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ÅRE · MARCH 27–29, 2023

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R&D areas/s: B) Technology

Chemical coating solutions for turbine blade icing

Don Browning, Phazebreak, US

Don Browning (Phazebreak Coatings, USA)

The industry standard solution to ice build-up on wind turbine blades is focused on ice removal - heated blades, helicopter-aided spray removal, and risky uptower maintenance operations. Phazebreak believes the best way forward is to change the conversation from removal to prevention.
For this reason, Phazebreak has developed NEINICE icephobic coating for use on wind turbine blades as well as common leading edge protection (LEP) systems. Used in the field since 2018, the patented NEINICE formula has been deployed on over 6,000 blades around the world. NEINICE's phase change material (PCM) formula helps to improve turbine energy output during winter storms and reduces recovery time following such events, while also diminishing the risk of severe ice throw.
This presentation focuses on successes we've seen in helping owners and operators improve turbine performance: By reducing ice build-up before removal is necessary, NEINICE also helps lower maintenance costs, protect blade integrity, promote worker safety, and ensure that profitability remains high for owners and operators.
To this end we will present data on the following:
Turbine output data comparing the performance in MWh of coated vs uncoated turbines. (including a case study illustrating actual revenue increase)
Robotic application procedures and efficacy
Road maps for future innovations in icephobic coating technology

Web site: phazebreak.com

Short biography: With 15 years of experience in wind energy and aviation, Don Browning brings know-how and confidence to his role as Vice President of Operations at Phazebreak. A graduate of University of California, Don has helped lead Phazebreak Coatings in its rapid growth during its early years. Between networking with customers, organizing field crews, or attending wind energy tradeshows, he still makes time for his favorite things: family, cigars, and, as he puts it, "Golf is a good hobby."

R&D areas/s: B) Technology

Mythbusters: wind energy in cold climate edition

Patrice Roberge, Université Laval, CA

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

The private nature of wind energy production in many countries slowed down the advancement of knowledge since little field data is shared. Thus, researchers and operators often have to rely on old or incomplete studies to lead their decisions. In this presentation, two unsettled topics are investigated by finding their origin and then, by testing their premises with field data.
In the past years, multiple studies evaluating icing losses have been conducted with different temperature thresholds (0°C, 1°C, 3°C or even 5°C) under which icing can be observed. One of these studies has found that the choice of this threshold may have a significant impact on the final icing losses estimation. One of the first occurrences with a threshold different from 0°C came from a study where a bias was observed between the measured ambient temperature by the turbine sensors and the actual temperature. Using a combination of meteorological field data, camera images and turbine data, this topic was investigated.
In multiple reports, it is stated that ice detection on the nacelle is not suitable since the blades may experience icing conditions while the nacelle is ice-free. This statement originated from a 2003 study made using relative humidity and temperature measurements made on a meteorological mast. The technology has greatly improved since then, and this method is no longer considered accurate. To revisit this statement, the timing of icing events inferred from turbine data was compared to detections made by nacelle-based ice sensors.
Those two topics were investigated using field data coming from 4 different wind farms, with turbines from different manufacturers, in environments prone to heavy icing. Using this large data set, a new temperature threshold more representative of reality is proposed. Furthermore, it was observed that a nacelle-based ice sensor was able to match the start of 71 of the 74 icing events inferred by turbine performance. The remaining events had minor production losses and could not be linked to the incapacity of ice sensors to detect ice from the nacelle.

Web site:

Short biography: Patrice is currently doing his Ph.D. in mechanical engineering at Université Laval in André Bégin-Drolet's lab. He has been working on the operation of wind turbines in cold climates for over 6 years where he had the chance to contribute in the development of an ice detection device. He has authored and co-authored eleven scientific publications. He completed his bachelor's degree in engineering physics. He also completed a master's degree in mechanical engineering. He is a very inquisitive person that loves to learn and understand the why and the how of the everyday phenomena. He is passionate about skiing, snowshoeing, and trekking.

R&D areas/s: B) Technology

Modelling ice accretion on a cylinder, simple? Right?

André Bégin-Drolet, Université Laval, CA

Daryl Plante Montminy (UL, Can), Patrice Roberge (UL, Can), Jean Lemay (UL, Can), Jean Ruel (UL, Can)

Countless studies have been published recently on modelling ice accretion on a reference cylinder or on blade profiles. However very few of them actually validated their results with field data. This problem originates from the low availability of complete meteorological outlooks in actual icing environments. These kinds of environments offer conditions that are different from wind tunnel testing due to the unsteadiness of parameters (i.e. wind speed, wind orientation and temperature).
This study presents results obtained from the LEWICE ice accretion software using high-resolution meteorological data. The field data was retrieved on a wind turbine nacelle using the Meteorological Conditions Monitoring Station (MCMS). On the same nacelle, ice accretion on a reference cylinder is monitored using a camera. It was observed that the frequency at which the meteorological data was updated in the model had a significant impact on the final ice shape in part due to the time variation of the wind orientation. Some limitations were observed with the ice accretion software for high angles of attack. Some typical ice accretion examples will be provided and presented as well for eastern Canada typical ice conditions.

Web site: www.gmc.ulaval.ca

Short biography: André Bégin-Drolet is a full professor of mechanical engineering at Université Laval in Canada and CEO of Instrumentation Icetek, a spinoff company launched in November 2020 that commercialize the ice sensor he and his team have developed at Université Laval. His research, in the wind energy sector, focuses toward improving wind power production in cold climate where atmospheric icing is prevalent. His research led him to the design of a patented smart sensor, the Meteorological Conditions Monitoring Station (MCMS), adapted to measure meteorological conditions in cold and icy environment. He is very interested in developing methods to improve the production of wind energy in cold climates and have done so with many industrial partners. Wind is also part of his hobbies as he is an active racing sailor who loves to perform in both inshore and offshore regattas.

R&D areas/s: B) Technology

ESS – Energy Storage Systems in cold climates

Christoffer Carlsson, INKOM, Industrikomponenter AB, SE

CTO Jimmy Henningsson, (PowerTech Sweden, AB), CAE Martin Zierer (Schaltbau, GmbH)

INKOM, Industrikomponenter AB, has been a supplier of electro-mechanical products since 1967, with a significant focus on safe DC (Direct Current) for the power industry. With the changing market towards more significant fluctuations in the electrical grid, the demand for ESS (Energy Storage Systems) has increased. We at INKOM deliver plug-and-play finished battery containers for FCR, peak shaving and arbitrage for unique and highly demanding systems in cold climates.

Web site: https://inkom.se/e-container-en-stor-succe/

Short biography: Application Engineer at INKOM for Energy Storage Systems with M.Sc. from Chalmers university of technology. Responsible for solutions to industrial production lines, DC charging stations, electric utility companies and marine applications etc. My personal interest is green energy systems.

R&D areas/s: E) Operation, maintenance and forecasting

Innovative technology to increase efficiency and extend the lifetime of gears and bearings

Stefan Bill, REWITEC GmbH, DE

Claire Ward (Cargill), Pourya Parsaeian, Vanessa Bill (REWITEC GmbH)

1. Introduction

The size and requirements of wind turbines are constantly increasing. Therefore, it is even more important that maintenance of each mechanical system is carried out regularly, which is essential to avoid and reduce failures. However, while some maintenance can be routine, unscheduled maintenance of key components like gears and bearings can have significant cost implications in terms of operating downtime and expensive component repairs and replacements.1 This paper presents an innovative, microparticle-based phyllosilicate technology for use in lubricants to tackle wear related damage which is a known cause of wind turbine bearing and gearbox failures. Whereby the focus is on the impact of the technology on increasing the efficiency of a wind turbine based on an actual field test.

2. Laboratory Investigations

In this study, a 2-disk test rig was used to simulate the tribological system in gears, and precisely monitor the friction and sub-surface disk temperature during the experiments. The figure we want to show here is the 2-disk friction results in an ISO VG 320 industrial wind turbine gear oil. After a preliminary running-in phase to create a worn disk surface, 0.2 % of the phyllosilicate-additive was added after ~20 hours and a friction force reduction of 20 N (32 %) was achieved.

The tribological performance of the phyllosilicate technology was also investigated in industrial grease formulations. The next figure would show a results from the SRV grease rolling friction draft test method (ASTM WK71194) on a NLGI 1 special lithium soap based-grease specifically designed for rolling bearings in wind turbines. Here, addition of 2 % phyllosilicate gave an average of 94 % reduction in coefficient of friction at 2000 N load.

3. Summary

A series of laboratory tests which highlight the impact of the phyllosilicate technology on repairing existing surface damage and helping to extending the lifetime of the mechanical components by reducing friction, temperature and surface roughness will be discussed in this investigation. A field trial case study also shows this surface repair performance in a wind turbine bearing grease. Furthermore, our current field results from our efficiency project will be available at the beginning of the new year, which are promising. Finally, to support the laboratory and field trials, a Computational Life Prediction (CLP) study was completed, modelling the impact of the phyllosilicate on the lifetime calculation of a wind turbine main-shaft bearing.

4. References

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3. A. Schneider, Rolling greases test adapter offers new testing opportunities, Lubes`n`Greases EMEA, April 2018, p. 32-39

Web site: www.rewitec.com

Short biography: Stefan Bill is Managing Director of REWITEC GmbH and also Global Business Director at Cargill Bioindustrial. He developed the REWITEC technology, applied for the relevant international patents in 2012 and has been in the lubricant and additive business for 18 years. Stefan studied electrical engineering with a focus on electrical drives and has already held various management positions at drive technology companies such as ABB and others.

R&D areas/s: B) Technology, C) Development and financing

Power Curve Tests in Cold Climates on Complex Terrain

Katie Gracie-Orr, Wood Renewables, UK

Katie Gracie-Orr, Florin Pintilie, Alice GowardBrown, Shaji Mathew, Andrew Martin, Iain Nisbet

Power curve testing (PCT) is of importance in gaining a deeper understanding of the power performance of a wind farm. Presently, under the terms of turbine supply agreements (TSA), a PCT process compliant with IEC Standard 61400-12-1 is the most common method of verifying whether assets are performing to the warranty.
PCTs undertaken in cold climates on complex terrain are challenging. This is due to numerous factors, such as icing events limiting data recovery under the practicalities of Project budgets, short daylight hours and strong winds in Nordic autumn to spring reducing time available for site work, challenges of placing guyed masts on exposed rock on the Nordic coast, and un-optimised contractual filters removing significant percentages of measured data. We will discuss some of the challenges faced and present our successful methods and learning points drawn from practical experience undertaking PCTs in these conditions.
Our experience indicates that an early start to incorporating a PCT campaign into the Project plan, and ensuring the power curve warranty is suitably site-specific, have the benefits of facilitating: an optimised flow of discussion between site developer and wind turbine manufacturer regarding the power curve offered; effective control of scheduling site calibration into the demanding construction schedule associated with northern climates; retention of site-relevant percentages of data during measurement campaigns; a warranted power curve, and its verification, which best represents expected performance at site. With respect to pre-construction energy yield assessment, these factors contribute towards an associated higher confidence in power performance, hence the central (P50) energy yield estimate, and a reduced level of uncertainty that influences probability of exceedance estimates (e.g. P75/P90) commonly used in financing.

Web site: https://www.woodplc.com/solutions/ensuring-energy-security/renewable-energy,-future-fuels-and-low-carbon-solutions

Short biography: Katie specialises in power performance testing of renewable energy turbines, and joined the Analysis team at Wood after studying at Strathclyde University for honours and PhD degrees in Mechanical Engineering. Her doctoral research, undertaken within the SuperGen doctoral training programme, focussed on the overspeed power regulation method for horizontal axis tidal turbines with a view to increasing industry understanding of associated benefits and constraints, developing a blade design methodology for use in this power regulation method. This experience feeds directly into Katie's role at Wood, where she has involvement throughout the power curve testing (PCT) process for wind turbines, including independent review of power curve warranty documentation, terrain and forestry complexity assessments, and meteorological mast and power measurement data analysis, under the various stages of IEC Standard 61400-12-1 compliant PCTs for wind turbines. She has worked on projects located from the USA to Pakistan, with a strong focus with our Nordic client base. Katie also has practical on-site experience micro-siting mast and anchor points and installing power measurement equipment in turbine nacelles. Her work includes the use and manipulation of various GIS data sources (contour, grid, lidar elevation data), analysis of meteorological measurement, SCADA and independent power measurement data, and of the associated uncertainties.
Katie sits on the British Standards Institute PEL/114 for Marine Energy, and the IEC Management Team responsible for the development of IEC/TS 62600-200, outlining the industry specifications for best practice in PCT for tidal energy converters, leading the team working on uncertainty estimation.
Outside of work, Katie loves taking her son into the wilds to pick berries and splash in lochs, and taking chances to get out into the hills or for a dook (as we say in Scotland) in any body of water deep enough to contain a human being.

R&D areas/s: B) Technology

On the performance of ice detection methods used in wind energy: a long-term field study

Charles Godreau, Nergica, CA

Claudia Hodonou (Nergica, CA), David Durette (Nergica, CA)

With good wind resources and high air density being favorable for wind turbine power production, wind farms are developing in cold climate regions. In this environment, severe ice formation can significantly reduce the annual energy production. To face this challenge, sensors and methods to monitor ice formation on wind turbines have been proposed and qualitatively compared.
Few long-term quantitative comparisons have been published in order to identify reliable ice detection techniques for wind turbines in cold climate. In this presentation, a long-term quantitative comparison of icing sensors and methods is described for instrumental, meteorological and rotor icing.
The analysis of the data allowed to review the International Energy Agency ice classes proposed by the Technical Collaboration Program on wind power in cold climate (IEA Wind TCP Task 54) to classify icing severity on wind farms. This article also presents a site classification based on rotor icing duration, to complete the current site classification based on meteorological and instrumental icing only. Future research and development questions are also raised to further improve ice detection techniques used in the wind energy industry.

Web site: https://www.linkedin.com/in/charles-godreau/

Short biography: Charles Godreau specializes in wind turbine performance assessments in cold climates and
icing detection/protection systems. He possesses strong skills in data analysis for operational turbines as well as for developing, planning and implementing research projects. He notably represents Canada in the International Energy Agency’s Task 54 working group on wind energy in cold climates and is an active member of Winterwind's program committee. In his free time Charles enjoys improv and backcountry skiing.

R&D areas/s: B) Technology

The Next Generation Ice Detection System – Control System Integrated Software Solution for Substantial Cost Optimization

Carsten Ebert, Wölfel Wind Systems, DE

Dr. Carsten Ebert, Wölfel Wind Systems, DE
Dr. Frank Bunge, Enercon, DE
Marc Reitmaier, Phoenix Contact, DE
Dr. Bastian Ritter, Wölfel Wind Systems, DE

Title
The Next Generation Ice Detection System – Control System Integrated Software Solution for Substantial Cost Optimization

Abstract
This talk presents the completely novel approach to integrate the proven and well established ice detection functionality of Wölfel as a software solution directly into turbine controller environment. This requires only a performant industrial PC based on the PLCnext technology which is used for the main control application.
Vibration-based ice detection systems are well-known for its robust and reliable performance in the field which allow for early restart after icing events. The state of the art are stand-alone hardware systems which are separately installed on turbines as additional systems and then connected via a communication interface to the WTG controller. In order to bring down the costs for these systems substantially, there is only one way namely to remove hardware components from the product which are practically redundant in functionality.
In cooperation with ENERCON and Phoenix Contact this step was realized for the ENERCON Next Generation Control System (NGCS) development. With this integration step, the data acquisition and processing is done on the turbine controller which reduces the additional hardware to a minimum. Only sensors and cables have to be installed. As a result the costs for an ice detection system are substantially lowered.
In addition also well established damage detection methodologies are directly available and can be activated by a license key only.

Web site:

Short biography: Carsten Ebert is civil engineer (Dr.-Ing.) and 46 years old. He has been working for Wölfel Wind Systems since 2008 and is CTO of the company. He has an extensive knowledge in structural dynamics, especially in the field of structural health monitoring based on vibration measurements. At Wölfel, he is mainly responsible for the products and services for the structural monitoring of rotor blades, towers and foundations. In addition, he is a member of various working groups for the preparation of guidelines and standards and was in this role involved in the preparation of VDI-Guideline 4551, a German guideline for the condition monitoring of offshore wind foundation structures.

R&D areas/s: B) Technology, E) Operation, maintenance and forecasting

Can we make better use of ice protection systems?

Franziska Gerber, Meteotest, AG

Paul Froidevaux (Meteotest AG, CH)

Ice protection systems (IPSs), play a central role in protecting wind turbines against icing. However, IPSs have limited effectiveness and cannot prevent blade icing under all external conditions. Thus, in Central Europe and Scandinavia, it is quite common for wind turbines equipped with IPSs to lose several percent of their annual production due to icing. Many state-of-the-art IPSs are still controlled in a very trivial way – i.e. using a fixed heating duration, a fixed heating power and a predefined icing criterion. Hence, there is a hidden potential by optimizing the control of the heating system by relaxing the constraints taking into account real-time turbine parameters and future atmospheric conditions.

Within the research projects "Smart Operation of Wind Power Plants in Cold Climate" (SOPWICO) and "Smart Operation of Wind Turbines under Icing Conditions" (SOWINDIC), we aim at optimizing IPS control to reduce production losses without impacting safety. We consider wind turbines of four wind parks in Scandinavia and Central Europe, from different OEM's, equipped with different heating systems, and with different types of constraints on operation from authorities. To optimize the turbine control based on the current and upcoming atmospheric conditions, it is important to understand the efficiency of the heating system under different atmospheric conditions. Therefore, parameterizing the efficiency of a heating event based on the current atmospheric conditions and blade icing is crucial.

Here, we will elaborate on the potential and challenges to achieve an optimized IPS control, ranging from parametrizing the efficiency of particular heating events, to the development of a smart algorithm calculating production scenarios for the days ahead and accounting for different heating strategies. Therefore, we will discuss the performance of current IPSs in their standard configurations, as well as the challenges related to the development of an optimized IPS control. Finally, we will present a first attempt to take into account these constraints in a smart algorithm for optimized IPS control of wind turbines by calculating different scenarios of production for the days ahead.

Web site:

Short biography: Franziska Gerber was always interested in snow and ice, which was part of her work throughout the years. Snow distributions and small-scale wind fields in complex terrain were the topic of her PhD at EPFL Lausanne and the WSL Institute for Snow and Avalanche Research SLF (Davos). She continued her work at SLF Davos on blowing snow over Antarctica as a PostDoc. In April 2021 she joined the wind and ice team at Meteotest AG, where she extended her horizon to icing of wind turbines. When not at work she can be found on skis in winter, hiking or cycling in summer or chasing shuttles on the badminton court throughout the year.

R&D areas/s: B) Technology

NICE - Reduction of ice formation by nanostructuring of surfaces with an ultrashort pulse laser

Claas Rittinghaus, Energiewerkstatt, AT

Martin Hoeher (Energiewerkstatt, AT), Dr. Alexander Stoekl (Energiewerkstatt, AT)

According to the current report of Task 19 of the IEA Wind TCP, more than 130 GW of wind energy have already been installed internationally at locations with icing conditions and an annual increase of 12 GW is expected. In Austria, practically all wind turbines installed so far are at least affected by moderate icing conditions, posing a considerable challenge to both the project development and the operation of wind turbines.
The three main aspects are:

- Risk to life and limb caused by ice throw or fall
- Decreased yield due to deterioration of aerodynamic properties
- Imbalances causing increased mechanical stress

In a number of countries, such as Austria, as soon as icing is detected on a wind turbine, the turbine is shut down and stays out of operation until the ice melts or is actively removed. The state of the art in de-icing wind turbine is heating the rotor with hot air or with electrical resistance heating on the rotor blade surface. These measures are costly and are only effective for a limited range of meteorological conditions (temperature, wind speed, liquid water content etc.). Preliminary investigations have shown that hydrophobic surfaces can hinder icing or reduce the duration of icing. Hydrophobic surfaces on rotor blades of wind turbines could thus potentially by a method to reduce ice buildup or to improve the efficiency of de-icing methods.
Within the scope of the NICE project, an ultrashort pulse laser was used to generate sub-μm nanostructures in various formation, periodicity and composition on test sample surfaces, which proved to be highly hydrophobic and potentially ice-phobic. The effects of different structuring on the wetting behavior of water droplets on different sample materials were analyzed with a contact angle measuring device. In addition, a pre-existing simulation model of the wetting behavior of surfaces was extended into the sub-μm range to enable the identification of optimal structures, reduce the number of experiments and improve the general understanding of the physical processes. The ice adherence properties of the nanostructured samples were then investigated under laboratory conditions.
The most promising laser-processed samples and unprocessed reference samples were then tested under harsh weather conditions in different field tests. The samples were continuously monitored together with corresponding meteorological data and the ice formation on the sample surface was quantitatively measured in the range of "0" for no icing to "6" for maximum icing. This allowed statements about the degree of ice formation and the duration of icing under conditions near practical use. The investigation of surface profiles and the hydrophobic behavior before and after exposure allowed statements about changing properties and the lifetime of the nanostructures.
The results of the field tests in conjunction with the laboratory tests and simulations have shown differences in ice formation and duration as a function of the structure formation, periodicity and composition, but not in a significant extent as to allow formulating a clear dependence or advising on ice-phobic surface treatment in general. More research is necessary to clarify the relation between (super-)hydrophobic surface properties and characteristics of ice accretion and ablation processes.

Web site:

Short biography: Claas Rittinghaus earned his diploma in physics at the University of Bielefeld, Germany. After 10 years of working as a product manager for Phoenix Contact in Blomberg, Germany, he joined the Energiewerkstatt in Friedburg, Austria, in 2021 as a project manager in research and consultancy services. As Austrian participant of IEA Wind TCP Task 54 specifically icing topics are in his focus.
He is a mountain enthusiast, in summer as in winter, and enjoys hiking, climbing, bouldering, downhill skiing and ski touring. Another passion of his is music, especially playing the guitar and singing.

R&D areas/s: B) Technology

Proof of concept of using an existing foundation structural health monitoring system to detect icing

Wout Weijtjens, Vrije Universiteit Brussel, BE

Mustapha Chaar (VUB, BE), Pieter-Jan Jordaens (Sirris, BE), Christof Devriendt (VUB,BE), Wout Weijtjens (VUB, BE)

Structural health monitoring (SHM) systems are used to monitor overall structural properties of both onshore and offshore wind turbines. They offer the possibility to monitor the fatigue life consumption and the resonance frequencies of the substructures over time. Especially in offshore wind these systems have found wider adoption as design uncertainties motivate monitoring.
One of the objectives of any SHM system is to continuously track the resonance frequencies of the substructure, primarily to detect sudden variations in the boundary condition. However, results from several sites equipped with a SHM system revealed that the resonance frequencies of the rotor can also be observed from a SHM system installed on the tower. These resonance frequencies of the rotor are known to be sensitive to the development of icing. So the research question rose whether the observation of the rotor resonance frequencies from the tower is of sufficient accuracy to reliably detect icing.
In this contribution we will discuss the double use of a vibration-based structural health monitoring system to detect icing occurring on the blades of an onshore wind turbine. The vibration monitoring system was designed to be installed by the operator in the tower in less than 30 minutes. As the hardware costs are brought down by widespread use in offshore wind and the hardware serves multiple purposes aside of icing detection, the cost of the ice-detection solution itself is brought back to a minimum. For the system to correctly function also the SCADA data, in particular the rotor speed of the turbine, has to be collected.
To proof the concept an onshore Enercon 2MW turbine was equipped with a portable structural health monitoring device, installed at about two thirds of the tower's total height. The site was selected as icing conditions are fairly common, by Belgian standards, and occur a few times every winter. Measurements were collected during the winter of 2020-2021. A methodology was developed to first estimate the resonance frequencies of the wind turbine. Secondly, the resonance frequencies of the rotor were tracked during operation and standstill. The results were in line with the past observations that these rotor modes can indeed be reliably monitored from the tower. Then a (simple) machine learning strategy was adopted to detect any anomalous variations in the tracked resonance frequencies over time. In particular sudden drops of the resonance frequency are sought for, as these indicate the occurrence of ice on the blade(s).
Results showed that the methodology alarmed during one icing event at the end of January. Icing was confirmed as the existing icing detection system of the turbine shut down operation. However, results confirm that the tower mounted solution picked up icing approximately 1 hour earlier and restarting the turbine could have happened sooner. A second weaker icing event was detected by the algorithm, however the turbine continued operation throughout this period. In absence of any additional icing detection system, or a video confirmation, it is still uncertain whether this event is a false positive of the tower mounted icing detection, or a valid detection of icing for which the turbine was not shut down. No other icing events were reported or detected by the algorithm.
This initial proof of concept showed the potential for the dual use of tower-based structural health monitoring solutions to be used to detect icing. While the methodology also has some disadvantages, including the need for a "training period", the low-cost, dual-use and ease to install might make it a suitable (complementary) strategy for icing detection.
This work was conducted in the frame of Collective R&D and knowledge transfer project: "Fighting Icing", led by Sirris. Research was done at the Vrije Universiteit Brussel in part as the Master Thesis of Mustapha Chaar.

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

Short biography: Wout Weijtjens (°1988) is a junior Professor at the Vrije Universiteit Brussel with an expertise in structural health monitoring, with a particular focus on (offshore) wind energy applications. As researcher he was involved in monitoring campaigns at all Belgian offshore wind farms and on various onshore wind farms, with a particular curiosity to quantify fatigue life consumption and sudden variations in resonance frequencies, e.g. as caused by icing.
Wout enjoys running, is an avid quizzer and tries to be a 'maker'.

R&D areas/s: B) Technology

Winterwind Workshop - "Performance envelopes of blade heating systems" - A Subtask of IEA Wind TCP Task 54 "Cold Climate Wind Power"

Claas Rittinghaus, Energiewerkstatt, AT

Daniela Roeper (Borealis, CA), Charles Godreau (Nergica, CA), André Begin-Drolet (Université Laval, CA), Paul Froidevaux (Meteotest, CH)

This abstract is a proposal for a workshop to be held on the first day of the conference.
In recent years, the broad implementation of Ice Protection Systems (IPS) has led to an increase of electricity generation from cold climate sites as well as the development of sites hitherto excluded due to their harsh climatic conditions. The assessment of the performance and the efficiency of these systems has so far been up to the manufacturers and hence, differs largely in terminology and methodology. Generally, the so-called performance envelopes of IPS are described as the conditions of wind speed and temperature for which an IPS efficiently removes or prevents blade ice. There is however no consensus on e.g. how to define or validate such envelopes, or whether additional atmospheric parameters should be accounted for.
The vast expansion of renewable energy generation, in particular wind power, in course of the Clean Energy Transition will require to develop even more cold climate sites in the coming years. For site assessment, operational control as well as estimating the annual electricity production, it thus becomes ever more important to assess the performance of a specific IPS to be implemented and to compare different systems to one another. A reference terminology and methodology for such assessments, accepted by the whole wind industry, is therefore key to the propagation of cold climate wind power.
The IEA Wind TCP Task 54 on cold climate wind power has designated a subtask to the development of such terminology and methodology. The subtask comprises participants from seven different countries (AT, CA, CH, DE, DK, FI, SE) coming from system manufacturers, consultants, research institutes and universities. The agenda of the subtask is based on the following work packages:

- WP1 – Terminology and definitions
- WP2 – Exemplary sets of icing events
- WP3 – Modelling of IPS performance
- WP4 – Recommendations on field validation of IPS performance
- WP5 – Collaboration with wind tunnel subtask
- WP6 – Dissemination

This workshop focuses on WP1, WP2 and WP4.
WP1
What constitutes the performance and efficiency of an IPS? What metrics should be used to measure and describe it? Discussion of terminology proposals and devising of mutually agreed definitions.
WP2
Presentation of examples for icing event data and discussion about useful metrics for representing and applying icing event data.
WP4
How to test and validate the performance and efficiency of an IPS in the field? What are necessary and suitable indicators? Discussion of measurement proposals and devising of effective and easy to implement procedures.

Web site:

Short biography: Claas Rittinghaus earned his diploma in physics at the University of Bielefeld, Germany. After 10 years of working as a product manager for Phoenix Contact in Blomberg, Germany, he joined the Energiewerkstatt in Friedburg, Austria, in 2021 as a project manager in research and consultancy services. As Austrian participant of IEA Wind TCP Task 54 specifically icing topics are in his focus. He is a mountain enthusiast, in summer as in winter, and enjoys hiking, climbing, bouldering, downhill skiing and ski touring. Another passion of his is music, especially playing the guitar and singing.

R&D areas/s: D) Construction

Sea ice conditions in the Baltic sea and impact for offshore wind farm foundations

Florian van der Stap, Wood Thilsted, DK

F. van der Stap (Wood Thilsted, DK), M. B. Nielsen (Wood Thilsted, DK), Cody C. Owen (TU Delft, NL), P. van der Male (TU Delft, NL), H. Hendrikse (TU Delft, NL)

As a result of the growing demand for renewable energy, the offshore wind industry has been moving towards sub-arctic areas such as the Baltic Sea, where sea ice is likely to occur. It is long known that the interaction between sea level ice and slender structures, such as monopiles, can lead to severe structural vibrations, due mainly to intermittent crushing and frequency lock-in. Since these ice-structure interactions can have a large, often detrimental, effect on monopile design, it is extremely valuable to quickly be able assess the magnitude of the potential ice loads and, by extension, the feasibility of monopiles in various regions of the Baltic Sea. The authors have sought to produce a means to undertake such feasibility analysis efficiently.

By evaluating air temperature datasets, sourced from regional meteorological institutes around the entire Baltic Sea basin, a high-level sea ice thickness map has been developed for the entire region. Similarly, data on the length of the ice season has been used to derive a map for the ice strength coefficient CR, as defined in the ISO19906. Ice ridge properties have been found based on previously determined relations between sea level ice and ice ridges. The exposure of the structure to sea ice, measured in number of ice interaction days, was calculated using the length of the ice season as well as an estimated additional delay for the formation of ice offshore. The derived values have been validated based on known measurements of ice exposure, as well as the Copernicus reanalysis data for the Baltic Sea.

The maps produced by the methods described above, have been combined with bathymetry and wave height information obtained from ERA5 reanalysis datasets, allowing the authors to divide the sea in question into nine characteristic regions: the Danish Straits, the Baltic Proper South, the Baltic Proper North, the Gulf of Riga, the Gulf of Finland, the Archipelago Sea, the Bothnian Sea North and the Bay of Bothnia. For each region, representative values for ice thickness, CR, and number of ice interaction days have been found.

A monopile design assessment for offshore wind turbines has been conducted for each of the regions, by using the preliminary representative ice conditions obtained. The authors have thus produced an ice feasibility map, which predicts the necessity of ice-mitigating measures in the foundation design. Results showed that in five out of nine regions, the use of monopiles is feasible, namely: the Danish Straits, the Baltic Proper South, the Baltic Proper North, the Gulf of Riga, and the Archipelago Sea. More research into alternative foundations and their cost competitiveness is required to determine the feasibility of monopiles for the Bothnian Sea South and the Gulf of Finland. For the Bothnian Sea North and the Bay of Bothnia significant additional weight was required for sufficient resistance to the ice loading, which resulted in infeasible designs.

Keywords: sea-ice, Ice-induced vibrations, ice ridges, offshore wind turbine foundation, ice thickness, ice strength coefficient CR, characteristic regions.

Web site:

Short biography: Florian van der Stap is a recently graduated offshore engineer from the TU Delft currently employed at Wood Thilsted. Throughout his studies Florian had a strong focus on offshore wind as well as arctic (offshore) engineering. This came together in his MSc thesis conducted at Wood Thilsted in close cooperation with the TU Delft, in which the impact of sea ice on monopiles was investigated via the coupling of the numerical VANILLA ice model to aero-elastic simulation software (HAWC2).
Besides his work Florian enjoys a wide variety of sports, including but not limited to crossfit, squash & running.

R&D areas/s: A) Policy and Market

AEP losses - less than half of the truth of the economic icing losses

Lasse Hietikko, Wicetec, FI

Petteri Antikainen (Wicetec, FI)

Wind power has quickly evolved from marginal to very significant part of the electricity markets. When wind power was just some percentage of total electricity consumption, the situations when icing is destroying the electricity production were rather easily solved using other sources or by purchasing electricity from balancing power markets with reasonable price. When the role of wind power on the electricity markets has got bigger the deviation from production forecast is getting significantly bigger weight in Finnish market, a part of Nord Pool. The balancing power price has become dramatically more expensive and when talking about wind power icing economics, the yearly balancing power costs are higher than the cost of AEP losses. The reason is that demand for balancing power is increasing and therefore the price is getting higher. Particularly if icing is sudden or otherwise unexpected the balancing power can cost thousands of euros / MWh on Nord pool markets.
Some might say that the high cost of balancing power is not affecting their wind power business as they have outsourced their balancing management to balance service provider with long term fixed price contract. However, the balance service providers are aware of the rapid market change and are aware of the risk of the high costs if production forecasting is failing when the balancing power price is peaking. Nowadays it is impossible to have a long-term fixed price contract whereas the typical offer is a maximum of a one-year contract where a certain level of icing risk is on behalf of the wind farm owner. The price levels for the balancing service are on average four to five times higher than what was expected some years ago.
Icing hits the hardest to wind turbines during the low and medium winds because icing affects the power curve and moves the cut-in speed up to the level of 7 - 8 m/s. Wind power capacity is increasing rapidly, but the electricity storage technologies are not keeping with the current pace. Therefore, the electricity price is really low, almost free of charge, when the winds are high and the opposite to this the prices are high when the winds are low. Traditionally icing losses have been indicated as a percentage of AEP. A more accurate estimate of the economic effects of the AEP losses can be achieved when estimated icing losses are weighted with electricity SPOT prices.
This presentation reveals the huge importance of the electricity markets when talking about icing loss economics. It is misleading in today's market situation to talk only about AEP losses when the more realistic and accurate is to talk about the economic icing losses. The total icing losses are a sum of balancing power costs, the high electricity price on low winds and the AEP loss. For example, the site with 3 % AEP losses has been estimated to have a total of 7-10 % economic icing losses yearly.

Web site: https://wicetec.com/

Short biography: Will be delivered later

R&D areas/s: B) Technology, E) Operation, maintenance and forecasting

The importance of early-stage ice detection

Matthew Stead, Ping Services, AU

Eike Lueken (Ping Services, Portugal)

Operating wind turbine blades in icy conditions at the best performance requires optimisation between different factors: safety (ice throw), damage prevention (critical loads), and maximised power output while limiting the energy consumption of the anti-icing or de-icing systems.
An early shutdown of the wind power plant will result in lost production; a late shutdown carries severe risks for people and equipment. A suitable ice detection system is required to correctly time the operational decisions.
The available ice detection technologies are diverse and range from meteorologic to instrumental measurements analysing sound, vibration, eigenfrequencies, impedance, power curves, optical inputs, etc. The characteristics of sensitivity, accuracy, continuity, automation, ease of installation and integration vary significantly between the systems.
However, the factor of sensitivity (early-stage detection of ice) seems to be of utmost importance for two of the most critical use cases for ice detection:
Anti-icing measures need to start early to be effective. But a too early activation of active anti-icing systems will result in high energy consumption.
Safety-relevant ice throw mitigation also relies on early detection. This allows for early warnings for both staff and people from the surrounding communities who pass by the wind farm area.
In both of the above applications, ice detection methods with low sensitivity (e.g. power-curve analysis) are impractical. Likewise, nacelle-mounted systems that don't measure ice at the critical blade tip might generate an unusable signal for the wind turbine operator.
Considering that recent studies suggest the ice production ratio (energy produced in icing /available energy in ice-free conditions) to be around 70 % on average, a significant financial benefit from optimising operations in icy conditions can be achieved.
In summary: Early ice detection lets a wind farm owner benefit from increased energy production (timely activation of anti-icing system) and ensures safety and compliance (ice throw mitigation). The sensitivity of an ice detection system is a crucial criteria.
Attendees can expect to gain the following from the presentation:
- Introduction to the challenges and goals of optimising wind turbine operation in icy conditions
- Overview of the types of ice detection solutions available
- Understanding the benefits of early-stage ice detection
- Financial implications for deployment of solutions available, including a Return on Investment (ROI) review

Web site: https://ping.services/

Short biography: Matt has over thirty years of experience in the areas of wind farm acoustics, environmental noise, low vibration design, building acoustic design and transportation noise. His professional acoustic consultancy experience has been gained in both Australia and the United States, where his advice has been provided to a range of companies and industries.
Matt has been instrumental in rapidly commercialising and scaling the Ping Monitor as a global service and driving the innovation of new products based on customer needs, to round out Ping's product portfolio.
He has an undergraduate Bachelor of Engineering (First Class Honours) degree under the acoustician Colin Hansen and also a Masters of Engineering Science specialising in signal processing and condition monitoring. He is a prolific author of technical papers, is actively involved in the industry and is the past Chairman of the Association of Australian Acoustical Consultants and a past Australian Acoustical Society Federal Councillor.
Education:
- Master of Engineering Science, Acoustics Monash University
- Bachelor of Mechanical Engineering (First Class Honours) The University of Adelaide

R&D areas/s: E) Operation, maintenance and forecasting

Experiences with IPS icing losses

Simo Rissanen, Kjeller Vindteknikk Oy, FI

Øyvind Byrkjedal (Kjeller Vindteknikk, NO), Rikke Bjarnesen Andersen (University of Tromsø, NO)

IceLoss is a state-of-the-art model for estimating long-term icing losses. In addition, IceLoss is used in operational icing forecasts. IceLoss 2.0 was developed in a research project partly funded by the Swedish Energy Agency in 2018-2020. Recently the model (v.2.2) is recalibrated with historical icing losses from > 400 WTGs from 27 wind farms spread over Sweden, Norway and Finland. The presentation will discuss the challenges of the calibration process and show the results of the validation study.
As an integrated part of the IceLoss2 model a dynamic module for estimation of icing losses for turbines operating with IPS has been developed. IPS from different suppliers vary in their technical specification, this is reflected also in the estimated losses from IceLoss. However, the amount of information available from the different suppliers varies. Depending on the site and technical specification of the systems the gain from IPS is found to vary and a gain within the range 20-60 % is found for sites with expected losses of 3 % and above. For sites with lower losses the IPS gain is lower, and for some cases less than 0.
The module has been tested for one operational wind farm with four defined turbine pairs. One of each pair has IPS in operation while the other has IPS deactivated. The four pairs are located at varying degree of exposure to icing within the wind farm, reflected by the base elevation of the tower. Results show that there is a large difference in icing losses depending of exposure to icing for the turbines without IPS. For the most exposed turbine pair we find that the IPS reduce the losses significantly, but for the less exposed turbine pairs the benefits of the IPS are marginal. The results agree quite well with the modelled IceLoss results. The results both from the operational wind farm and from the IceLoss model will be presented.

Web site: www.vindteknikk.com

Short biography: Mr Rissanen has a Master's degree in mechanical engineering from Helsinki University of Technology. He has worked in the wind industry for 15 years. In 2003-2006 and 2011-2019 he worked at VTT Technical Research Centre of Finland Ltd in Wind Power team. Since 2019 he has been working as adviser at Kjeller Vindteknikk. At Kjeller Vindteknikk, he works with commercial and R&D-projects, mainly related to icing losses, wind resources, energy yield assessment and post construction production analysis. In his free time, he enjoys fishing and skiing.

R&D areas/s: C) Development and financing

Experiences analyzing operational wind farms in cold climate

Utku Turkyilmaz, Kjeller Vindteknikk part of Norconsult, SE

to be provided later

The new wind turbine models used in the cold climate sites are becoming larger in both rotor size and hub height. The wind turbine manufacturers are adapting to such development either through new operational strategies and/or through new ice protection systems. Better estimates of the future energy production of the wind farms requires a good pool of validation data from operational wind farms as well as tuned and optimized tools to adapt to future needs.
Kjeller Vindteknikk (KVT) has been developing an icing loss tool, IceLoss2, for more than a decade. The model is based on the mesoscale weather model WRF (Weather Research and Forecasting). Historically the IceLoss2 model has been used extensively in the Nordics to assess the long-term average icing losses for wind farms in pre-construction phase. Simultaneously, KVT has been developing methods for post-construction phase energy production assessment of wind farms and utilizing IceLoss model for prediction of the long-term icing losses valid for the wind farm operation lifetime. Using the research and commercial experiences from post-construction phase analyses, KVT has been continuously calibrating its IceLoss model from both climatic conditions assessment point of view as well as operational strategies applied to wind turbines in cold climates. The gap between the models and the observations can be minimized by various sensitivity tests and continuous research.
This presentation focuses on the general post construction energy yield assessment methods as well as the quantification of the icing losses based on both the operational and the model data, and the long-term adjustment of the historical icing losses for future lifetime of the wind farms. The lesson learned and the current challenges in the methods will be presented, the future development ideas will be outlined and discussed.

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

Short biography: Utku Turkyilmaz works as a consultant at the science-based consultancy company Kjeller Vindteknikk (KVT) AB at the Swedish office, and is responsible mainly for energy yield assessments. He holds a master's degree in Aeronautical engineering specializing in wind energy from Istanbul Technical University. In 2010, he moved to Finland to work for Winwind, the Finnish wind turbine manufacturer as a wind analysis engineer. In 2014 he moved to Sweden to work for KVT. Since then, he involved in various wind energy topics including remote sensing devices, cold climate topics and pre and post-construction phase wind energy yield assessments. In his spare time, he is still trying to get acclimatized himself to the Nordic weather, to grow vegetables and to run outdoors.

R&D areas/s: E) Operation, maintenance and forecasting

Icing detection with LiDAR

Sara Koller, Meteotest, CH

Sara Koller, Meteotest

One of the goals of IEA Task 52: Large-scale deployment of wind LiDAR is to try to replace measurement towers with LiDARs in wind energy. Many attempts and efforts are being made to solve the problems encountered in LiDAR applications, for example, in complex terrain and cold climates. As production losses, increased load and risk of failure, increased noise emissions, and also safety issues due to ice throw and fall are challenges for wind farm operation in cold climates, ice detection with LiDAR becomes an unavoidable task. However, a satisfactory solution for ice detection with LiDAR that works in all different types of cold climates does not yet exist. IEA Task 54 has defined five ice classes that describe the loss of production due to weak to strong icing. Therefore, rather vague results are still sufficient as long as the ice frequency can be correctly assigned to one of the five classes. One advantage of LiDAR compared to cup anemometers is that LiDAR detects in-cloud icing and provides information on meteorological icing that represents periods when icing forms on rotor blades. Cup anemometers are not able to distinguish between meteorological and instrumental icing. For wind farm operation in cold climates, detection of meteorological icing is required to control blade heating systems. So far, the reference for meteorological icing detection is the use of a webcam.
In September 2022, a measurement campaign was started in the Swiss Alps with a Windcube V2 next to an 80m measurement mast. The measurement mast is equipped with heated and unheated anemometers and wind vanes, temperature and humidity sensors, and a webcam monitoring the operation of an unheated anemometer. This facility allows meteorological icing events to be correctly detected with the camera installed on the measurement mast. The goal this winter is to develop a method for detecting icing with LiDAR by, among other things, analyzing the backscattered signal from the laser beams and assigning the correct IEA icing class. As a starting point, the findings of Cattin et al. (2015) [1] are used and the weather situation is analyzed. Are there typical weather situations that correlate with icing conditions at this location? Then, wind speed, wind direction, temperature, and humidity measurements are added to refine the search. Finally, the information from the backscattered signal is analyzed to determine icing in the cloud. Two icing events have occurred at the site so far, but more will be recorded this winter. The results of this winter of measurements will be presented at the Winterwind 2023.
[1] Cattin, R., Koller, S., Heikkilä, U. (2016) Vereisung WEA St. Brais, Auswirkungen der Vereisung auf das Betriebsverhalten und den Energieertrag von Windkraftanlagen im Jurabogen. Final report, Swiss Federal Office of Energy SI/500692-01. Meteotest AG.

Web site: www.meteotest.ch

Short biography: Sara Koller holds a Master's degree in Environmental Geosciences from the University of Basel. Since 2009, she has been working in the wind department at Meteotest in Switzerland. In 2019, she became head of the Wind & Ice team. Meteotest represents Switzerland in IEA Tasks 54 and 52, at which Sara is active in the LiDAR Correction in Complex Terrain and Icing Detection with LiDAR working groups of Task 52. Wind in all its aspects has been her topic for the last 13 years, although every time she works in the field she regrets that she is not working in the solar energy department. In her second life, Sara is a performance artist.

R&D areas/s: E) Operation, maintenance and forecasting

Challenges for a smart algorithm controlling wind turbines under icing conditions

Simon Kloiber, VERBUND Green Power, AT

Thomas Burchhart (VERBUND Green Power, AT), Franziska Gerber (Meteotest, CH), Paul Froidevaux (Meteotest , CH), Michael Sedlmayer (University of Vienna, AT), Radu Bot (University of Vienna, AT), David Gruber (Austrian Institute Of Technology, AT), Georg F

Icing losses decrease the efficiency of wind turbines under cold climate conditions significantly. Thus, operating wind turbines efficiently in cold climate is challenging, let alone developing a smart algorithm to mitigate or prevent icing losses. First results of the ongoing research project "Smart Operation of Wind Turbines under Icing Conditions" (SOWINDIC) show selected difficulties and solutions for raised questions.
The aim of SOWINDIC is to develop a real-time algorithm to optimize the control of wind turbine's rotor blade heating system to enable an increased energy yield in cold climate conditions. The algorithms make use of turbine data, in-situ meteorological measurements, observations of blade icing, as well as weather forecasts including icing forecasts. Hereby, physics-inspired heuristic algorithms and a machine-learning approach are considered.
One important aspect for creating a smart algorithm is to gather training data in sufficient quantity and quality. That being the case, rotor blade icing is tricky since the events are not homogeneous and measurements of the rotor blade icing are affected by the operation mode of the wind turbine. Especially for machine learning there has to be a sufficient amount of data. The next challenge is to operate such an algorithm in real-time. While in the training phase of the algorithm data can be provided within a well-structured data base, in real time it is difficult to maintain a high data quality as well as high availability for the diverse data sources and communication paths. Additionally an interface to the wind turbine to control the rotor blade heating system must be established. This can be a challenge again since wind turbine OEMs (original equipment manufacturer) and local laws can be very restrictive when it comes to control the rotor blade heating system due to arising safety concerns.
SOWINDIC tries to tackle the mentioned difficulties and proposes solutions for developing a smart algorithm to control wind turbines under icing conditions. Finally, an outlook to the next steps within the research project and existing collaborations will be discussed.

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

Short biography: Bachelor and master degree in meteorology at the University of Vienna (2011-2017). Visitor at NCAR **-** The National Center for Atmospheric Research (2016 – Three month). Weather forecaster at Ubimet (2017-2018). Performance Analyst Wind and PV at VERBUND since 2018. Project staff within the research project ICE CONTROL. Member of the VGBE project SOPWICO. Project leader of the research project SOWINDIC. Interested in sport – active and passive.

R&D areas/s: C) Development and financing, E) Operation, maintenance and forecasting

Case study on vertical variability in icing conditions in Finland

Timo Karlsson, VTT Technical Research Centre of Finland Ltd, FI

Timo Karlsson (VTT, FI)

Wind power is an important part of the Nordic power infrastructure and due to political developments during 2022 it's role will increase in the future as well. The number of wind turbines built in cold climates is expected to grow significantly in the coming years. [1] At the same time, both the average size of the turbines and the height of the towers of land-based wind turbines are growing [2].
In cold climate wind power sites wind turbine blades can collect ice. Icing happens when the turbine blades come into contact with liquid water in sub-zero temperatures. This can either happen as in-cloud icing, where the turbine blades collide with super cooled cloud droplets or as a result of freezing rain. As turbines get larger and the tip height grows, the blades sweep an ever-larger vertical area.
Due to rotation of the blades, in-cloud icing can affect the rotor even if the entire rotor is not in contact with clouds, it is enough that the blades reach the cloud at some point of the rotational cycle. Meaning that for in-cloud icing, it is important to look at icing closer to tip height instead of at nacelle level. As turbines become larger and larger, the difference between icing conditions at tip height and nacelle height becomes more and more relevant.
A dataset of icing measurements from a meteorological mast in Finland was analyzed. The dataset contains icing and other meteorological measurements at two heights in the same mast. Both levels use identical instrumentation. The goal of the analysis was to see the differences in:

- Icing frequency
- Icing intensity
- Icing event length
- Meteorological conditions during icing

At the measurement levels and estimate the impact these changes would have from wind power perspective as well.
In addition to this the timing differences between the two measurements were analyzed and an icing profile for the location is presented.
The mast measurements were then compared to icing atlas information. The reference icing atlas here is the VTT WIceAtlas [2]. WIceAtlas contains meteorological icing information calculated at different heights. WIceAtalas is built based on measurements and reanalysis data and has been calibrated for wind power applications [3]. The WIceAtlas database also contains an icing profile for any given point and icing event lengths and conditions during icing.
The results from the measurement campaign are compared with the information from the icing atlas and relevance of these results to cold climate wind power is discussed.

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[1] Karlsson, T. (2021). IEA Wind Task 19: Climate wind market study 2020-2025. Winterwind 2021.
[2] Finnish Wind Power Association (2022), Wind power in Finland 2021, Retrieved November 28.11.2022 from https://tuulivoimayhdistys.fi/media/tuulivoima_vuositilastot_2021_in_english-2.pdf
[3] VTT.. Wind Power Icing Atlas – WIceAtlas. Retrieved November 17, 2022, from https://projectsites.vtt.fi/sites/wiceatlas/www.vtt.fi/sites/wiceatlas.html
[4] Cattin, R. (2017). Blind Icing Map Validation. Winterwind 2017, Skellefteå. http://windren.se/WW2017/7_2_09_Cattin_IEA_Task_19_-_Blind_icing_map_validation_Pub_v2.pdf

Web site: https://www.vttresearch.com/en/ourservices/wind-power

Short biography:
Timo Karlsson (M.Sc):

Timo has a decade of experience in working with cold climate wind power related research and development mostly at VTT. The projects Timo's been working on at VTT have covered a wide variety of topics: icing detection method development, pre-construction icing assessment, ice mitigation and blade heating system development and production data analysis. Currently he's also the head of IEA Wind task 54 "Cold Climate Wind Energy", an international expert group. He has a Master's degree from Aalto university school of electrical engineering.

R&D areas/s: E) Operation, maintenance and forecasting

6-month seasonal forecasting of monthly wind speed anomalies

Albert Bosch, VORTEX, ES

Albert Bosch (VORTEX, ES), Gerard Castro (VORTEX, ES), Jordi Ferrer (VORTEX, ES)

Climatology is commonly used in the wind industry to compute production for the following year. It has been found that using monthly climatology averages is not effective for anomalous cases because monthly wind speed anomaly predictions change every month. Therefore, some annual predictions must be updated monthly or quarterly to fulfil predicted budgets calculated with historical data.
A new methodology for seasonal forecasting has been developed to improve on climatology for 6-month wind speed anomaly predictions. This methodology combines 30-year historical time series and seasonal climate models with statistical methods and machine learning techniques, which does not require prior wind-speed measurements. A modelled 30-year time series from the Weather Research and Forecast model (WRF) at 3km resolution prepared by Vortex is used as a reference for the climate period 1991-2020.
Seasonal climate models from Copernicus Climate Change Service (C3S) are used for 6-month projections. The seasonal models used are from European Centre for Medium-Range Weather Forecasts (ECMWF), the UK Met Office, Météo-France, the German Weather Service (Deutscher Wetterdienst, DWD), the Euro-Mediterranean Center on Climate Change, the US National Weather Service's, and Japan Meteorological Agency (JMA).
All the gathered information is analysed on a site-specific basis using intelligent analysis to evaluate the best performance for each exact location. Seasonal single and post-processed models, multi-models, statistical projections, persistence and climatology are all studied to provide the best anomaly prediction for each point. Furthermore, budgets for Annual Energy Production (AEP) can be updated every month. And, better information can be produced for planning wind farm operations, maintenance, storage and construction for the months ahead.
Monthly anomalies were calculated from 30-year hourly time series for reference. Then, anomalies from the seasonal models were post-processed and combined, enabling the use of different derived models. Statistical methods were considered to provide monthly time series projections and anomalies for up to 12 months.
The previous models were intelligently analysed using the following metrics: bias, mean absolute error (MAE), improvement over climatology (IoC), and trending (percentage of anomaly sign hits). The models were then compared for each site and lead month and ranked based on the reference anomalies. To further enhance the skill of the provided predictions, machine learning techniques were employed, and the IoC and trending were maximised to obtain the best performing seasonal model.
The validations were carried out using two regions: 1) 50 locations across several wind industry regions around the world and 2)19 locations in Europe, and a bias of approximately 0 was obtained in both cases. For the global validation, the values obtained for IoC and trending were 57.9% and 60.5%, respectively, with an MAE of 8.6. These metrics are an average for all months and lead months.
A closer look can be taken by analysing IoC and trending metrics by month, and even further analysis by month and lead month. Then, for one-month predictions an IoC of 67% was achieved for some of the predicted months.
For the European validation an IoC and trending of 59.1% and 64.7% were obtained, respectively, with an average MAE of 3.4.
In conclusion, a new methodology using machine learning techniques has been developed without using previous wind-speed measurements to choose the best prediction from different seasonal models. The validation of this methodology demonstrated that it is useful for 6-month forecasting of wind speed anomalies and is able to outperform climatology predictions and skills. This methodology will allow more accurate 6-month wind-speed-anomaly predictions for the wind industry.

Web site: https://vortexfdc.com/

Short biography: Albert Bosch is a physicist and wind meteorologist who has spent a considerable amount of time working in the renewable energy industry. He holds a Masters of Science in Meteorology from the University of Barcelona. Albert has been working at Vortex since 2016 in the Technical Department developing tasks such as short-term forecasting, icing time series and wind and site mapping. He was also a Vortex team member for the Global Wind Atlas project in conjunction with The Work Bank

R&D areas/s: E) Operation, maintenance and forecasting

Group (globalwindatlas.org). During the last few years, his main research interests have been in long-range forecasting for the wind industry.

R&D areas/s: E) Operation, maintenance and forecasting

Addressing lightning risk in cold climates - a swedish case study

Andreas Christian Espersen, Wind Power LAB, DK

Magnus Aagren Jensen (Wind Power LAB)

With the increased demand for sustainable energy, the wind turbine manufacturers are battling for taller and higher energy producing turbines. However, with the increased size of wind turbines, increased exposure of lightning strikes are unquestionable. Lightning strikes to a wind turbine blade can create severe damage, even with a lightning protection system (LPS) installed. The response time to a lightning strike is crucial to avoid catastrophic blade failure. Also, lightning damages are adding a significant cost to the O&M budget both due to the cost of repair but also due to down time.
To make things worse, smaller lightning strikes have a higher risk of hitting outside LPS receptors, possibly causing structural damage to the blade. These events are usually not in the scope of a Service Agreement for blade inspections. The IEC standard specifies that 2% of all lightning strikes will cause blade damage independent of peak current and polarity. Unfortunately, there are many examples of lightning damages that have caused blades to collapse/fail within a short timeframe after any strength lightning event.
What can be done to minimize the risk of lightning strikes and down time to turbines? First thing, we need to understand the lightning risk through proper data. Secondly, react in time if a turbine gets hit by a lightning strike. Get notifications if lightning strikes have occurred in close proximity to a wind turbine and follow the recommended wind turbine operation actions based on characteristics of the lightning strikes. Optimize your lightning strike inspection planning and verify if a lightning strike is within or outside the certification: IEC 61400:24–2010.
If applicable, trigger a Service Agreement blade inspection to mitigate risk of catastrophic blade failures or initialize your own inspections.
Following the above will help asset owners become a prudent operator by mitigating foreseeable lightning risk events. It is not only good for the industry's LCoE but, it is also good for individual O&M costs.

Web site: https://windpowerlab.com/

Short biography: Mr. Andreas C. Espersen holds a master´s degree in Geoinformatics. He specialises in the wind power industry with specific focus on how technology can assist in driving down the cost of operating a wind farm. Mr. Espersen has extensive knowledge and experience in data gathering, data conversion, data mining and data quality control. He also has strong knowledge of working different data format, raster, vector, text data and combining different data sources. As a result of his extensive university studies and career within the utility sector, Mr. Espersen has obtained sound theoretical and practical knowledge of the complex aspects inherent in the industry, which enables him to turn both complex and non-complex business challenges into IT solutions. Mr. Espersen has expertise and experience with project management of both small- and larger projects. and data driven insights from fleet management of wind turbines. In 2016 Mr. Espersen co-founded Wind Power LAB ApS with the aim to develop an automated defect detection algorithm to help analyse and assess wind turbine blades. By means of cloud computing and a defect detection algorithm, based on a global data set of wind turbine blades, Wind Power LAB is able to provide customers with a quick, automated and high precision analysis and assessment of wind turbines blades quality assured by a team of experienced and professional blade specialists. Outside work, Mr. Espersen spends his time in the nature. A good vacation for Mr. Espersen is a trip to Norway or Sweden to wander the woods and mountains.

R&D areas/s: A) Policy and Market

Potential and costs for wind power of providing system services to the electricity grid

Salur Basbug, RISE, SE

Anders Wickström (RISE, SE), Mats Goldberg (RISE, SE)

Wind power has an extraordinary ability to contribute with the grid system service FFR (Fast Frequency Reserve). The most cost-effective way to achieve this power reserve is by increasing the rotor speed at low winds in order to store desired FFR capacity in the turbine's rotational energy. The total rotational energy stored in Swedish wind turbines during operation amounts to close to 10% of the existing stored kinetic energy in the Swedish electricity system. But the wind turbines are not synchronously connected to the grid. This means that special turbine control is required to use this energy for grid stabilizing purposes.
The strategy for today's wind turbines is to maximize energy production in all wind situations, based on the technical limitations the plant is designed for. This mode of operation does not allow for contribution of system services to the grid.
In this project a generic land-based wind turbine of 3.4 MW and 130 m rotor diameter has been modelled in the aeroelastic code FAST. By upgrading the control system, the turbine operates at higher rotor speeds in low winds. Thousands of simulations have been executed to analyze potential and consequences for different combinations of winds, rotor speed concepts and different degrees of FFR power increases.
One proposal suggests that the rotor speed is about 2 rpm higher than the optimal speed for the lowest winds. It generates a power capacity which very quickly can be applied in winds between 3 and 8 m/s in accordance with the requirements for FFR that ENTSOE set up. If this capacity is summarized for all Swedish wind power, the FFR reserve reaches 415 MW. This is quite more than what ENTSOE requires to maintain 49 Hz in the electricity grid in the worst case, a production loss of 1450 MW.
The cost of this capacity, i.e. the increase in rotor speed, is decreased energy production for the wind turbine of 3.4 MW. It will go from optimal 12.716 to 12.556 GWh/year, corresponding to 1.3%. This is a relatively small and therefore cheap reduction.
An alternative option to generate FFR is to operate at the turbine with a power curtailment in order to have a power reserve capacity over time. This method is only possible in winds above rated power. However, this strategy is significantly more expensive in terms of production loss.
The loss of production costs different depending on when the loss occurs as the energy price varies over time. The next step will be to calculate the production loss in [SEK/year] hour by hour rather than [GWh/year] based on the compensation for produced energy and the compensation for the power reserve. These two market signals become control signals to the turbine control to operate in the most optimal way to maximize revenue and thus benefit.

Web site: https://www.ri.se/en/person/salur-basbug

Short biography: I am working at RISE within the unit "Renewable energy from wind and sea". My expertise is in computational fluid dynamics (CFD) and other types of simulations related to wind energy, such as aero-elastic analysis using BEM method. Currently, I am involved in the following projects:
-Active yaw control for increased windfarm production
-Influence of wind-wave interaction on the blockage effect for offshore windfarms
-Potential and costs for wind power of providing system services to the electricity grid (Part 2).
Besides engineering and technology, I am quite interested in economics and finance.

R&D areas/s: B) Technology

An active/passive coating stack for surface icing mitigation tested under various climatic conditions.

Bram Cloet, Sirris, BE

Ozlem Ceyhan Yilmaz (Sirris, BE), Bram Cloet (Sirris, BE), Joey Bosmans (Sirris, BE), Pieter-Jan Jordaens (Sirris, BE)

A coating stack of an active heatable and a passive hydrophobic anti-icing coating is investigated as a flexible system providing anti-icing solutions for various icing conditions. In times of low temperature (<0°C) and rain, the hydrophobic surface will shed the water droplets before icing can occur on the surface. In high humidity conditions however, frosting will occur on the surface which cannot be completely prevented by the hydrophobic system. In such conditions, the active part of the coating can de-ice the surface where the hydrophobic coating makes the water flow off easily. Applications that could benefit from such a system are wind blades, boat landing ladders on offshore systems or cold climate applications where other heating systems are difficult to apply.
The active coating is an aqueous, solvent-free, electrically conductive low-resistance acrylate dispersion with a resistance of 2 Ohm Square at a thickness of 75µm. By diluting with water or binder, the coating is adjustable in its electrical spectrum. The coating can be applied by rolling, screen printing or rackel and curing is at room temperature. The hydrophobic coating applied over de heatable coating is a nanocomposite coating that reduces the adhesion strength of ice by 40 to 60%, compared to bare metal and painted surfaces.
Functional tests of the system are performed in a large climate chamber using a state-of-the-art icing set-up at -10°C,comparing samples uncoated, passive coating only and the active/passive coating stack. The functionality of the systems is tested starting from a fully iced surface after which the heatable coating is activated. Secondly, the heatable coating is activated from the start of the icing test. The samples are monitored visually and with an IR camera for heat measurements. The energy input of the system is altered during the tests. The energy use of the system is estimated in comparison with existing technologies i.e. build-in heating mats, fan heating inside a blade and heat tracings.

Web site: www.sirris.be

Short biography: With over a decade of experience in the energy sector, Bram Cloet is a respected professional in the industry. He currently holds the position of Senior Engineer for Energy Transition Industry at Sirris, where he leads efforts to create a sustainable energy future.
Bram has a wealth of experience working on long-term operation projects for Belgian nuclear power plants with Tractebel/Syngenia and was also a team leader at the Global Product Design Group of CG Power Systems (formerly Pauwels Trafo), where he managed R&D projects related to the development and improvement of high voltage distribution transformers.
Bram's education in Mechanical Electrical Engineering (option electrical energy) from KULeuven in Leuven, Belgium in 2007, has been instrumental in his success. His expertise, dedication to the field and problem-solving skills have earned him a reputation as a trusted and valuable professional in the energy industry.

R&D areas/s: B) Technology

Gearing up for cold climate validation testing of 15MW+ wind turbine drivetrains

Pieter Jan Jordaens, Sirris, BE

Bram Cloet (Sirris, BE)

On - and offshore wind turbines keep increasing in power size in a race to bottom the levelized cost of energy. Recent publications related to onshore wind predict 10MW+ wind turbine designs will not be rare for specific locations in the future, for offshore wind energy the upscale is predicted to be even higher. 27MW offshore wind turbine designs are currently being considered for certain offshore locations. On the other hand these wind turbines are more frequently installed in remote areas due to profitable wind conditions but such locations in some cases need to deal with extreme inhospitable environmental conditions. Hydrodynamic loads for floating wind for example are can be tough for the full system, but also climatic conditions such as (extreme) cold for on & offshore sites up North can be challenging for the machines.
For onshore wind power these machines need to survive -40°C conditions, for offshore wind power the survival limit is set for -20°C. OEM's and component suppliers have develop specific cold climate package solutions for different components than can be sensitive to temperature variations and extreme cold temperature drops after grid failures for example when supply for stand-still heaters are cut off. Dedicated cold-start-up procedures, the use of other materials, lubrication and isolation adaptations are set-up to cope with these challenges and to ensure optimal performance, reliability and safety.
In order to learn and validate how these solutions perform in a real cold climate event, and to investigate the reliability of such adaptations in real scale, dedicated testing infrastructures are needed to help the industry. Sirris | OWI-Lab has been operating one of Europe's largest climatic test chambers for 10 year now with specific attention to cold climate testing of turbine components.
In 2022 the lab was involved in the validation testing of offshore 1X MW transformer designs. The set-up and findings of these tests will be presented in this presentations. But, in 2022 the lab also reached the limits for the upcoming 10MW+ drivetrain designs. In order to be capable of testing full drivetrain solutions (mail shaft, gearbox and generator) the facility needs an upgrade.
In 2022, Sirris | OWI-Lab was granted the "Harsh-R&D-Test" project by the Federal government via the Energy Transition Fund in order to design and upgrade the existing climatic test facility for the upcoming 15MW+ drivetrain designs. This presentation will give insights in the set-up of the project, it's goals, the current status and how the next generation climate chamber will support the development and validation testing of the upcoming 15MW+ offshore wind turbines.

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

Short biography: Pieter Jan Jordaens joined Sirris (the Belgian collective technology center – www.sirris.be) in 2010 in the role of project leader to manage the Offshore Wind Infrastructure (OWI) project lead by Sirris, VUB and a group of Belgian companies active in the early days of offshore wind power. Since then he has been responsible to initiate, set-up and roll-out the operations of the (offshore) wind energy RD&I department at Sirris and it's supporting services in different roles (project engineer, senior engineer, business developer, cluster manager). Pieter Jan also acts as operating officer of OWI-Lab (www.owi-lab.be), a joint collaboration between Sirris, VUB and UGent to support (offshore) wind RD&I activities in Belgium. During the past years PJ has set-up the large climatic test facility for wind turbine components in Antwerp, supported the structural health monitoring (SHM) RD&I trajectory of OWI-Lab in partnership with VUB, and together with UGent managed the IBN Offshore Energy Cluster as cluster manager in which between 2007-2020 more than 40 large RD&I projects linked to offshore wind energy were set-up with industry. Pieter Jan now acts as Program manager Energy Transition within Sirris. Before joining Sirris, Pieter Jan obtained a Master's degree in Electro-Mechanical Engineering at KU Leuven. He also joined the International Postgraduate Programme in Entrepreneurial Engineering after his Master. PJ is also the president of Technovation Hub vzw, a platform initiating and supporting hi-tech engineering student projects. PJ is also board member of Seacoop cvba, a cooperative venture that will co-develop the upcoming 3.5GW Princess Elisabeth offshore wind zone in Belgium in which participation of Belgian citizens will be supported.

R&D areas/s: B) Technology

Anti-icing coating from the customer's perspective to technical development

Urandelger Tuvshindorj, Mikron.X B.V, NL

Urandelger Tuvshindorj (Mikron.X B.V), Valentina Litovchenko (Mikron.X B.V)

Ice build-up is a natural phenomenon, which can pose a catastrophic impact on a wide range of systems and equipment. For wind energy, the problem grows with the increasing number of wind turbines, positioning of those in more and more remote areas, cold climates, and sadly enough with “global warming”.
The blades of a wind turbine are the most susceptible to icing events. The current approach to the problem is mainly divided into: “no problem – do nothing” or the installation of active de-icing electrical heating systems. The installation of an active anti/de-icing system is costly, and ice build-up on blade failure and maintenance contribute significantly to downtime and repair costs.
Passive de-icing systems and anti-icing coatings are an alternative solution to the problem. However, currently, there is no reliable anti-icing coating in the market. As Mikron.X, last year we conducted 100 interviews with experts on wind energy, and owners and operators of wind turbines identified the most crucial properties of the anti-icing coatings from a customer perspective. We found the perfect formula which checks all the boxes of the customers and develops it EU market. We are going to share how the application of anti-icing coating supports wind operators generate additional energy. This presentation will give information about the latest development and experiences of innovative anti-icing coating.

Web site: https://www.mikronx.com/home

Short biography: Urandelger Tuvshindorj has a strong background in research with her BSc in Chemical Engineering (Gazi University) and MSc in Materials Science and Nanotechnology (Bilkent University). In the period 2016-2022 she obtained her PhD at Maastricht University. In Mikron.X, she is leading technical development of the functional coatings.

R&D areas/s: B) Technology

Lightning Monitoring in Cold Climates? Is there any need?

Nils Lesmann, Phoenix Contact, DE

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Even though the Winterwind is all about icing, snowfall and survival in cold climates. Why should be there any invest additionally to lightning monitoring? Lightning should only be in warm areas with high humidity, shouldn't it?
Cold climates lightning areas are also known for Winter-Lightnings. These are lightnings with a low amplitude lightning current but with a high energy that can course severe damages. But what kind of damages occur and how can they be measured?

Web site: www.phoenixcontact.com/wind

Short biography: Being with Phoenix Contact for 15 years Nils Lesmann is doing working now with eleven years most of his business career in the wind sector. Starting as application engineer, he is now in charge for the blade monitoring platform called "Blade Intelligence"
If he doesn't feel the wind at work he likes to feel the wind while driving his motorbike.

R&D areas/s: B) Technology

ENERCON E-175 technologies

Timo Müller / Moritz Rodenhausen Timo Müller / Moritz Rodenhausen, ENERCON GmbH, DE

will be sent asap

Producing energy when the society and industry need electricity as most – not least during the cold winter months – is vital for today's energy crisis. We cannot afford wind turbines having longer still stands and not contributing to the system. It is no longer only a question about the safety and economy of the turbine owner; it is also a matter for everyone's electricity bill in the end.
To install the right the turbine with the right options for winter conditions is crucial and with ENERCONs latest development, the new E-175 EP5 turbine, we take it one-step further. At 175 meters, the new ENERCON top model has one of the largest onshore rotor diameters currently available in Europe. The turbine, which is optimized for low wind sites, has a rated power of 6 MW. This turbine is very attractive for low wind inland sites in Europe and has an outstanding grid performance with its full converter. This results in more full-load hours and enables better grid integration, so less reserve capacity needed for grid regulation. Once available for the Scandinavian market, the E-175 will also be equipped with the ENERCON Rotor Blade Heating System (RBHS). In addition, ENERCON is currently developing our software system to improve AEP under ice conditions, which also will be communicated to the market within short.
ENERCON has nearly 3900 turbines installed worldwide equipped with its hot air blade heating system to prevent and minimize ice being built up on the rotor blades. In areas with minor health and safety risks, turbines are allowed to continue operation with ice accumulated on the blades and with a heating system operating at the same time while remaining in the turbine's design limits. This allows for reduction of downtime and increase of performance in icing conditions. The efficiency of the heating system determines the extent of this improved performance and is used in the planning phase of a windfarm to estimate losses due to icing. In areas where high icing losses are expected, a proper evaluation of the heating system efficiency could actually render a project financially feasible or not.

Web site: www.enercon.de

Short biography: Moritz Rodenhausen Dipl.-Ing., M.Sc. Head of Product Management and Timo Müller Senior Platform Product Manager (more info will follow)

R&D areas/s: B) Technology

Multi-fidelity modelling of wakes and blockage for realistic atmospheric conditions in cold climate

Narges Tabatabaei, DNV,SE

James Bleeg (DNV, GB), Narges Tabatabaei (DNV, SE), Christiane Montavon (DNV, NL)

Multi fidelity approach is common in industries with high-value products subject to complex fluid dynamics. Low fidelity flow models are used in early design and as the design matures, there is a shift to higher fidelity models, such as computational fluid dynamics(CFD). In this respect, the wind industry is an outlier, typically using a single fidelity approach to turbine interaction loss.
Historically, the design and assessment of wind farms has been almost exclusively the domain of relatively simple and fast models, at least when it comes to turbine interaction loss, which has a huge impact on energy production at most wind farms specifically where the stable boundary condition is strong, i.e. cold climate regions.
The engineering models for wake and blockage miss several aspects including stratification above the boundary layer and stratification within the boundary layer. CFD is capable of directly simulating many of the important effects that engineering models miss. The validation indicates that the engineering models provide reasonably accurate wake predictions for currently operating wind farm sizes, but the uncertainties of those predictions increase when those models are used outside of the validation envelope (e.g. in the presence of complex terrain, large wind farm clusters, and atmospheric conditions that differ from the offshore conditions for which most models have been validated). Particularly relevant to the cold climate aspects are the increase in turbine heights with rotors operating near the top of thin stable boundary layer, where low level jets are often observed.

Additionally, the exclusive use of these models when more reliable, higher fidelity models are available does not sound reasonable. Indeed, the simple models should be complemented with higher fidelity approaches for most planned wind farms. Most of the traditional fast wind farm flow models ignore blockage effects, where high-fidelity flow models are more complete and accurate, but turnaround times can be relatively long. Accordingly, we need a multi-fidelity approach to turbine interaction modelling. DNV has combined high-fidelity CFD models with machine learning (ML) to create a next-generation prediction tool for use in the design and analysis of wind farms. In 2018, DNV presented that there is a bias in flow models used to predict the energy production of a prospective wind farm [1]. These models assumed that wind turbines could only affect one another through their wakes, but the research clearly demonstrated that blockage is also a significant contributor to turbine interaction loss. CFD.ML predicts turbine interaction loss using a graph neural network model that has been trained to replicate results from CFD simulations [2].
Thus far, results look promising, and the model is already being used to supplement CFD analyses, improving accuracy and reducing the number of CFD simulations required. CFD.ML was found to replicate the wind farm pattern of production remarkably well given its novel approach to turbine interaction modelling [3]. We will use model results and measurements, including dual-scanning lidar, at a variety of wind farms to demonstrate how a multi-fidelity can significantly improve the assessments, with evidences from field observations as well as the model.

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3. Bleeg, J. (2022). CFD.ML for wind farm flows. Retrieved from DNV: https://www.dnv.com/research/review-2020/featured-projects/cfd-ml-wind-farms.html

Web site:

Short biography: Narges has more than 10 years of experience in CFD simulations of turbomachinery. She has also worked with aerodynamics investigations in different applications, as well as the algorithm development for modeling the various flow systems. Narges is a senior engineer who has been working in different industries and research groups, with expertise in fluid mechanics. She received her doctoral

R&D areas/s: B) Technology

degree from Luleå university of technology with the doctoral thesis on icing effect over wind turbine performance. Important part of her work includes the CFD developments as a part of her PostDoc in KTH Royal Institute of Technology.

R&D areas/s: E) Operation, maintenance and forecasting

Climate change impacts on Nordic icing climate

Emilie Iversen, Norconsult, NO

Emilie C. Iversen (KVT, NO), Bjørn Egil Nygaard (KVT, NO), Øivind Hodnebrog (CICERO, NO), Maria Sand (CICERO, NO), Kristian Ingvaldsen (KVT, NO)

Climate change is and will further impact the icing climate in icing prone regions of the world. But estimating in what way is not straight forward, due to the non-linear dependance on several meteorological variables in combination. Trying to estimate the future evolution of the icing climate is important for the planning of future wind farms and their production – for investors, wind park owners and operators.
The only tools available to project future climate are global climate models, but they are typically relatively coarse resolution (~80 km). This is too coarse to represent the meteorological conditions important for atmospheric icing, which is highly dependent on topography. We therefore here apply dynamical downscaling of the two global climate models, CESM2 and MPI-ESM1-2-HR, and three future scenarios, using a regional model, WRF, to obtain high resolution data for future climate. Atmospheric icing can then be modelled using this data as input to icing models. This is performed for a domain covering Norway, Sweden and Finland.
Results will be presented from the two climate models, the three future scenarios, and three future time periods. The results reveal relatively large differences between the two climate models, due to different projections of regional warming level, making it challenging to conclude. More research, involving downscaling of more climate models or the use of other methodologies, is needed to obtain more robust projections and uncertainty estimates. However, large uncertainties in climate model projections of large-scale oceanic and atmospheric circulation and regional climate response, as well as climate model biases, challenge the constraint of climate projections in this region.

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

Short biography: I recently obtained my PhD within atmospheric icing, weather modeling and climate prediction, and have been working as a consultant for wind engineering tasks for close to four years, with a specific focus on atmospheric icing.
I enjoy snow and ice in my free time as well, as I enjoy snowboarding both down and uphill.

R&D areas/s: B) Technology, E) Operation, maintenance and forecasting

Increasing O&M benefits from icing sensors by means of smart data augmentation

Michael Moser, eologix sensor technology, AT

Harald Hohlen (eologix, AT), Edwin Taferner (eologix, AT)

Since we expect that in the close future, more new wind turbines will be erected in or close to populated areas while at the same time energy prices are high, safety is still and again an important concern about wind energy in cold climates.
Capacitive measurement of icing by means of autonomous, wireless sensors is widely in use and can deliver accurate information about early icing and trigger turbine stops and re-starts without the need to connect to remote . However, the autonomy, while providing a high level of cyber security, also brings the drawback of a lack of connected services.
As a first appraoch, icing data can be augmented by additional, locally acquired information such as the icing situation and temperature distribution not only at the blades but also on nacelle, tower or other auxiliary structures (not necessarily being part of the turbine). Independently acquired data such as loads, accelerations, rotor speeds or pitch angles provide a big benefit which can deliver additional input for planning O&M activities and at the same time use existing connections to turbine control systems to e.g. trigger turbine stops to avoid major damages.
Furthermore, we are looking at the concept of linking measurement data with meteorological forecasts. This enables a re-adjustment of models in both time and space domain by feeding forecast model outputs to the detection systems (e.g. for adjusting measurement ranges) and feeding back measurement data about icing events to the forecast models. Depending on the performance of the data link, this can be done as a pure post-processing task, however, the best advantages could of course be realized by real-time operation.

Web site: eologix.com

Short biography: Michael Moser obtained his MSc in Electrical and Sound Engineering and his PhD in Electrical Measurement from Graz University of Technology and Graz University of Music and Performing Arts in 2007 and 2013, respectively. After an incubation phase at Science Parkt Graz, he founded eologix sensor technology together with 2 former colleagues. Since then, he is managing director and CTO of the company with more than 25 employees. He is attending Winterwind since 2011 and in his free time, he enjoys hiking and playing the piano.

R&D areas/s: E) Operation, maintenance and forecasting

Turbine performance during icing events

Ines Runge, Nordex Energy SE Co. KG, DE

Ines Runge (Nordex Energy SE & Co. KG, Germany), Konrad Sachse (Nordex Energy SE & Co. KG, Germany)

The development, production, project planning and service of onshore wind turbines has been the core competence and passion of the Nordex Group with its more than 9,000 employees worldwide for over 35 years. However, our current focus is on turbines in the 3 to 6+ MW class. The Group's comprehensive product portfolio offers individual solutions, both for markets with limited space and for regions with limited grid capacity.
This presentation will focus on the comparison of SCADA operational data from different wind farms in Scandinavia. The interaction of aerodynamics, mechanics and control systems is very complex and leads to the fact that the behavior of a wind turbine during icing cannot be predicted based on a simple parameter like the number of icing hours. Important parameters for the validation of the performance are presented. Furthermore, the influence of an anti-icing system on the performance is presented.

Web site: www.nordex-online.com

Short biography: Ms. Ines Runge works as a Senior Engineer in the Blade Engineering department at Nordex Energy. She has a PhD in mechanical engineering. After starting her career at an automotive supplier, she has been working on the Nordex anti-icing system since 2011. In addition to system design, her responsibilities include prototype evaluation.
Ines likes long walks with her dog and baking cakes for her family.

R&D areas/s: E) Operation, maintenance and forecasting

How to handle the sea ice

Erik Almkvist, Viking Supply Ships, SE

Erik Almkvist, Viking Supply Ships, Head of ice operations
Andreas Kjöl, Viking Supply Ships, CCO

Operational challenges and solutions for floating offshore windfarms in areas with sea ice or risk of sea ice. Can effective ice management handle sea ice and make floating windfarm structures in areas with sea possible. Experience from different projects, handling large moored structures in drifting sea ice and how an effective ice management can be used.

Web site: www.viking-ice.com

Short biography: Master mariner and ice advisor with more than 20 years of experience from offshore operation in harsh conditions, arctic operations and ice management.

R&D areas/s: B) Technology

Determining power requirements for de-icing/anti-icing systems for onshore and offshore turbines

Daniela Roeper, Borealis Wind, CA

Daniela Roeper (Borealis Wind, Canada) and Dylan Baxter (Borealis Wind, Canada)

Borealis Wind has created a wind turbine de-icing system that is simple to retrofit to existing wind turbines. The system circulates heated air inside the leading edge cavity of the blade and has been adapted to work in blades with partitions or bulkheads in the leading edge. To develop the system Borealis Wind created a detailed thermodynamics model to determine the heat required for the system based on the size of the blade. Since 2017 Borealis Wind has retrofitted wind turbines at 6 onshore sites in Canada and on 5 different blade models. During this presentation we will show the thermodynamic model used to determine the heating power required, the validation of that model using the 5 different blade models that have been retrofitted and the expected power required for offshore blades, which are significantly larger.

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

Short biography: Daniela is the CEO and Founder of Borealis Wind, a company offering a blade de-icing retrofit for wind turbines. A mechanical engineer by trade, Daniela applies her practical thinking and passion for renewable energy to her company. She is inspired by the opportunity to increase wind power production in cold climates.

R&D areas/s: B) Technology

Development and deployment of a new anti-ice product – an OEM perspective

Stephen Jude Buggy, Vestas Technology UK

Stephen Jude Buggy (Vestas, UK)

The Vestas Anti-icing System (VAS) is a relatively new optional specification applicable for Vestas wind turbines that operate in low temperature, ice affected sites, where the ice conditions can impact and reduce the annual energy produced. The VAS, which is fully integrated in the wind turbine, maintains an ice-free surface on the blades and thereby reduces the aerodynamic impact of ice and the consequent effect on power output. The VAS uses electrothermal heating elements embedded in the blade to remove the ice. The control and monitoring of the VAS is fully integrated into the turbine controller and can be activated automatically via plant control (VestasOnline® Business – a SCADA system), where an ice detection method, e.g., Power Curve Ice Detection (PCID), Vestas Ice Detection (VID) or other ice sensors can be configured to act as the VAS trigger. Provision of manual activation is also provided for specific operational needs.

This presentation captures some of the design challenges met when creating the Vestas anti-icing system for cold climates. It highlights some of the design methods, verification approaches and general experiences in taking an early initial idea through a technology program to becoming a product in the customers hands.

Examples of performance of the initial Vestas Anti-icing Systems (VAS) based on data from some of the early VAS sites that adopted the technology are presented. These sites are representative of icing conditions typical in Northern Europe. The data was captured over a recent winter period. Some of the test data was captured from a single site with neighbouring turbines that did not have anti-icing systems installed and therefore acted as reference turbines to aid with the assessment.

As part of this assessment, some of the metrics used to describe performance are discussed to highlight some of the challenges in using them. Finally, some of the learning gathered using different operating strategies running a turbine with an anti-ice system are reflect on - what works and what doesn't.

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

Short biography: Stephen has been working for Vestas since 2012. Originally working in the blades design area on sensors systems, he now works in the blades protective functions team and has technical responsibility for the cold climate blade systems.

Previously he has worked in academia on optical fibre technologies and monitoring systems and in the power industry for GE - online transformer monitoring systems, and for Pirelli Cables - real time thermal monitoring systems.

He holds a PhD from Cranfield University in optical fibre sensors, and an MSc. and a BEng from the University of Portsmouth in Electrical and Electronic Engineering. He enjoys running up hill, jumping in the sea and spending time with the family.

R&D areas/s: B) Technology, E) Operation, maintenance and forecasting

Numerical study on inversed designed airfoil under adverse weather conditions

Ibrahim Rotich, Eötvös Loránd University, HU

Prof Kollár László

Increasing uncertainties on climate change pose a great challenge to the wind energy industry, with icing hampering the performance. Climatic conditions such as winter icing storms have been hitting some regions in the recent past, causing the stall of wind turbines and causing power surges leading to fatalities. The icing of turbine blades causes microcracking and delamination, resulting in the change of airfoil shape, an increase in the surface roughness, the reduction of lifetime of the wind turbine blades, and structural engineering failures. The surface roughness is determined by environmental and physical features on the wind turbine affecting the flow over the surface due to separation, which leads to the blade's aerodynamic performance degradation.
The study on ice reduction on wind turbines to increase power production due to change in airfoil shape through inverse design combined with numerical studies using ANSYS software is employed. The unfavorable climatic conditions combined with the surface roughness of the resulting ice accretion greatly reduces the performance, making the basis for the study. The surface roughness employed in an inversed-designed airfoil is numerically calculated from the Shin et al. and NASA model, and the performance is compared with that under hypothesized bare blade operating conditions. The study found that the vortices obtained as a consequence of icing impacted the aerodynamic performance and changes on the stall angle due to increased suction power on the airfoil surface. Ice accretion has been independently studied on the airfoil obtained by inverse design with the physical conditions determined by airfoil orientation and free stream velocity. The present study proposes an optimization of operating with ice accretion by considering numerical, physical, and environmental conditions and checking on a potential solution for ice reduction on blades.

Web site: -

Short biography: Ibrahim Kipngeno Rotich is currently a PhD student working under supervision of Professor
Kollár László at Eötvös Loránd University (Savaria Egyetemi Központ), Szombathely. I am currently working on an inverse design of a section of wind blade under adverse weather conditions.