnel costs for starting the blade heating and restarting the wind turbines. Accurate forecasts of start, duration, the end and intensity of rotor blade icing together with detailed knowledge about the icing situation on the rotor blades during all operating conditions would therefore be valuable to optimize the operation.
The evaluation of the optimization potential is done within the project ICE CONTROL in collaboration with the University of Vienna (Uni-Wien), the "Zentralanstalt für Meteorologie und Geodynamik (ZAMG)" and meteotest.
Within the R&D project one turbine in moderately complex terrain in Rhineland-Palatinate, Germany, is equipped with conventional and innovative ice detectors, a meteorological weather station to monitor wind, temperature, humidity, visibility, and precipitation type and spectra and three cameras to visualize rotor blade icing and instrumental icing.
Ice detection via power curve method is compared with the ice detection system from eologix enabling direct measurement of ice thickness and surface temperature at specific positions on the blades and during all operating conditions, including standstill times of the turbine. Ice signals from both systems together with the rotor blade images from the webcam are combined to a reference time series representing rotor blade icing. The same procedure with icing signals from a Combitech IceMonitor, a Sommer ice detector, a separate eologix sensor and webcam images from the instruments is used to create a reference time series representing icing on top of the nacelle. Both reference time series are used to benchmark the accuracy of icing forecasts provided by three different market players and deterministic forecasts from ZAMG and Uni-Wien. To quantify the forecast accuracy, continuous and categorical verification measures are taken into account. The assessment of the monetary benefit of the provided forecasts including electricity prices and balancing energy costs is done with a Cost/Loss model based on probabilistic forecasts. In addition, the performance of the blade heating system is investigated to adjust the heating duration depending on ambient conditions e.g. wind speed and temperature.
The combination of innovative ice detection sensors to detect ice and no-ice direct on the rotor blades and the consideration of icing forecasts opens new possibilities for an automated decision making process about the operation of wind turbines - a new step forward to establish a standalone process without human intervention.

Web site: https://www.verbund.com/en-at/about-verbund/power-plants/power-plant-types/wind-power

Short biography: Thomas Burchhart was born in Klagenfurt, Austria in 1980. After obtaining a Master´s degree in electrical engineering at the Technical University of Vienna, in 2007, he started his PhD in the field of Nanoelectronics where he investigated one dimensional Nanostructures. From 2011 to 2012, he worked in the development department at EPCOS OHG in Deutschlandsberg. During that, he was involved in the design of NTC thermistors and got knowledge about root cause failure analysis as well as accelerated life tests. Since 2012 he works in the Operation and Service group at VERBUND Renewable Power GmbH. Since that time he is responsible for performance analysis and optimization of the wind portfolio. Currently his research is focused on the optimization of the operation during icing conditions. His personal interests are skiiing and playing with his kids.

R&D areas/s: 02. De-/anti-icing including ice detection & control

Variability in Ice Protection System efficiency

Stefan Söderberg, WeatherTech Scandinavia AB

Stefan Söderberg (WeatherTech Scandinavia AB, SE), Magnus Baltscheffsky, (WeatherTech Scandinavia AB, SE)

In the last few years an increasing number of turbine manufacturers offer turbines with Ice Protection Systems (IPS). The suppliers use different heating techniques and strategies for running their system. Wind farm developers and owners have for many years asked for warranties other than technical such as system performance warranties. As the market and techniques have advanced and suppliers have gained experience in running their systems the possibilities for efficiency warranties have progressed.
This work investigates the variability in the efficiency of using an IPS. The basis for the study is a dataset of modelled atmospheric data from high resolution WRF model runs (www.mmm.ucar.edu/wrf-model-general) and include example sites in Sweden, Norway, and Finland. Production losses are estimated using an in-house production loss model, WICE, developed and tested using SCADA data from several operational wind farms. Different formulations of IPS's were applied in a series of sensitivity experiments to study the system efficiencies.
In the study it was found that the IPS efficiency depend on the strategy for running the systems. It was also found that the efficiency varies in time and space depending on meteorological conditions and the site specific icing climate. This is of importance for the understanding of the outcome of IPS evaluations and IPS efficiency warranty setup.

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

Short biography: Dr. Söderberg has extensive experience in boundary layer meteorology and numerical modelling in complex terrain. He has been working with atmospheric numerical models since 1999 and holds an MSc in meteorology from Uppsala University and a PhD in dynamic meteorology from Stockholm University. After working for 7 years as a scientist at the Department of Meteorology, Stockholm University, his interest in renewable energy and wind power in particular, brought him back to Uppsala in 2006 where he founded WeatherTech Scandinavia. Dr. Söderberg is currently a senior consultant and researcher at WeatherTech Scandinavia specialized in wind resource and icing climate studies.

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

Atmospheric stability consideration for cold climates

Hanna Vollan, Prevailing Ltd, UK

Joel Manning (Prevailing Ltd, UK)

Cold climates produce significant variation in atmospheric stability. This variation has the potential to significantly affect wind farm energy yield. For this reason, robust characterisation of atmospheric stability is required to produce accurate energy yield analyses.
Prevailing present an atmospheric stability characterisation method that employs the Richardson number derived from the NASA-MERRA2 global atmospheric model.
Characterising atmospheric stability using global weather model output, rather than on-site measurements, allows every site to be considered simply and consistently. Due to the relatively small height variation that can be practically achieved between mast mounted instruments, an extremely high degree of measurement accuracy is required to show the subtle variation of atmospheric conditions. This is challenging even in benign conditions, however in cold climates, where instruments are heavily affected by icing, obtaining a reliable seasonally balanced dataset is rare. Furthermore, measurements made on site are subject to both orographic and atmospheric effects, which cannot be separated. For example, two locations which are very close to each other, so subject to virtually identical atmospheric conditions, may suggest very different atmospheric conditions due to differing exposure to a local terrain feature such as a region of forest.
Richardson number is the ratio of turbulence created from buoyant forces to turbulence due to shear. This single value captures both thermal and mechanical stability drivers, without being polluted by microscale terrain features.
A frequency distribution of the NASA-MERRA2 derived Richardson number can be derived to provide a clear indication of the extent of atmospheric stability variation. Here, Prevailing compare this distribution to high quality mast based measurements to demonstrate the effectiveness of this approach.
Armed with clear information regarding the atmospheric stability variation, we can ensure that the most appropriate methodology is applied to shear analysis, cross-site correlations, wind flow modelling and wake modelling.

Web site: http://prevailinganalysis.com

Short biography: Hanna is an Analyst in Prevailing's pre-construction wind analysis team, undertaking financial-grade energy yield assessments and providing development support services for wind farm projects globally. Prior to joining Prevailing, she worked for the Norwegian transmission system operator, Statnett. In her spare time Hanna enjoys kitesurfing in the UK and abroad.

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

Use of LIDAR for power curve measurements in Nordic climate

Martin Grønsleth, Kjeller Vindteknikk AS, NO

Ove Undheim (KVT, NO), Utku Turkyilmaz (KVT, SE), Martin S. Grønsleth (KVT, NO)

At cold climate sites, such as inland sites in Scandinavia, large production losses due to icing have been reported in wind farms (see e.g., Byrkjedal, 2012a [1] and Ronsten, 2012 [2]). This is often related to meteorological icing or in-cloud icing.
To evaluate the actual production losses of a turbine exposed to icing conditions, and the efficiency of an icing mitigation system, Kjeller Vindteknikk has performed a LIDAR campaign on behalf of a client in a wind farm with turbines equipped with an anti-icing system. The LIDAR has been installed in between two turbines and has measured at multiple heights up to 200 m. The data coverage during the winter period was good and was used to calculate site calibrated operational power curves for turbines with and without an active icing mitigation system. One notable benefit of using LIDAR for this, is to avoid the implications of using two different nacelle anemometers that are known to be influenced by both icing and turbine performance.
The resulting differences between these power curves, is used to evaluate the value of the anti-icing system. A long term corrected value of the reduced production losses is calculated to give a value on the expected long term benefit of such a system.
[1] Ø. Byrkjedal, "Mapping of icing in Sweden – on the influence from icing on wind energy," in Winterwind 2012, Skellefteå, Sweden, 2012.
[2] G. Ronsten, "O2's wind pilot project – Large-scale cost-effective wind energy development," in Winterwind 2012, Skellefteå, Sweden, 2012.

Web site: http://vindteknikk.no/

Short biography: Martin Grønsleth holds a PhD in theoretical physics from The Norwegian University of Science and Technology (NTNU) in Trondheim, Norway.
He is working as an adviser at Kjeller Vindteknikk (KVT) and is involved in research projects, wind farm modeling and optimization, data analysis and software development. He has been in charge of several installations and operation of LIDAR campaigns carried out by KVT.

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

Cold Climate testcenter in Sweden

Stefan Ivarsson, RISE (Research Institutes of Sweden)

Stefan Ivarsson

Cold climate areas are providing huge potential for wind power all around the globe. But chill and ice demand a great deal on technology and require optimal testing conditions. Therefore we will offer…
Cold Climate Test – A Hot Spot for Icy Wind Power
The Cold Climate Test Centre will be a full scale test station in the northern part of Sweden. It will be focusing on test, validation and certification activities for the onshore wind industry.
Wind turbine and component manufacturers as well as academic partners will find…
-Excellent conditions for testing wind turbines, turbine components or sub systems in cold climate conditions.
-An opportunity to regularly perform tests based on the industry's constant technological development.
-An easily accessible test site – for engineers and technicians, as well as turbines and other components.
-Comfortable training opportunities for service personnel in cold climate conditions.
-Full test and validation service during the product development phase.
-Accurate wind measurements from precision instruments mounted on the test center's meteorological masts.
-All necessary permits for testing in place.
-A location calibrated and prepared for certification of cold climate editions of wind turbines.
-Tests following the current standards for low temperature wind power.

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

Short biography: Within the cold climate area Stefan Ivarsson has been involved in the planning of a Cold Climate Test Center in Sweden as well as chairmen of the Program Council for the national research program for Wind Power in Cold Climates within the Swedish Energy Agency. He is engaged as a Senior Project Manager within Renewables at RISE, Research Institutes of Sweden. He has in the past also been active as a Consultant and Senior Partner in Scandinavian Wind and Senior Product Manager for GE Offshore Wind. Stefan has been active in the energy industry for twenty years and the wind industry for ten years, where he during the last five years has focused mainly on research and development projects.

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

Ice Release and Erosion Resistant Materials for Turbine Blades

Wei Zhang, Ice Release Materials LLC/Polymer Exploration Group LLC

Alex Cook, Cameron Brinn

Icing conditions may cause wind turbine generators to partially lose productivity or to be completely shut down to avoid structural damages. The current commercially available technology to mitigate this problem is by using heating elements, which costs roughly $80,000 per medium size turbine. Conventional passive ice protection coating systems heavily rely on delicate surface structures and expensive materials to create water repellent superhydrophobic / low surface energy surfaces, which have been proven ineffective against ice accumulation. One reason is because ICE is different from WATER. Another reason is that many superhydrophobic materials are often reliant upon micro-structured surfaces to achieve their intended effects. This paper discusses a fundamentally different approach to the creation of a robust, low cost, durable, and multifunctional materials for ice release and erosion resistance. This National Science Foundation sponsored ice-release coating technology holds promise for protecting wind turbine blades and towers, thus potentially increasing reliability for power generation under icing conditions.

Erosion is a major wear and damage to the blades that reduces the life span, reduces production due to the change in the airfoil and aerodynamics, and increases cost to wind farm owners. Because the new ice release materials developed under this approach takes consideration of mechanical properties of the coating and also because the newly developed materials shared some common features with the conventional blade protection tape products, it is a dual function blade protection product for wind turbines. Due to the vulnerability of wind turbine blades to ice buildup and erosion damages, wind farm facilities stand to benefit from this new technology.

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

Short biography: Dr. Zhang has been conducting research and working in the materials and coatings industry for more than 20 years. His expertise is in surface science, polymer processing, nanocomposites, green technology, coatings and films, and polymer recycling. He is currently the President and Chief Technology Officer of his technology startup company PEG LLC. His recent research experience at Virginia Commonwealth University is on functional surface sciences. While working at VCU, he developed a new adhesion model that emphasizes not just surface energy, but also the mechanical and geometrical properties of a surface coating. The surface modification method he used is to incorporate minimum amount of functional surface modifier into to an engineering polymer. It takes advantage of the low cost and good mechanical properties of the engineering polymer. His company is now past the research stage and is launching a new product for the wind industry for the protection of wind turbine blades against erosion and ice.

R&D areas/s: 02. De-/anti-icing including ice detection & control

Ice detector research results from wind turbine field tests and from icing wind tunnel tests

Tatu Muukkonen, Labkotec Oy, FI

Jarkko Latonen (Labkotec, FI)

Labkotec presents ice detector research results from wind turbine field tests and from icing wind tunnel tests. Wind turbine results are needed for finalizing the development of blade-mounted ice detector. Icing wind tunnel results are mainly related to VTT Pre-Certification for updated nacelle-mounted sensor LID-3300IP Type 2. Behavior of ice detectors and accumulation of ice on wind turbine blades have been studied in different types of icing conditions (freezing rain, moderate/light in-cloud icing and harsh in-cloud icing) during field tests and wind tunnel tests as well as simulations.
Labkotec is currently finalizing the development of new generation blade-mounted ice detectors. The very first blade-mounted ice detector prototype by Labko was installed to a wind turbine blade in 1994. The ice detector was integrated to the turbine to optimize blade heating and to minimize ice accumulation on the blades. The knowledge from those days has guided the recent development for new generation blade-mounted ice detectors.
Development focus of nacelle-mounted ice detector LID-3300IP Type 2 has been on functional safety aspects. Functional safety analysis has been carried out according to the standard ISO 13849-1. Comparing to the current product, LID-3300IP, functional safety classification of LID-3300IP Type 2 has been further improved from PL b to PL d. This was possible because of updated design, including separate safety processor and improved diagnostics and because this technology has shown millions of hours of operating time without critical faults.

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

Short biography: Working on ice detection R&D and customer related applications for about six years as Project Manager and about three years as Product Manager.
Having three teenage boys keep me busy back home

R&D areas/s: 02. De-/anti-icing including ice detection & control, 07. Laboratory and full scale testing, test centers, small wind turbines, 13. National strategies, research programs, grid access and new developments

Evaluation of Anti-Icing behaviour in terms of EIROS-project

Björn Speckmann, Fraunhofer IFAM, Germany

Nadine Rehfeld (Fraunhofer IFAM, Germany), Marta Alvarez (TWI, GB)

Winterwind
INTERNATIONAL WIND ENERGY CONFERECE
ABSTRACT
Björn Speckmann
EIROS – Erosion and Ice Resistant cOmosite for Severe operating conditions
The EIROS project will develop self-renewing, self-healing, erosion resistant and anti-icing composite materials for use in extreme environments (high erosion and very low temperature). Potential end user applications are numerous and the initial focus will be on wind turbine blades, aircraft and rotorcraft leading edges, automotive components and cryogenic storage tanks for space applications.
The enabling technology will be engineered multiple-functionalised nanoparticles added to the bulk resin of fibre-reinforced composites. These nanoparticles will be engineered to give a tougher more durable resin but without the associated increase in brittleness prevalent in the current state-of-the-art; thus increasing the damage resistance of the material. Additionally, at the surface, the nanoparticles will have functional groups that produce a wear resistant and hydrophobic surface.
Icing Wind Tunnel of Fraunhofer IFAM
As a participant of the EIROS-project, the Fraunhofer IFAM will use an icing wind tunnel to evaluate the anti-ice effect of the developed composite materials. The icing wind tunnel of Fraunhofer IFAM shows a broad compliance to relevant test standards (e.g. Society of Automotive Engineers (SAE) Aerospace Recommended Practice). Wind tunnel temperatures down to -30 °C and wind speed of up to 350km/h can be realized. Defined water injection system produces water spray in the test section for realistic and reproducible ice scenarios. Furthermore, this test facility can be used as ice lab (minus 30°C) for comprehensive ice-related tests, including reliability tests for technical components under icing conditions and ice adhesion tests for evaluation of icephobic materials.
The presentation includes detailed information about the EIROS-project, examples of the characterization process of the icing wind tunnel and detailed information about several tests, which have been carried out in the past. For example material performance tests, ice formation processes in combination with active heating devices and subsequent run-back ice formation on unheated areas of mock-ups are presented.

Web site:
https://www.ifam.fraunhofer.de/en/Profile/Locations/Bremen/Shaping_Functional_Materials/Energy_Systems_Analysis.html

Short biography: Björn Speckmann is a graduate of the Bremen University of Applied Sciences and earned his master's degree in engineering. During his studies he focused on thermodynamics and renewable energy systems. He started at the Fraunhofer Institute IFAM in April 2015 and in March 2016 moved into his current position as the engineer responsible for the ice laboratory and icing wind tunnel.

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

Lessons learned from ice ablation tests in icing wind tunnel

Raul Prieto, VTT Technical Research Centre of Finland

Raul Prieto (VTT, FI), Simo Rissanen (VTT, FI), Mikko Tiihonen (VTT, FI), Ville Lehtomäki (VTT, FI)

Ice ablation as defined by IEA Task 19 is the removal of ice by a combination of melting, sublimation, erosion, radiation, and ice shedding. Ice ablation is relevant to a wide range of technical challenges, notably wind turbine operation in cold climate, where the ice mass accreting on the wind turbine blades affects the extreme and fatigue loads, energy losses and ice throw risk.
The ice accretion - ablation models are also relevant to overhead power line icing, helping to connect climate models with icing loads and to better define the extreme design cases.
In this presentation, VTT summarizes the key findings of a first test campaign on ice ablation conducted in Aug/2017 in VTT's Icing Wind Tunnel. Three tests were performed with different external conditions to find out effect of wind speed, temperature and ice properties to ablation speed. A standard 30mm diameter steel cylinder was used in all cases. First sample ice was collected on cylinder in wind tunnel and then iced cylinder was exposed to controlled air flow which gradually sublimated and eroded the ice on the cylinder. The cylinder was weighted, and the ice shape characterized using a 3D laser scanner before and after the test to determine the mass of ice sublimated.
The ablated ice mass from the tests has been compared with the prediction from VTT ice ablation model, obtaining a significant departure between observations and the model. Analysis shows that the radiation plays a significant role in the selected test configuration, and that further testing is required to separate the individual contributions of the different ablation mechanisms.

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

Short biography: Raul joined VTT in 2017 as senior scientist - wind power. He has held several positions in wind turbine manufacturers (Gamesa, Winwind) and research organisations (Cener, ORE-Catapult), focusing on product development and research related to wind turbine blades. He has worked in

- Aerodynamics modelling applied to wind industry: design of blade aerodynamics, power curve, noise modelling, development of wind turbine airfoils.
- Wind turbine functional engineering, integration of Loads Aerodynamics and Control (LAC).
- Wind blade certification (Win 59 blade for the Winwind 3MW turbine)
- Development of blade ice prevention systems

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

Local effects on icing for wind power in cold climate

Esbjörn Olsson, SMHI

Heiner Körnich (SMHI, SE), Anna Rutgersson (Uppsala University, SE), Stefan Söderberg (WeatherTech, SE)

SMHI, together with Uppsala University and WeatherTech, has been awarded funds from the Swedish Energy Agency to start a new project that will address how local surface details affect atmospheric icing on wind turbines. The distribution of land use, the forest characteristics, and its snow cover, influences vertical heat, momentum and moisture fluxes, thus affecting the intensity and height distribution of atmospheric icing. These effects will be studied by developing a state-of-the-art modelling chain of numerical weather prediction, ice accretion and related loss of wind power production and by comparison with local observations of meteorological parameters and production losses. The local effects will then be implemented into a probabilistic forecasting system allowing for the operational assessment of icing risks. The overall goals of the project are a better understanding of these local effects on atmospheric icing, the improvement of the probabilistic prediction system and its increased usage for wind power in cold climate. The project will last for 3 years, 2018-2020, and a PhD student will be recruited by Uppsala University. Current forecasting systems are generally overconfident and underestimate the forecast uncertainty. By improving the representation of surface processes, the meteorological forecasts can be optimized for wind power in cold climate. In the project, we will address the benefit that small- and medium-sized enterprises can have by using the open data of national meteorological services. It has been found that current probabilistic forecasting systems improves the forecast of wind power in cold climate but they are under-dispersive both for the meteorological parameters and for the production loss. New methods to correct this behaviour have been developed in the meteorological community by perturbing surface moisture, surface temperature and vegetation. However, a focus on cold climate conditions and for wind power application is lacking. In this project, these deficiencies will be addressed by developing the model description of the surface characteristics. Results from sensitivity experiments will be compared to meteorological and wind power observations allowing to optimize the entire modelling chain. The project will lead to better knowledge how surface characteristics affect wind power in cold climate and how they can be represented in a forecasting modelling chain.

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

Short biography: Esbjörn Olsson is working at SMHI:s research department within the group the develops the operational forecast models. He has been involved in developing forecast methods for atmospheric icing for more than 20 years, utilizing output from numerical weather prediction models. At first this work was focused on aircraft icing but during the last 10 years the main interest has been on icing problems for wind power. He has a background as an operational aviation forecaster, both at SMHI and in the Swedish Air Force.

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

Towards the improvement of icing forecasts using the AROME/HIRLAM model

Gregory Thompson, NCAR

Gregory Thompson, Bjorg Jenny Engdahl, Harold McInnes, Lisa Bengtsson

Past research has shown that the AROME/HIRLAM model produces relatively less supercooled liquid water (icing) than the WRF model, although both are still somewhat insufficient as compared to most observational data. New efforts are underway using model inter-comparisons and translation of key WRF cloud physics aspects to improve the cloud physics in the current AROME model. Preliminary results involving small changes to aspects of the cloud physics scheme in various sensitivity experiments appear promising toward producing more supercooled liquid water. Results of these sensitivity experiments will be presented at the conference along with ideas for future work.

Web site: http://ucar.edu/

Short biography: Please include the biography from last year ;)

R&D areas/s: 13. National strategies, research programs, grid access and new developments

Don't look back in anger – a retrospective look on wind energy in cold climate

René Cattin, Meteotest

René Cattin, Meteotest, CH

From a year to year perspective, one might get the impression that there is not too much technological and scientific progress in wind energy in cold climate. In reality, there was a massive and impressive positive development during the past years. While cold climate was a niche market for a long time, it has become by today one of the fastest growing markets in wind energy. This presentation thus aims at giving an inspiring and motivating retrospective look at some of the stages which made such a rapid development possible.
The presentation will take a look at the cold climate scene in the beginning of this millennium. It will remember some of the protagonists of this period, pick up their visions and show how these have become reality by today. It will highlight some of the major milestones which allowed unlocking and boosting the potential of wind energy in cold climate. These milestones will be specific technological and scientific innovations, R&D projects, market studies, guidelines and standardisation work. The presentation will at the same time also take a look at some of the difficulties and wrong directions that were taken on that journey. There will be a comparison of today's availability of technological solutions for wind energy in cold climate with the situation 15 years ago. Finally, it will give a personal view on the most relevant obstacles which need to be tackled in the near future in order to be able to keep or even increase the pace. The whole journey will be presented in an informative and also entertaining way including some anecdotes, quotes and pictures.

Web site: https://www.meteotest.ch

Short biography: René Cattin holds a master degree in Geography. He works for Meteotest since more than 15 years. Today, he is managing director of Meteotest and head of the air & climate department. René Cattin is active in icing and wind energy since roughly 15 years. He was the Swiss member of IEA Task 19 between 2009 and 2016, the project manager of the "Alpine Test Site Gütsch" under the umbrella of COST Action 727 as well as of the projects at the test site St. Brais and was involved in a lot of other national and international projects in this field. Up to now, he participated in all international editions of Winterwind since 2008. Outside the office, he is a proud father of three kids and very interested in rock music.