NewEnergyUpdate

Anti-Icing and De-Icing Solutions for Wind Turbines

Mitigate the loss of energy from cold climate blade operations

This article was produced in association with the Wind Operations & Maintenance Canada 2017 Conference

New tools and techniques are helping wind operators cope with icy conditions, delegates heard at the 3rd Annual Wind Optimization & Maintenance Canada conference.

The innovations, aimed at boosting production even during heavy icing, include novel ice detection techniques, anti-icing systems and blade repair processes.

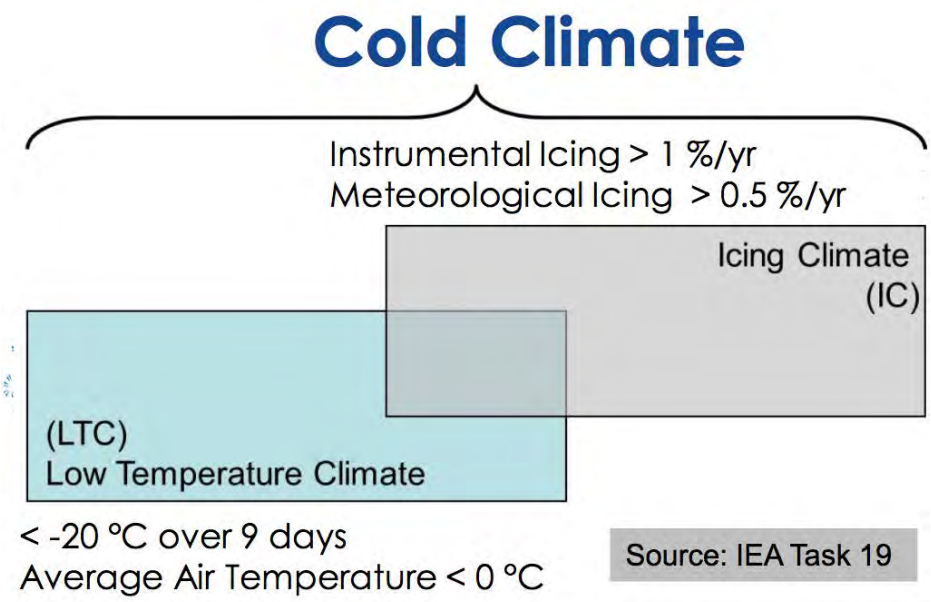
Among the ice detection technologies are oscillation measurement systems from Bosch Rexroth and fos4X. These detect the presence of ice from the way the extra mass affects the natural frequency of rotor blades.

A different approach is being taken by eologix, with a system that uses solar cells to monitor changes in impedance.

The sensors can be placed anywhere on the turbine but the company's technicians "still have to do some improvements in their technology," said Charles Godreau, research analyst at TechnoCentre éolien, which is testing all three technologies.

TechnoCentre éolien is also working with the Natural Sciences and Engineering Research Council of Canada, Senvion and the Cégep de la Gaspésie et des Îles college on a prototype image analysis technology that provides a graphic readout of ice intensity.

The system uses nacelle-mounted cameras, in warmed, ice-free housings, to capture images of icing on the machine and perform an automated analysis of ice depth.



Cold-climate definitions from the International Energy Agency. Source: TechnoCentre éolien.

Such systems complement mapping tools, such as VTT's WIceAtlas maps, that can offer icing predictions with a resolution of down to 50 meters.

Having detailed information on icing is critical in ice-prone markets such as Canada because ice's impact on production can vary greatly from one turbine to another, Godreau said.

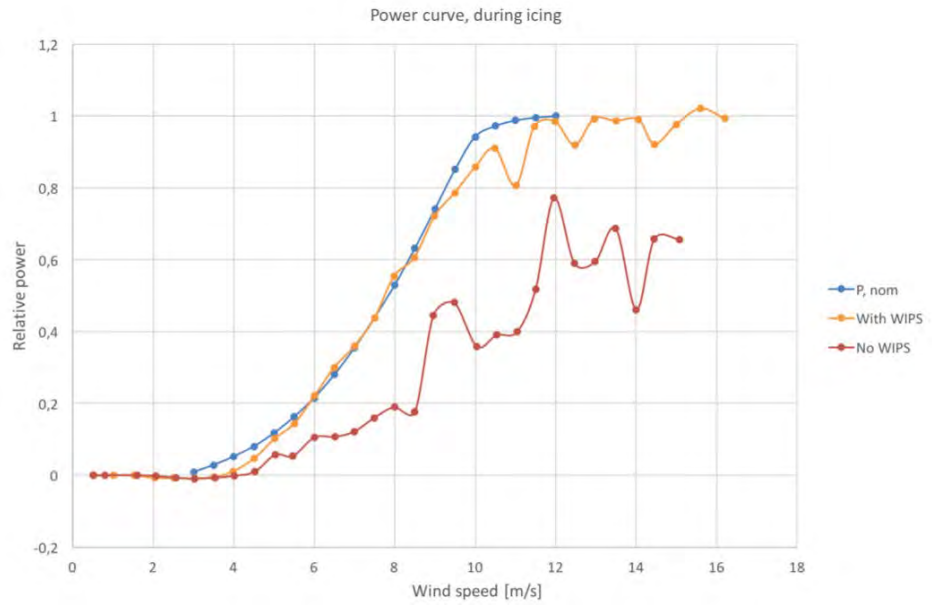
There is a strong correlation between altitude and icing severity, he noted, which means that on a wind farm with up to a 200-meter vertical distance between the highest and lowest turbine it might not be possible to detect blade icing at an average nacelle level.

Furthermore, he said: "Icing is really variable. It might change 100% from one year to another."

Measuring the yearly amount of icing on a turbine is important in evaluating whether it is worth investing in ice mitigation measures, he said, based on the annual energy production (AEP) that could be clawed back.

In cold climates such as Canada's, he said: "There will always be a level of icing losses. The idea is to reduce it. Once you know what you can gain back you're able to look at what capital you're able to invest to reduce the icing losses."

This is complex process because estimates of the AEP gain from ice protection systems are not publicly available, he said. Furthermore, de-icing technologies fall into three main categories, which have different characteristics.



Effect of wind icing protection system (WIPS) against nominal power (P, nom) and no protection. Source: Wicetec.

One of these categories, icephobic coatings, is still in the early stages of development and best suited to less severe icing sites, Godreau said. A second category is electrothermal systems, where electrical power is used to heat up the blade.

These systems can be retrofitted or integrated into blades during manufacture. They are one of the most efficient ways of de-icing blades and can be used tactically to avoid ice whenever an asset owner detects an icing event, said Godreau.

Finally, Enercon and Senvion use hot-air systems to de-ice blades. The technology is efficient, Godreau said, but "there's some concerns about maintaining this equipment and have it work for a long time."

Among the electrothermal options, Wicetec offers a technology that was developed in the early 1990s and has now been installed across more than 275 machines totaling around 700 MW, including an implementation on one project with 99 turbines.

The technology employs a carbon fabric that delivers optimal three-dimensional heat distribution, said Wicetec's CEO, Petteri Anitkainen. It has no aerodynamic effects and its mechanical and heating properties have been tested in the lab and the field, he said.

The technology has also passed lightning tests and the oldest systems have been in operation for more than 18 years. "It has been designed for moderate to severe icing conditions," Anitkainen said.

One northern Swedish wind farm operator tested eight turbines with Wicetec's ice prevention system and found it provided 25% more production than an unprotected turbine, Anitkainen claimed, even during what the client said was the "mildest winter ever."

Production losses

This was equivalent to an 85% claw-back of the production losses caused by ice. There is no data on how this compares to other de-icing systems, however. "Benchmarking is tricky," admitted Anitkainen.

Until now, Wicetec has mainly focused on working with original equipment manufacturers. But in Canada it is moving into the retrofit market in association with East Coast Wind, a wind turbine maintenance firm.

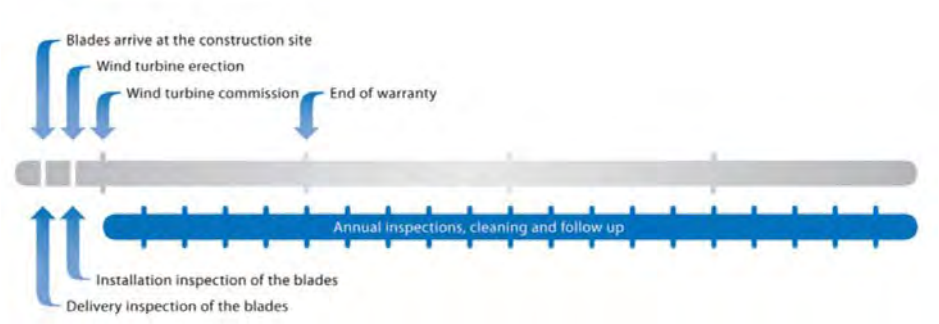
East Coast Wind is testing the Wicetec anti-icing technology on two turbines in Eastern Canada, after having abandoned a cheaper system based on heating mats.

The mats, which East Coast Wind piloted in 2011, had poor resistance to impacts and were difficult to repair. Also, they were connected to the blade using copper crimps that had a tendency to come loose, creating arcs that burned connectors.

Adding to the problem was the large number of connections needed for the mats. They required 246 connections per blade, compared to just two for Wicetec's anti-icing systems.

The experience taught East Coast Wind not to be "tempted by inexpensive solutions," said Steven Fugere, vice president of business development.

Retrofitting de-icing systems to blades should not be done up-tower, he added, so asset owners should choose a provider that can offer a site factory. East Coast Wind is looking to deliver a proof of concept of the Wicetec system with a customer in 2017, Fugere said.



Preventive blade maintenance schedule. Source: Bladefence.

As well as from anti-icing systems such as Wicetec, the Canadian wind industry is now benefiting from recently introduced ice damage remediation technologies including one offered by Bladefence, a north European service provider that was established in 2010.

Bladefence entered the Canadian market in 2016 with a GL-certified modified epoxy-based resin blade repair system that uses UV curing and can be used to make repairs in situ.

The system, compatible with polyester, epoxy and vinylester-based blades, is quicker and more flexible than traditional blade repair methods, according to Ville Karkkolanien, Bladefence's managing director.

Standard blade repairs have curing times measured in hours and usually require an ambient temperature above 15ºC and a relative humidity below 60%, he said. This limits in-situ repairs to the summer months.

The Bladefence resin, in contrast, can be applied in temperatures down to 5ºC, with a relative humidity of up to 90%, and cures in minutes using UV light. It also creates less waste than traditional blade repair processes, Karkkolanien said.

Along with other innovations to improve operations under icy conditions, the Bladefence technology is expected to offer significant benefits to Canadian wind farm operators, which face considerable losses from icing.

"I don't believe anyone would doubt we have cold climate in Canada," said Godreau of TechnoCentre éolien, but cold in itself is not a challenge since many turbines were now capable of operating down to -30ºC.

Instead, icing is the main climatic problem facing the Canadian wind industry, with in-cloud icing, in particular, posing a significant problem across the east of the country.

"In-cloud icing is the main driver for all icing events we see in eastern Canada," Godreau said, and is the main factor asset owners should consider when building a de-icing business case.

Vent de l'Est | East Coast Wind
Entretien d'éolienne Wind Turbine Maintenance

Anti Icing Retrofit Project

Eastern Canada 2016

ECW previous experience with anti-icing solutions

- 2011: Test Pilot in Eastern Canada
  - Type of Technology used:
    - Heating matts interconnected every 9 feet from the tip of the blade to ¾ of the root
    - Heater attached to the surface using presure adhesive.

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Technology flaws

- Poor erosion protection and fragile heating elements
  - Poor resistance to impacts
  - Questionable material choices
  - Grafite is like powder and cannot be repaired unless you change the affected section.

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Entretien d'éolienne Wind Turbine Maintenance

Technology flaws

- Weak connections
  - No mechanical connection, copper crimps
  - Crimps become loose with time creating arcs which burn connectors
  - **There was 246 connectors per blade!!**

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Entretien d'éolienne Wind Turbine Maintenance

Technology flaws

- Delamination
  - Presure adhesive traps moisture between blade and heater
  - When in service, humidity trapped under tend to expend and creates air bubbles that will ultimatly lead to catastrophic failures
  - When delaminating, it pulls on the heaters next to it.

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Been There, Done That!

- It's been a rough ride but we learned!

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Entretien d'éolienne Wind Turbine Maintenance

!!WARNING!!

- If you are looking into an Active system that will last your blades' life, do not be tempted by:
  - Inexpensive solution using low power
  - Up tower installation
  - *Good bargain for proof of concept or technology validation!!!!*

➢Ask for:

- References from hand users, Preferably a happy customer
- Track reccord
- A mature technology
- **Us, East Coast Wind**

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2016 Wicetec Anti Icing Solution Project

- 2 tests turbines in Eastern Canada
- Commissioning in December 2016
- December to April testing period
- Performance assessment by the Technocenter.
- Real time visual monitoring using hub cameras on retrofited turbines.
- 2 reference turbines with mounted cameras

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2016 Wicetec Anti Icing Solution Project

- Full Scale lightning strike testing for validation of WIPS position related to blade lightning protection configuration.

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Entretien d'éolienne Wind Turbine Maintenance

Retrofit requirements to obtain high quality installation?

- Blades on the ground
- Site factory

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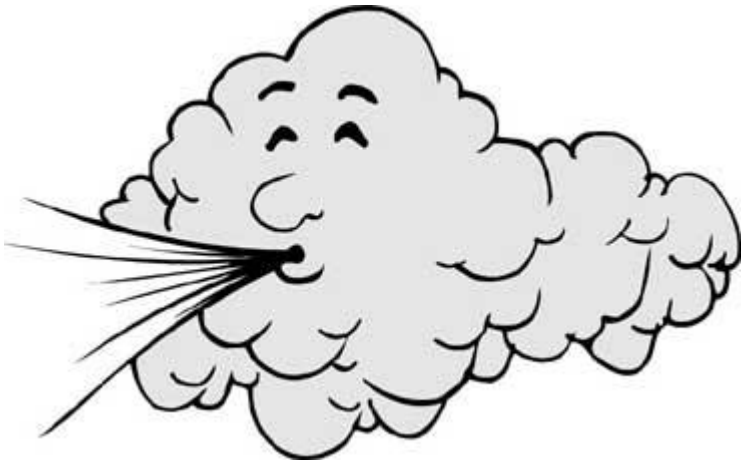
Retrofit requirements to obtain high quality installation?

- Protected from the element to minimize schedule delays and enhanced QC



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Retrofit requirements to obtain high quality standart!

- High quality lamination with experienced techniciens

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Remember, 246 connectors per blade

We have 2 per blade!!

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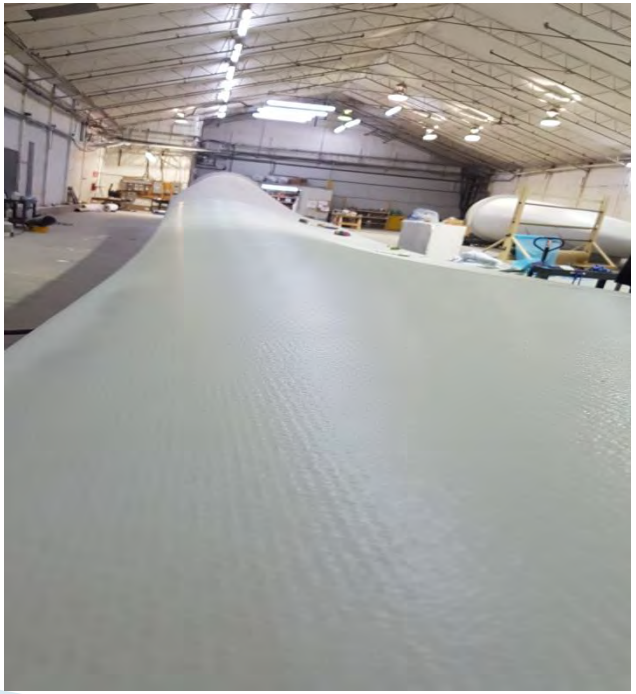
High Quality Retrofit results

- The blade looks original
- The magic is underneath, what you can't see!



Vent de l'Est | East Coast Wind
Entretien d'éolienne Wind Turbine Maintenance

For a Reliable, Proven Anti Icing Solution Retrofit

- We are taking orders for 2017
- Book now!

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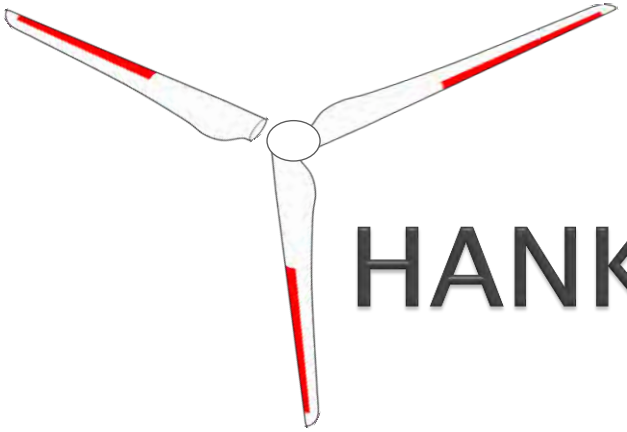
WICETEC
Ice Prevention Systems



HANK YOU

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WICETEC
Ice Prevention Systems

TechnoCentre éolien
Wind Energy TechnoCentre

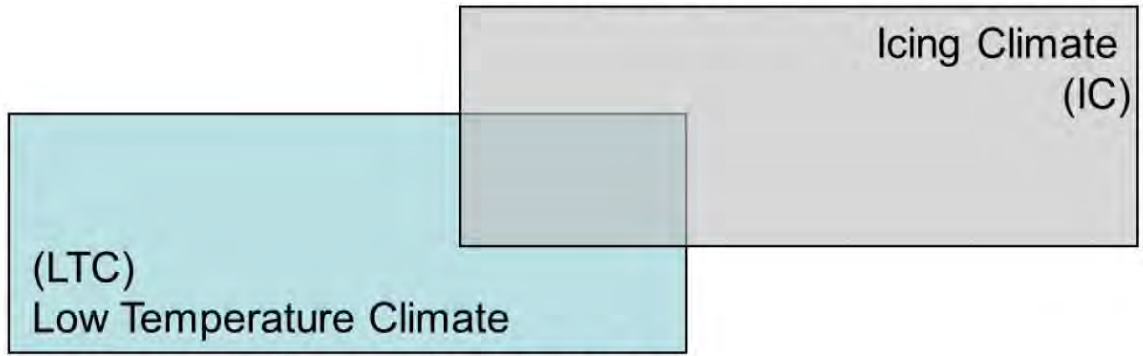
Develop a Business Case that Optimizes Cold Climate Generation

Cold Climate

What is it?

Cold Climate

Instrumental Icing > 1 %/yr
Meteorological Icing > 0.5 %/yr



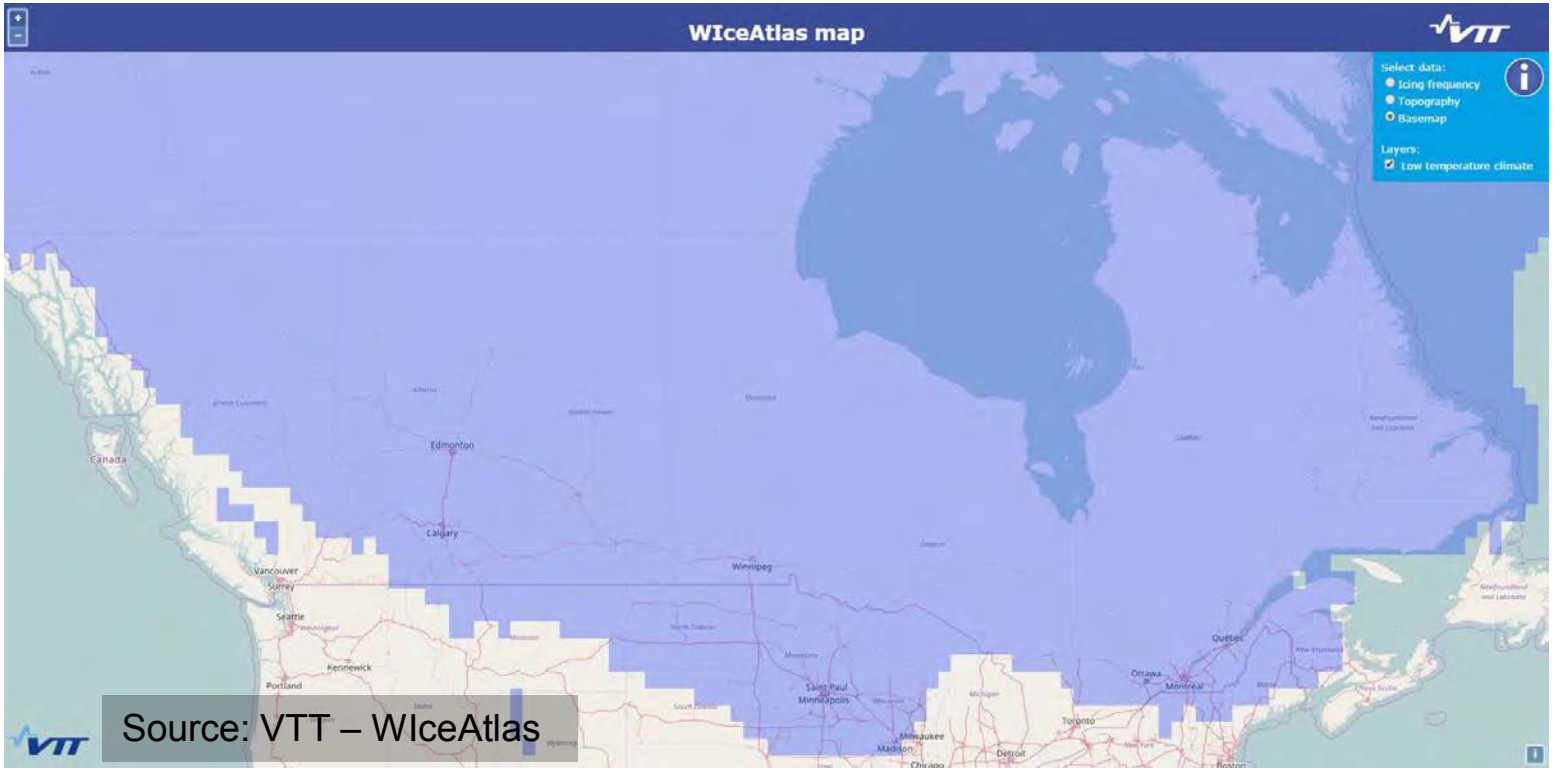
< -20 °C over 9 days
Average Air Temperature < 0 °C

Source: IEA Task 19

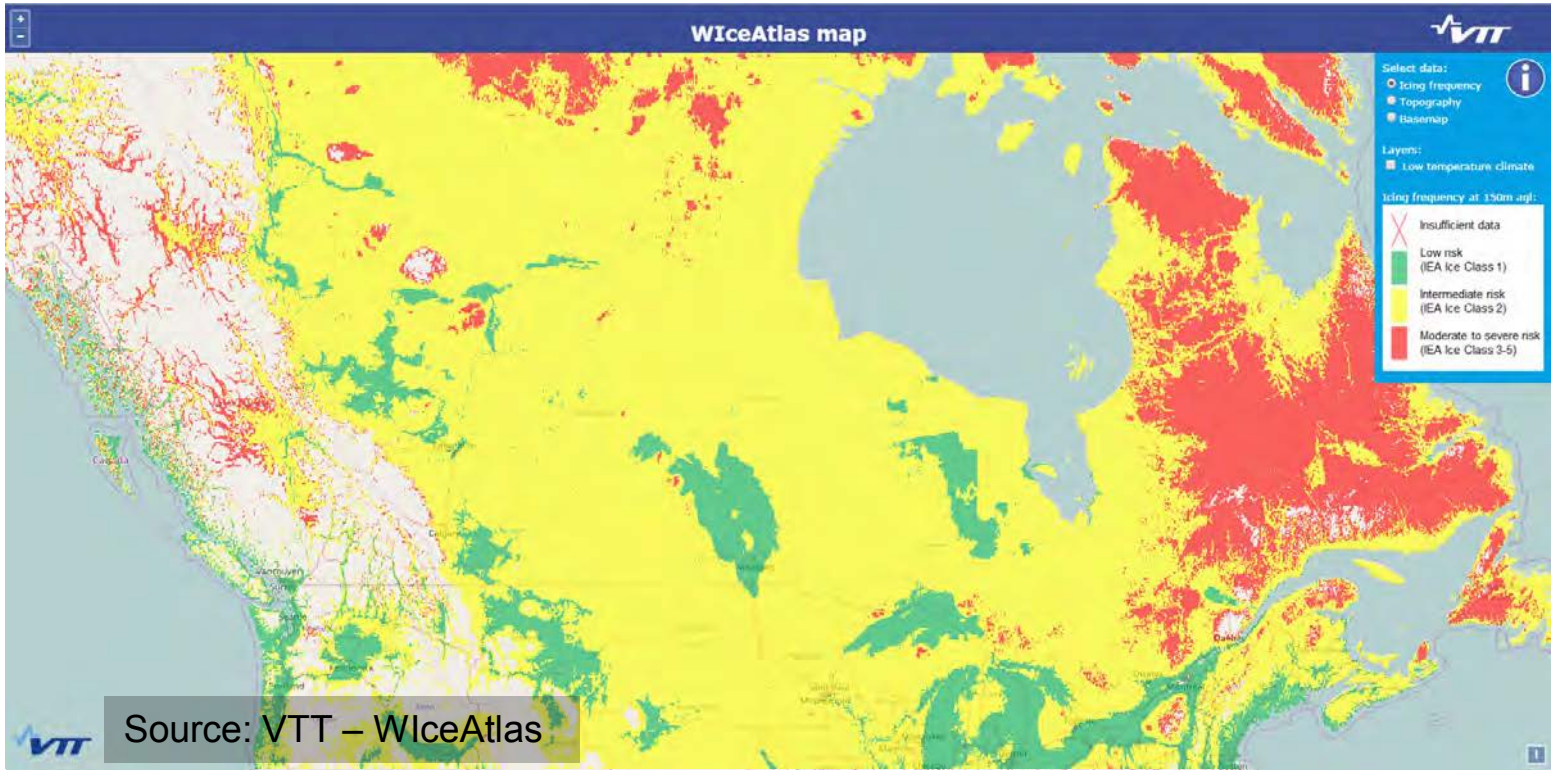
Canadian Cold Climate

Source: VTT – WIceAtlas

Low Temperature



Icing

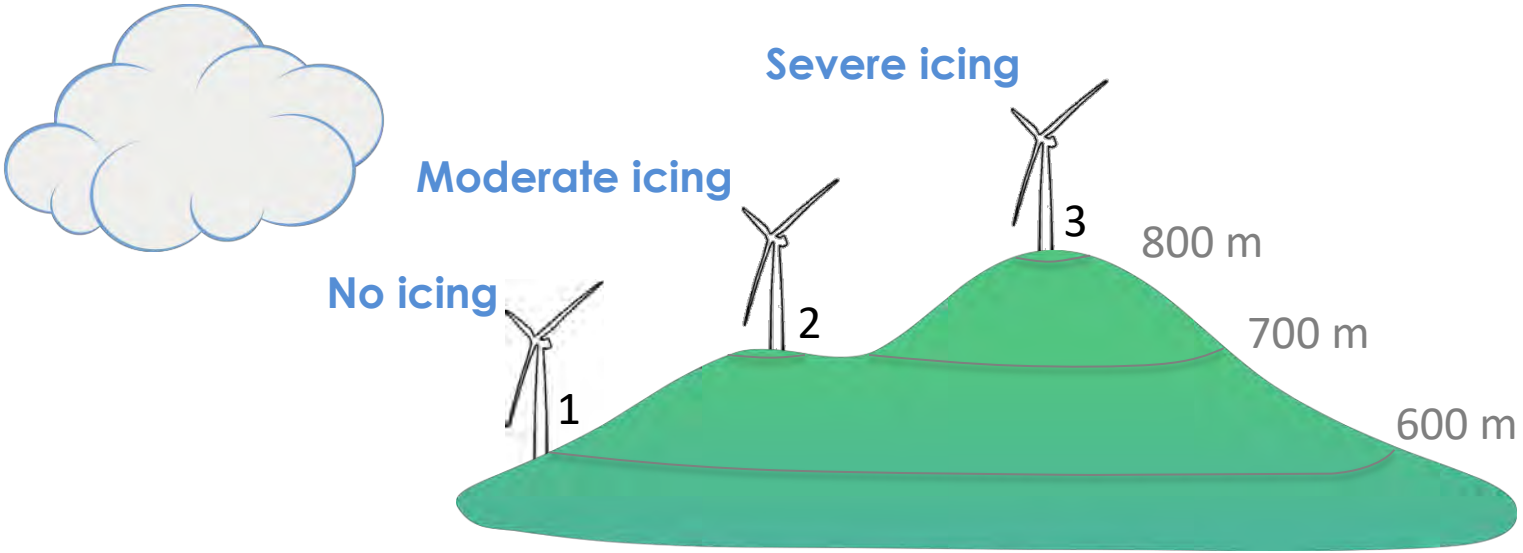


Source: VTT – WIceAtlas

Icing Process

Icing Process

and how it affects wind turbines

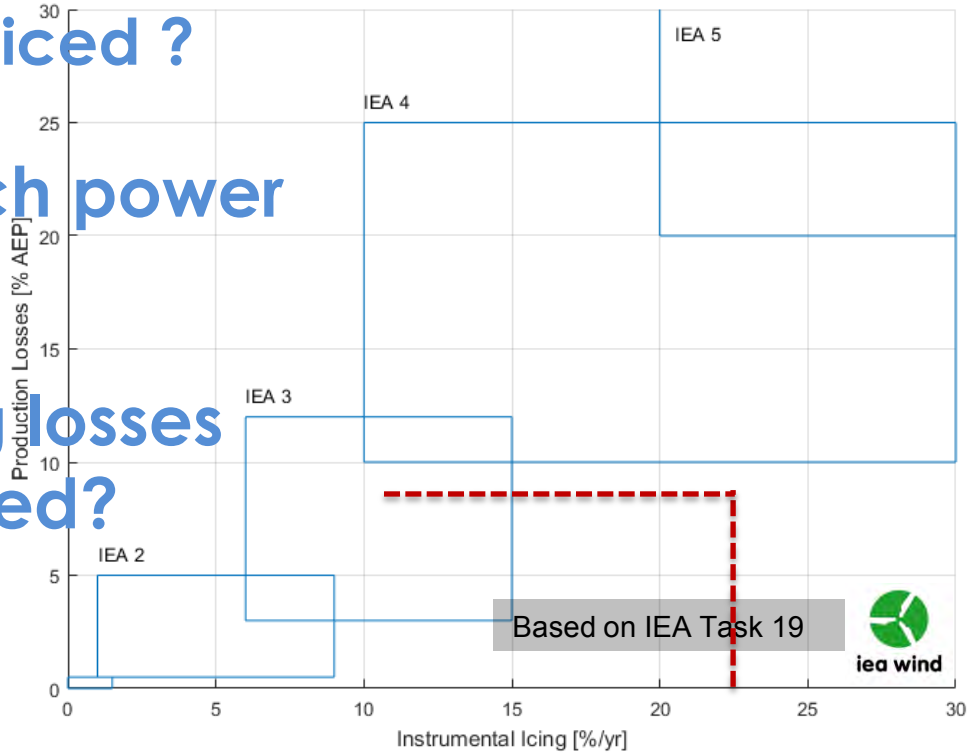


Assessing Power Reduction

When is it iced ?

How much power is lost ?

Can icing losses be reduced?



TechnoCentre éolien
Wind Energy TechnoCentre

TCE Research

CRSNG
NSERC

SENVION
wind energy solutions

Cégep de la Gaspésie
et des Îles

TechnoCentre éolien
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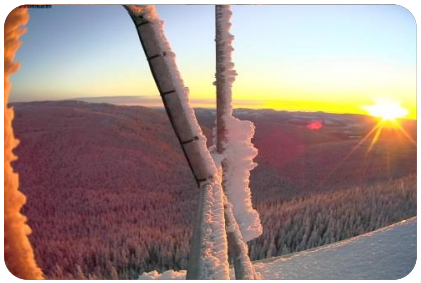
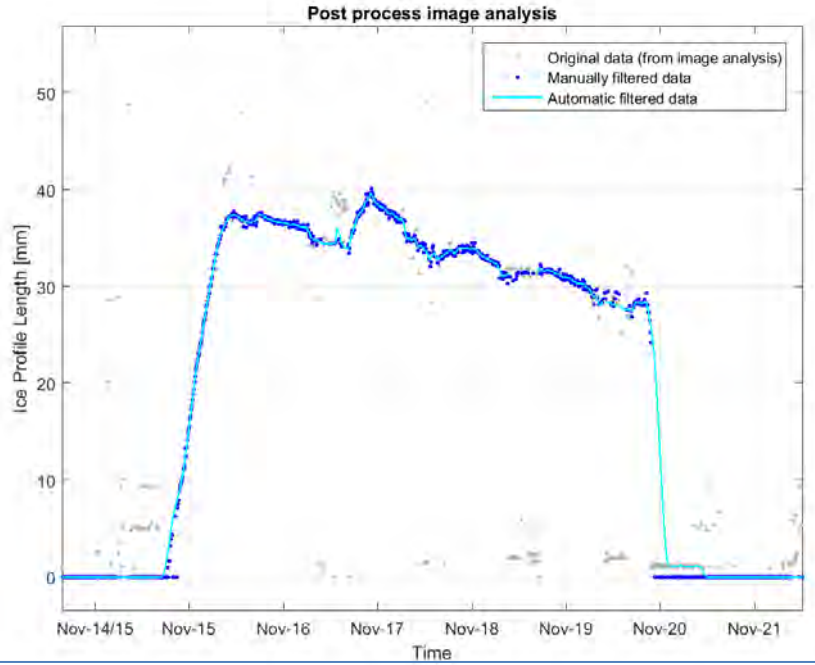
TCE Research

Ice Detection with Image analysis

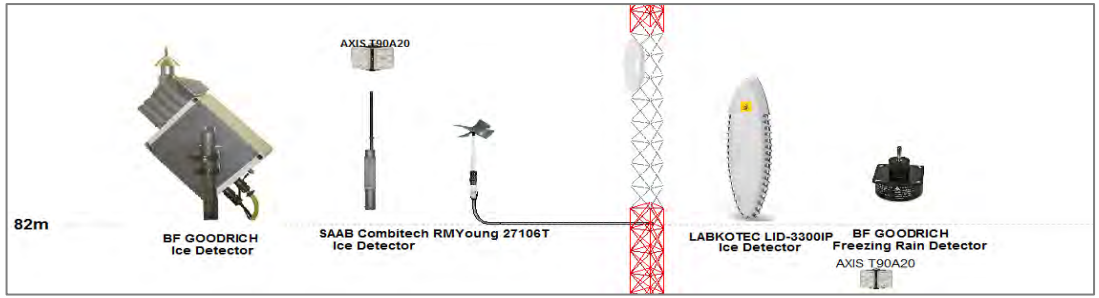




TCE Research

Ice Detection with dedicated sensors

Weather Mast



Rotor Icing Detectors

Rexroth Bosch Group

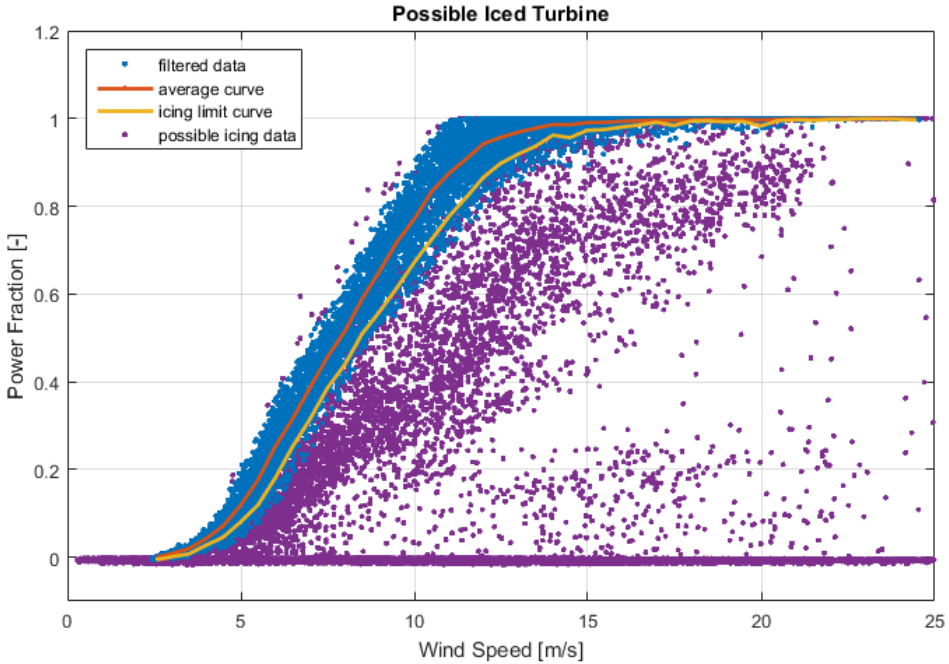
fos4X

eologix sensor technology

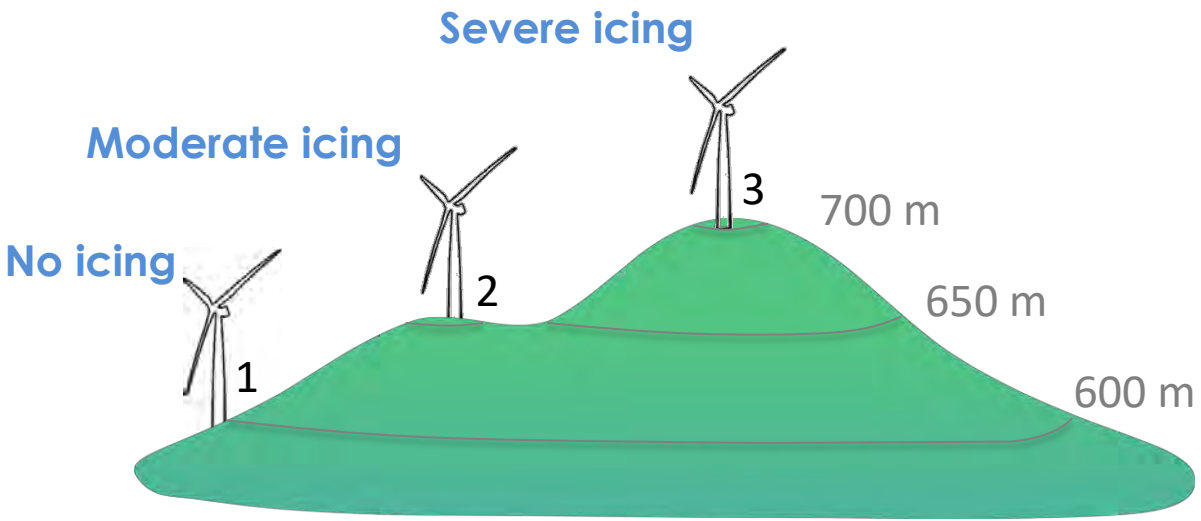
Wölfel

TCE Research

Power Loss Evaluation – Power Curve Method



Icing Business Case



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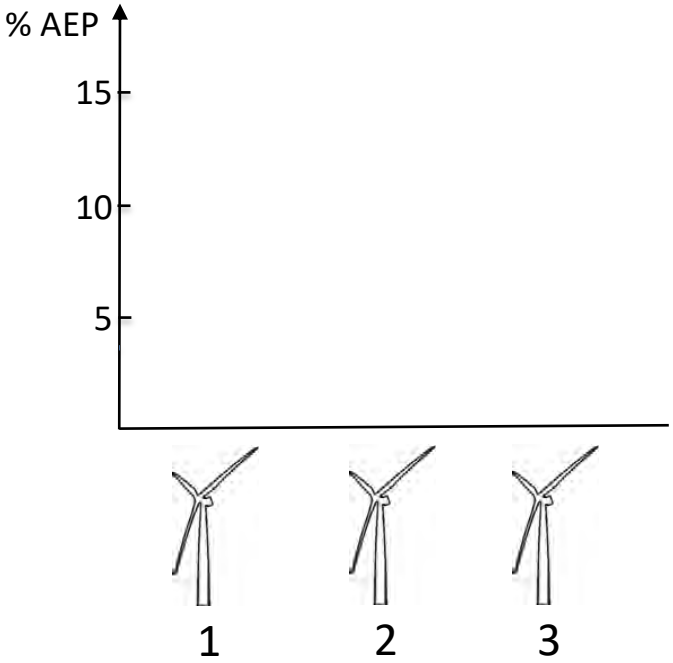
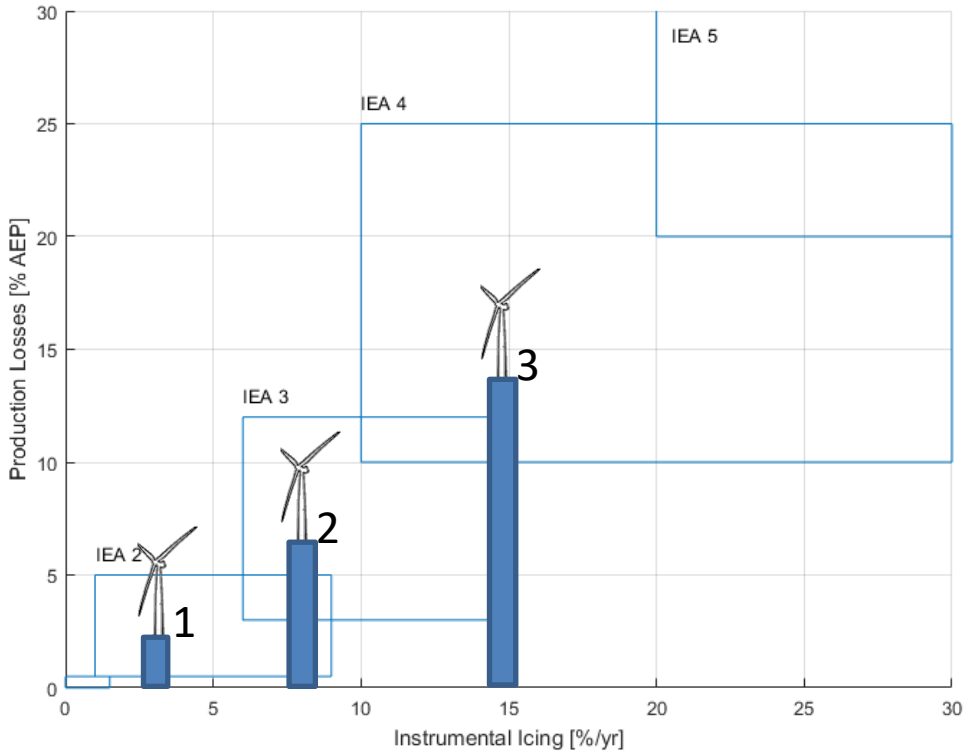
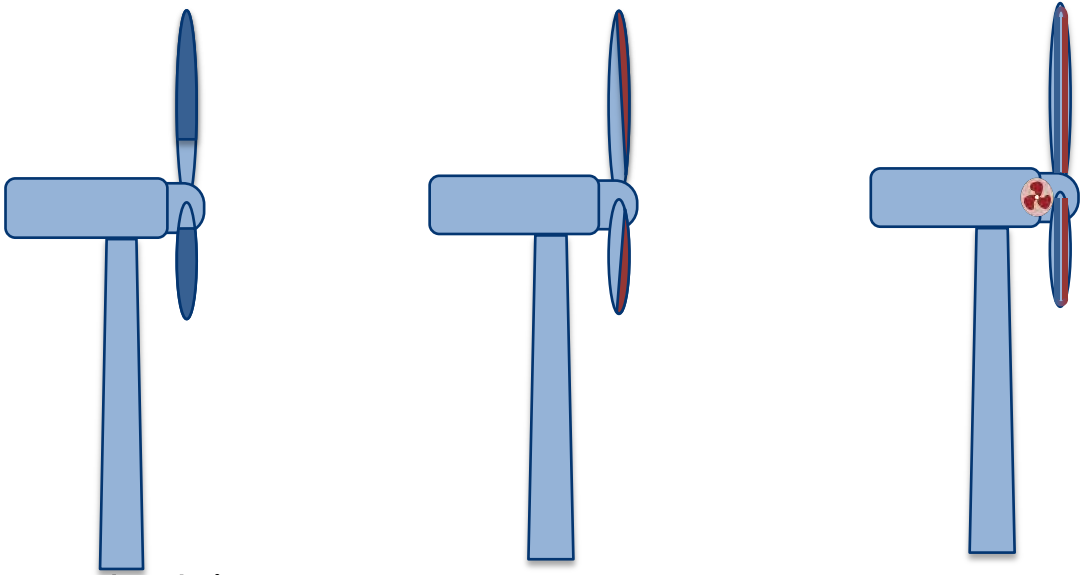




TCE Research

Ice Protection Systems

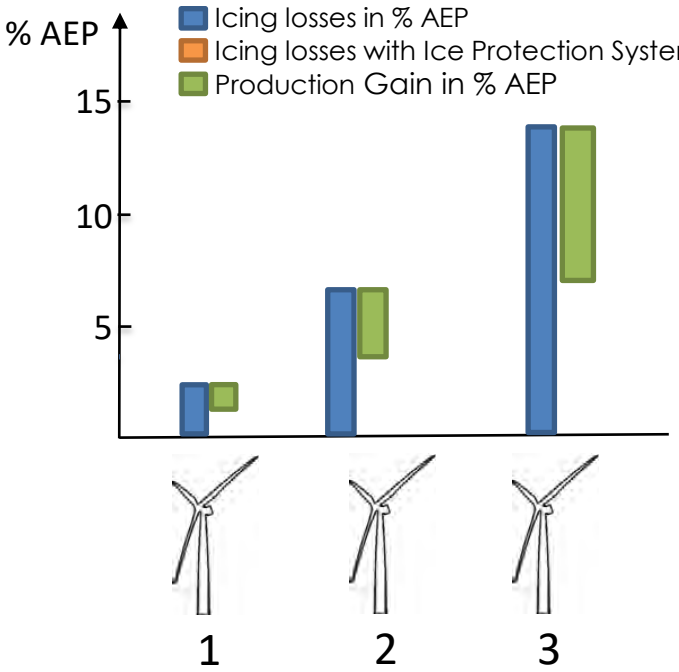


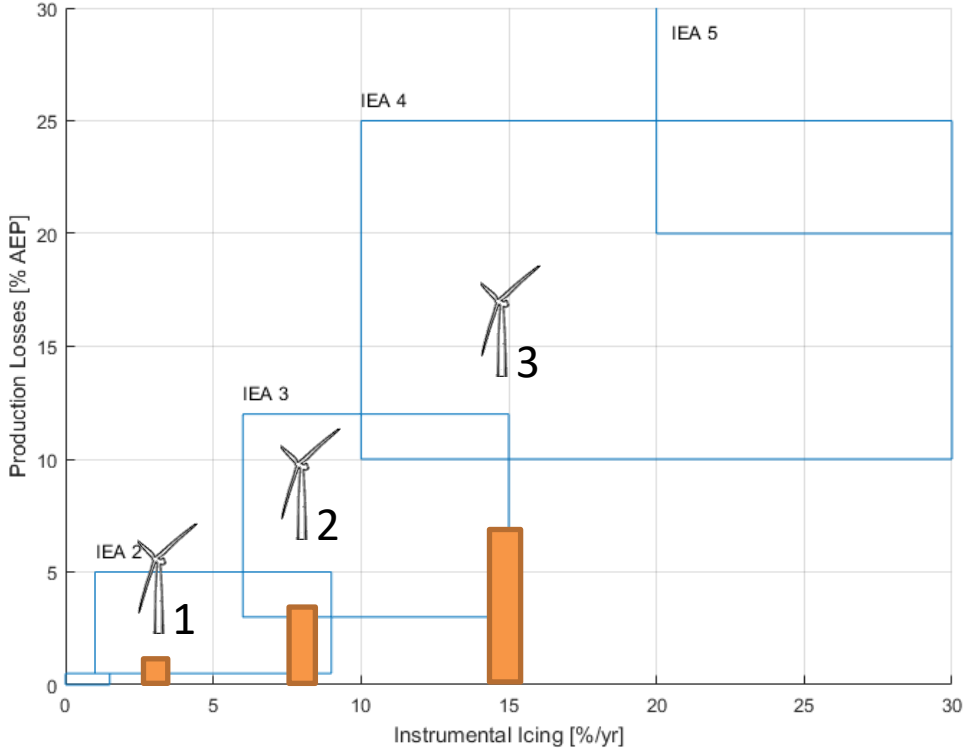
Icephobic Coating

Electrothermal

Hot Air

Icing Business Case





Key Takeaways

- Measure icing time
- Measure production losses
- Calculate the AEP gain from an Ice Protection System
- Do the math !

Thank you !

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WICETEC
Ice Prevention Systems

Ice Prevention Systems
for wind turbines

- Lowering uncertainty -
- Increasing availability -

2016

Raimo Huuhtanen, Vapo

WICETEC
Ice Prevention Systems

Company description

- Ice Prevention System (IPS) supplier for any wind turbine
- Founders have 30 years of experience in cold climate wind power
- Technology developed in research institute (VTT) since early 90’s
- IPR for IPS technology owned by Wicetec.
- 30 systems commissioned 2015
- 10-30 systems for 2016

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Activities

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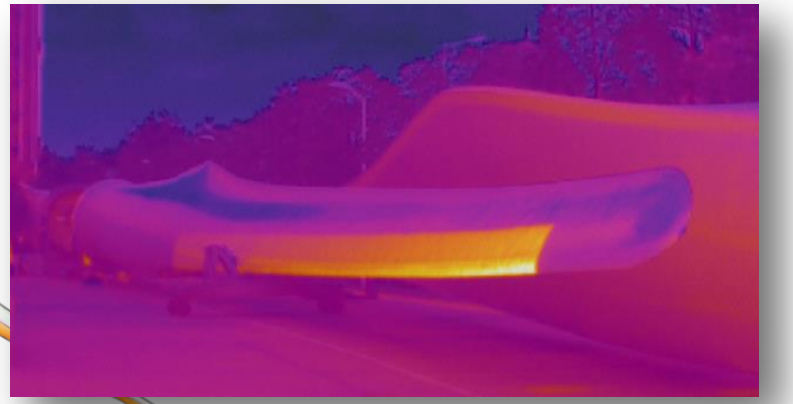
WIPS Heating elements

- Carbon fabric
- Optimal 3D heat distribution
- No aerodynamical effects
- Mechanical and heating properties tested in lab and field
- Several lightning tests passed
- Oldest systems in operation > 18 years!



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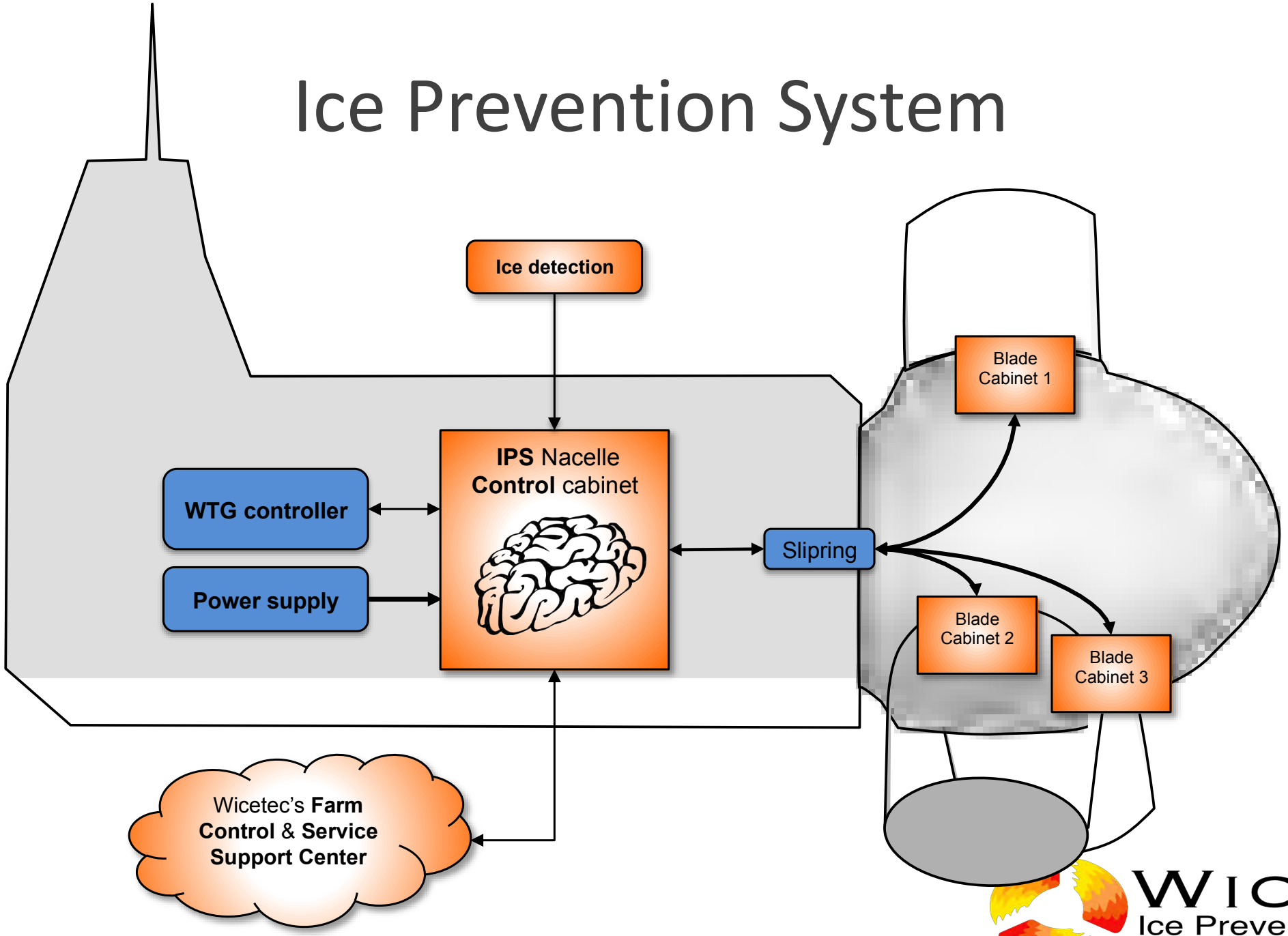
Ice Prevention System



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Ice Prevention Systems

Ice Prevention System

- Anti-icing approach (de-icing possible)
- For moderate to severe icing conditions
- Benefits
  - Allows efficient continuous turbine operation
  - No stoppages due to icing
  - Low operating costs
  - High availability

WICETEC
Ice Prevention Systems

Track record of IPS technology
Early days, research installations

Research installations:			
Site Location:	Size:	Year:	OEM:
Pyhätunturi (FI)	2.5 kW	1991	-
Jyppyrä (FI)	65 kW	1993	Nordtank
Pyhätunturi (FI)	220 kW	1993	Wind World

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Ice Prevention Systems

Track record of IPS tecnology

Demonstration and Commercial installations:				
Location:	Size:	Year:	OEM	Owner
Lammasoaivi (FI)	2 x 450 kW	1996	Bonus	
Olostunturi & Lammasoaivi (FI)	6 x 600 kW	1998-99	Bonus	
Suorva & Rodåvålen (SE)	2 x 600 kW	1998	Bonus	
Pori & Kotka (FI)	6 x 1 MW	1999	Bonus	
Uljabuouda (SE)	10 x 3 MW	2009-10	Winwind	SKAB
Jokkmokksliden-Storliden (SE)	17 x 2.5 MW	2010-11	Nordex	SKAB
Blaiken I & II (SE)	60 x 2.5 MW	2012-13	Nordex	SKAB/Fortum
Sites in Sweden	10 x 2.5 MW	2012-14	Nordex	
Sites in Finland and Sweden	67 x 3 MW	2013-16	Nordex	
Sites in Finland and Sweden	39 x 3 MW	2017	Nordex	
Tornio (FI)	1 x 4.5 MW	2016	Gamesa	
Blaiken III (SE)	30 x 2.5 MW	2015	Dongfang	SKAB/Fortum
Blaiken IV (SE)	9 x 2.5 MW	2016	Dongfang	SKAB/Fortum
China	1 x 2.5 MW	2016	Envision	
Canada	2 x	2016	Retrofit	
Ulyanovsk (RU)	14 x 2.5 MW	2017	Dongfang	Fortum
Total	718 MW / 275 turbines			

WICETEC
Ice Prevention Systems

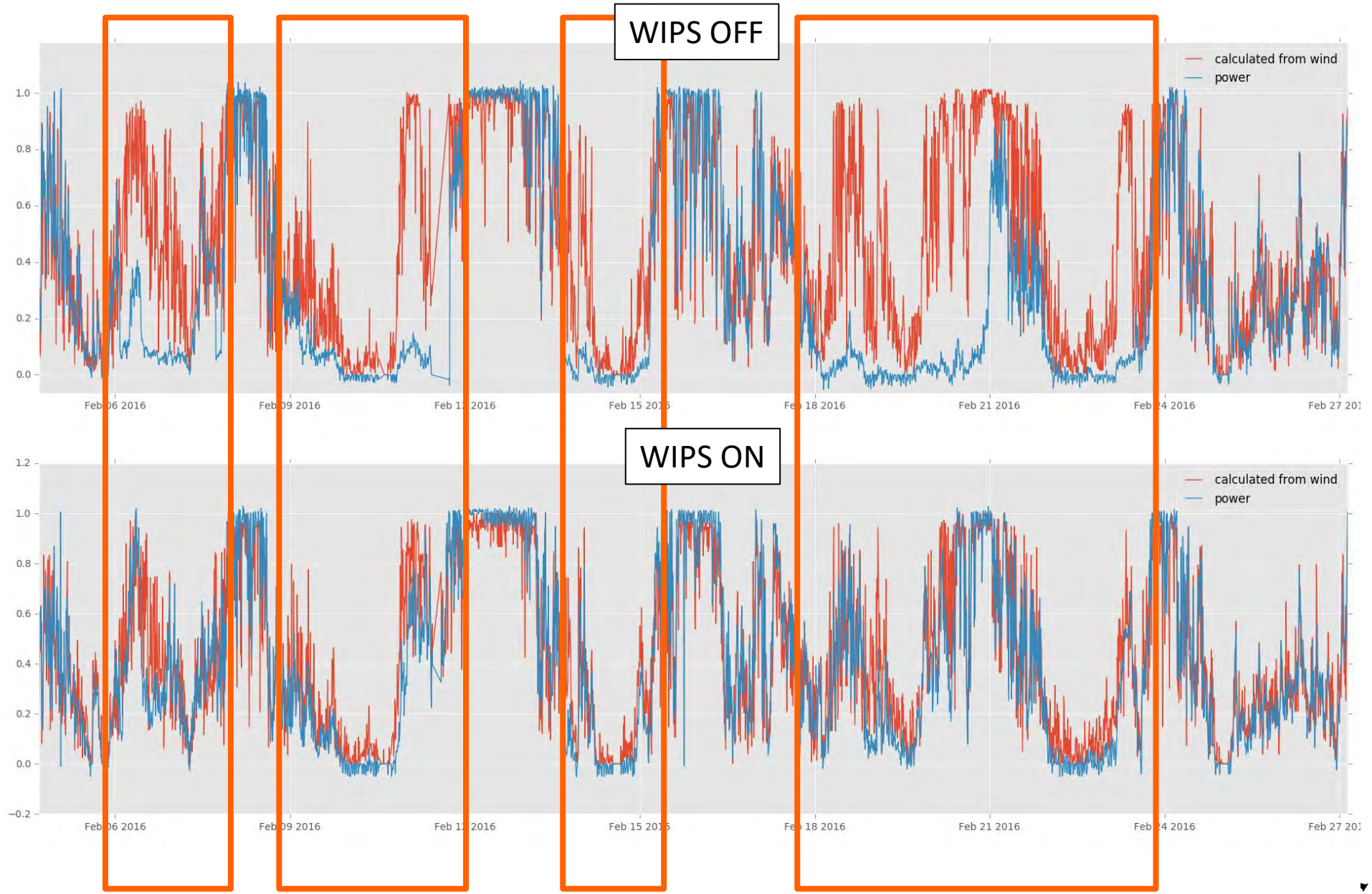
Experience from Sweden Feb 2016

- Test data:
  - 8 turbines with WIPS on
  - 1 turbine with WIPS off
  - February only full test month
- Analysis using T19 production loss -tool

- 25% more production with WIPS!!

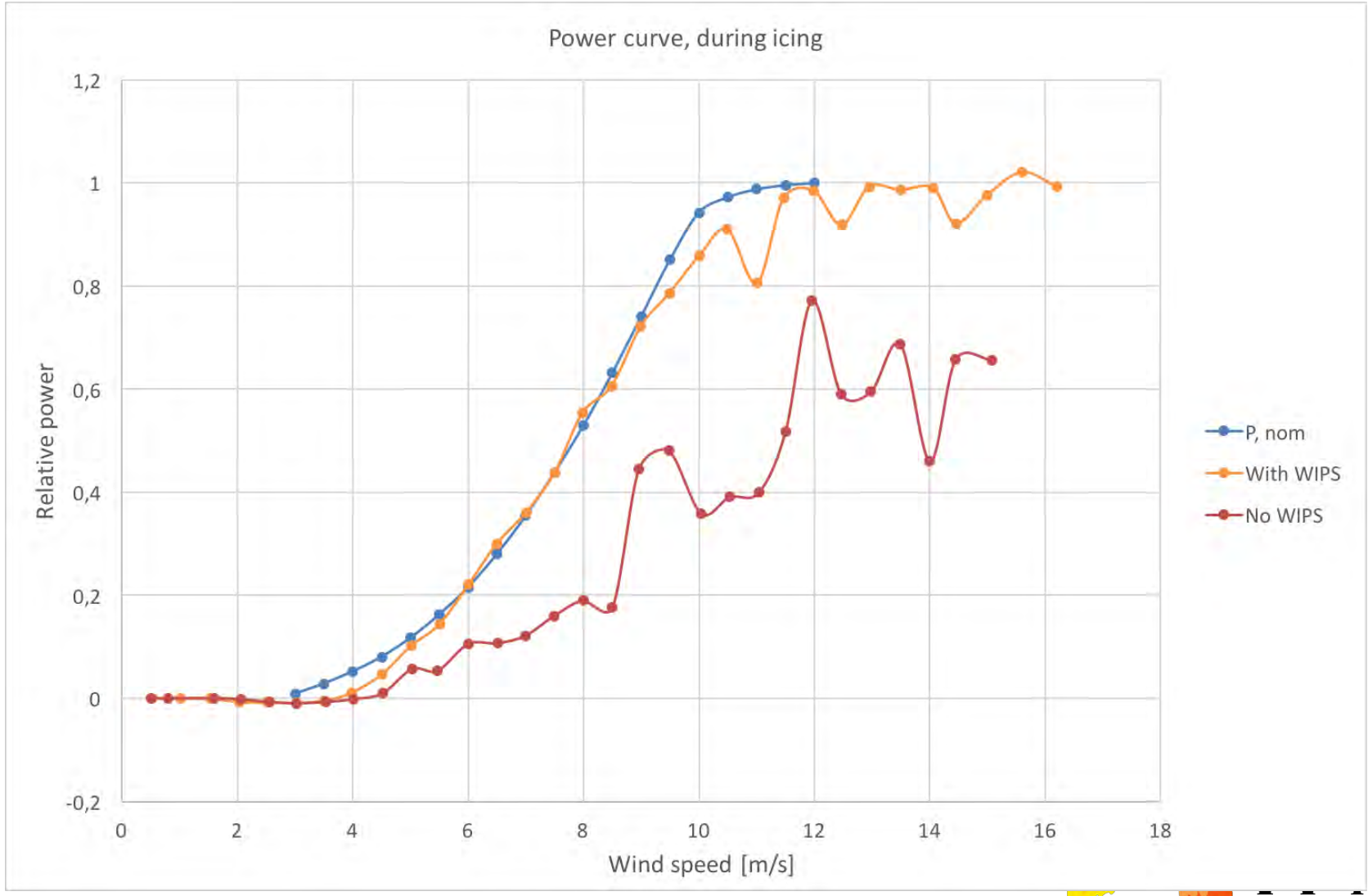
- Wind farm owner's comment: "mildest winter ever"

WICETEC
Ice Prevention Systems



METEC
Ice Prevention Systems

Experience from Sweden 2/2016



CETEC
Ice Prevention Systems

Retrofit

- Co-operation with East Coast Wind / Vent de l’est
- Test project for two turbines in Canada, installation in autumn 2016
- Test project planned in the USA, autumn 2016

VENT DE L'EST
EAST COAST WIND

WICETEC
Ice Prevention Systems

Retrofit

Factory-like installation

- Blades down
- Site factory work
- Weather risk for project schedule minimized
- High quality lamination

Requirements to wind turbine

- power to the hub → slip-ring adaptation

WICETEC
Ice Prevention Systems

With Ice Prevention System your cold climate project profitability is increased!

WICETEC
Ice Prevention Systems

Visit
wicetec.com!

Contact:

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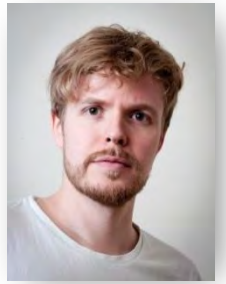

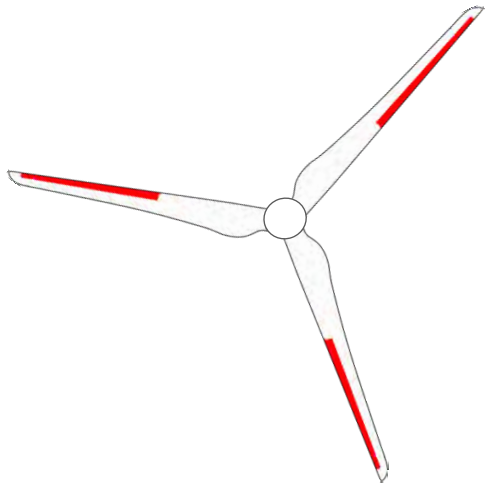

- Increasing availability -

WICETEC
Ice Prevention Systems

MITIGATE LOSS OF ENERGY FROM COLD CLIMATE BLADE OPERATIONS

BLADEFENCE - VILLE KARKKOLAINEN

3RD WIND OPTIMIZATION & MAINTENANCE CANADA

TORONTO, ON – 29 NOVEMBER 2016

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AGENDA

- BLADEFENCE IN SHORT
- BLADE INSPECTIONS, WHERE TO?
- BLADE MAINTENANCE STRATEGIES
- COLD CLIMATE REPAIRS AND MAINTENANCE
- CASE STUDIES

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BLADEFENCE IN SHORT

- Established in 2010
- Leading independent Blade service provider in Northern Europe
- Bladefence Canada Ltd. started operations in the spring of 2016
- Part of Janneniska group, the leading provider of skylift services in Northern Europe
- Group revenue 2016 ~ 10M €
- Total personnel ~ 75

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BLADEFENCE IN SHORT

PROJECT SERVICES:

- VISUAL AND NDT INSPECTIONS
- BLADE REPAIRS
- BLADE RETROFITS (PROTECTIVE TAPE, AERODYNAMIC DEVICES)
- BLADE CLEANING AND ANTI-/DE-ICING
- BLADE BALANCING

SPINDURANCE BLADE MAINTENANCE AGREEMENT

- LONG-TERM CONTRACT (3 OR MORE YEARS)
- PRE-EMPTIVE MAINTENANCE
- REDUCED TURBINE DOWNTIME AND INCREASED PRODUCTION

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GATHERING BLADE CONDITION DATA

- Several methods available
- Access is nowadays a lesser problem
- Each method have advantages and disadvantages

Source: www.atsite.dk

Source: www.offshorewind.biz

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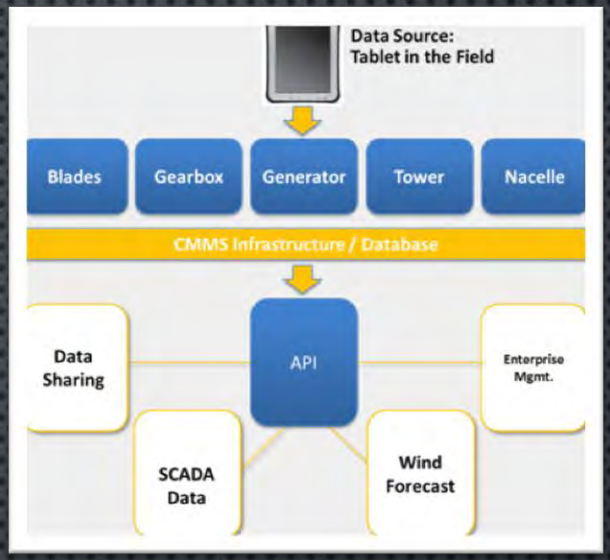
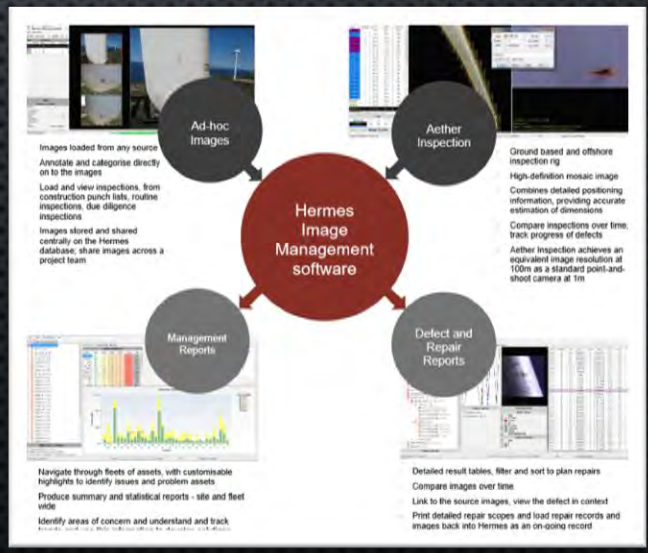
FROM DATA TO INSIGHT

- Blade Condition Data has often been gathered without continuity and consistency
- No clear industry standards or taxonomy has existed, but progress is happening
- Lack of reliable and consistent blade data is major source of problems when planning maintenance
- No information is information as well
- Patterns emerge even with relatively small sample



Source: Muir Data Systems



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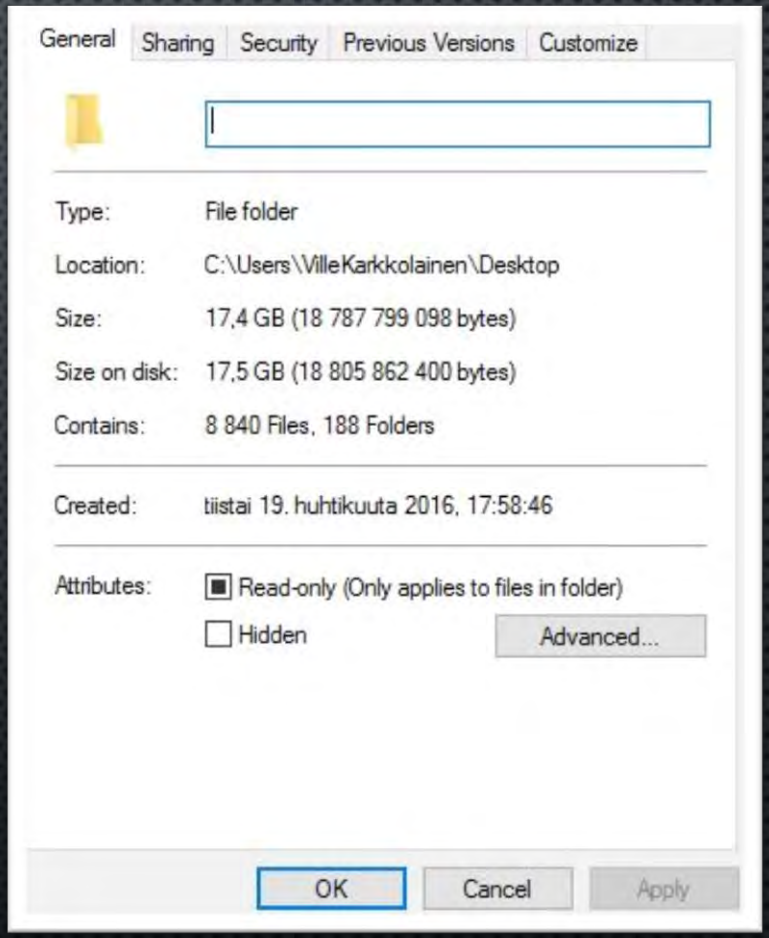
FROM DATA TO INSIGHT

- Blade Condition Data has often been gathered without continuity and consistency
- No clear industry standards or taxonomy has existed, but progress is happening
- Lack of reliable and consistent blade data is major source of problems when planning maintenance strategy
- Different parties may have different perspectives and incentives to gather data



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WHAT IS GOOD DATA?

- THE USAGE AND NEED WILL DEFINE THE PROCESS AND STRUCTURE
- OVERALL ASSET MANAGEMENT HAVE DIFFERENT NEEDS THAN TACTICAL WORK SITUATIONS
- IN THE BEST POSSIBLE SCENARIO THE FIELD DATA IS EASILY TRANSFERRED INTO STRATEGIC OVERVIEW FOR ASSET MANAGEMENT AND THEN JUST AS EASILY CONVERTED IN TO WORK ORDERS AND SUBSEQUENTLY REPORTS

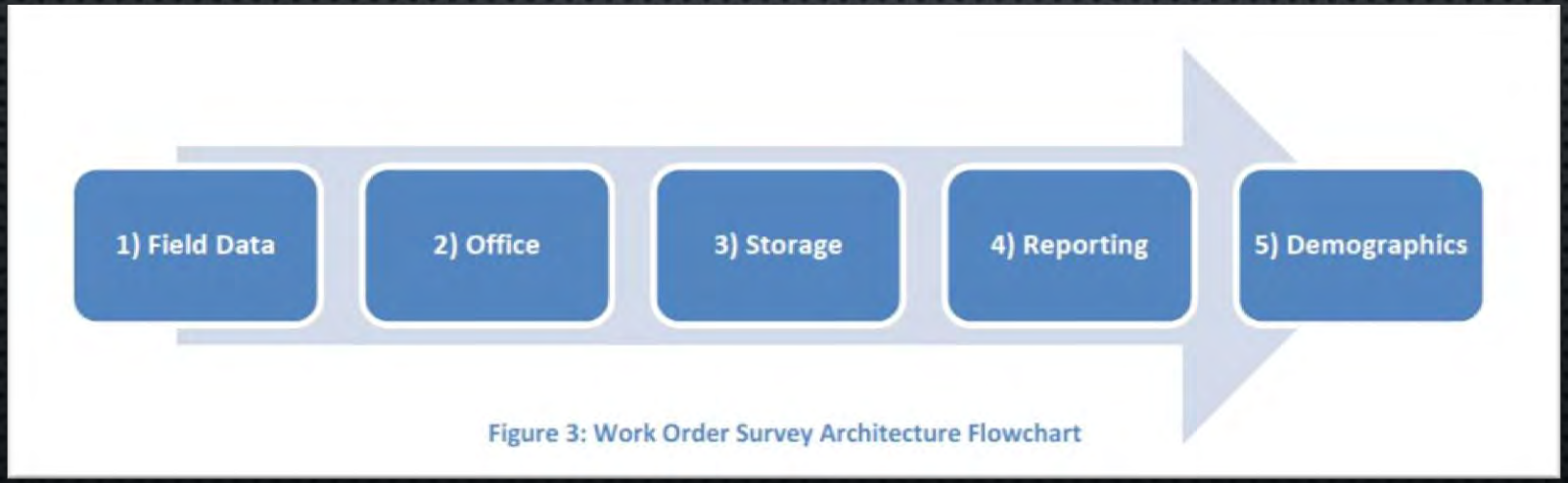

Figure 3: Work Order Survey Architecture Flowchart

SOURCE: MUIR DATA SYSTEMS

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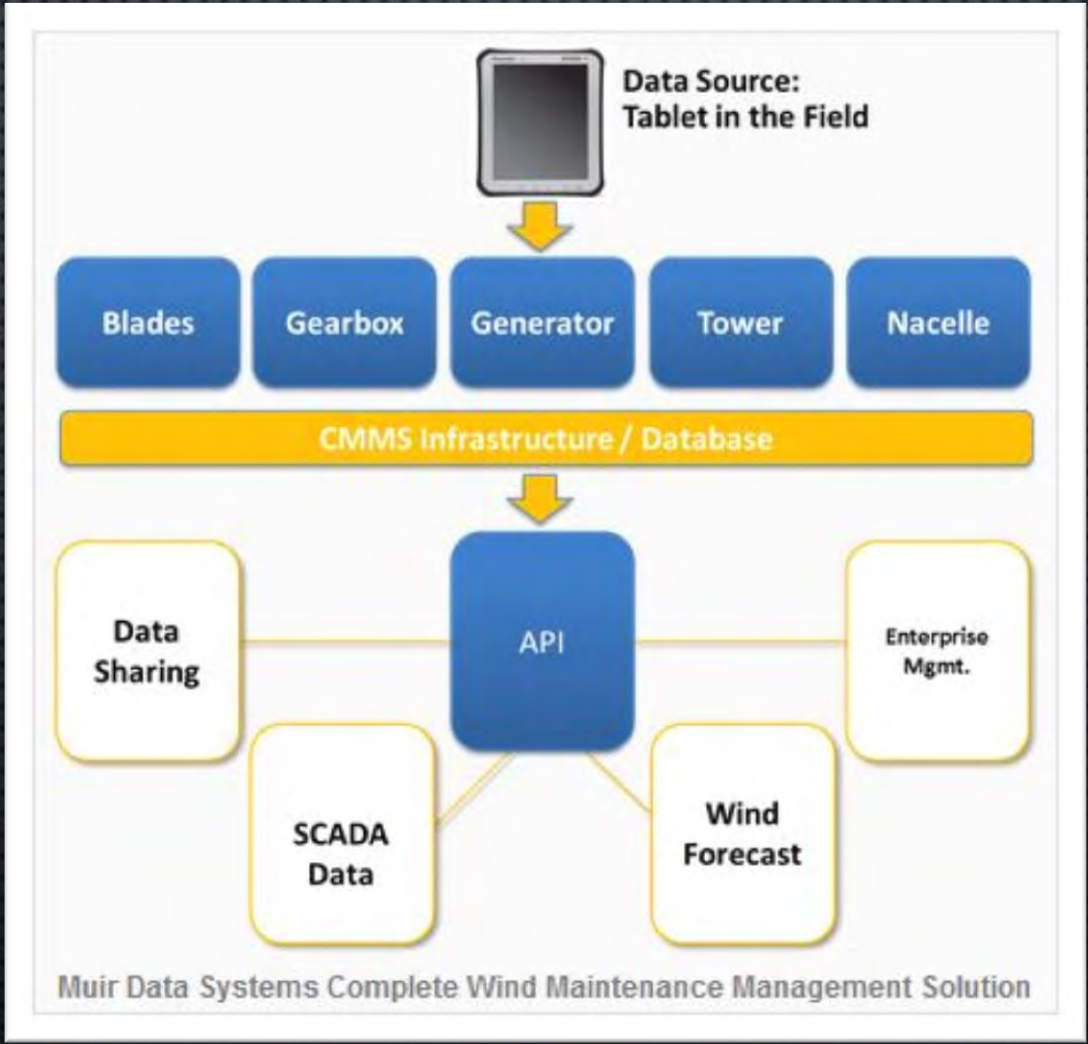
TOWARDS CONSISTENT DATA



SOURCE: MUIR DATA SYSTEMS

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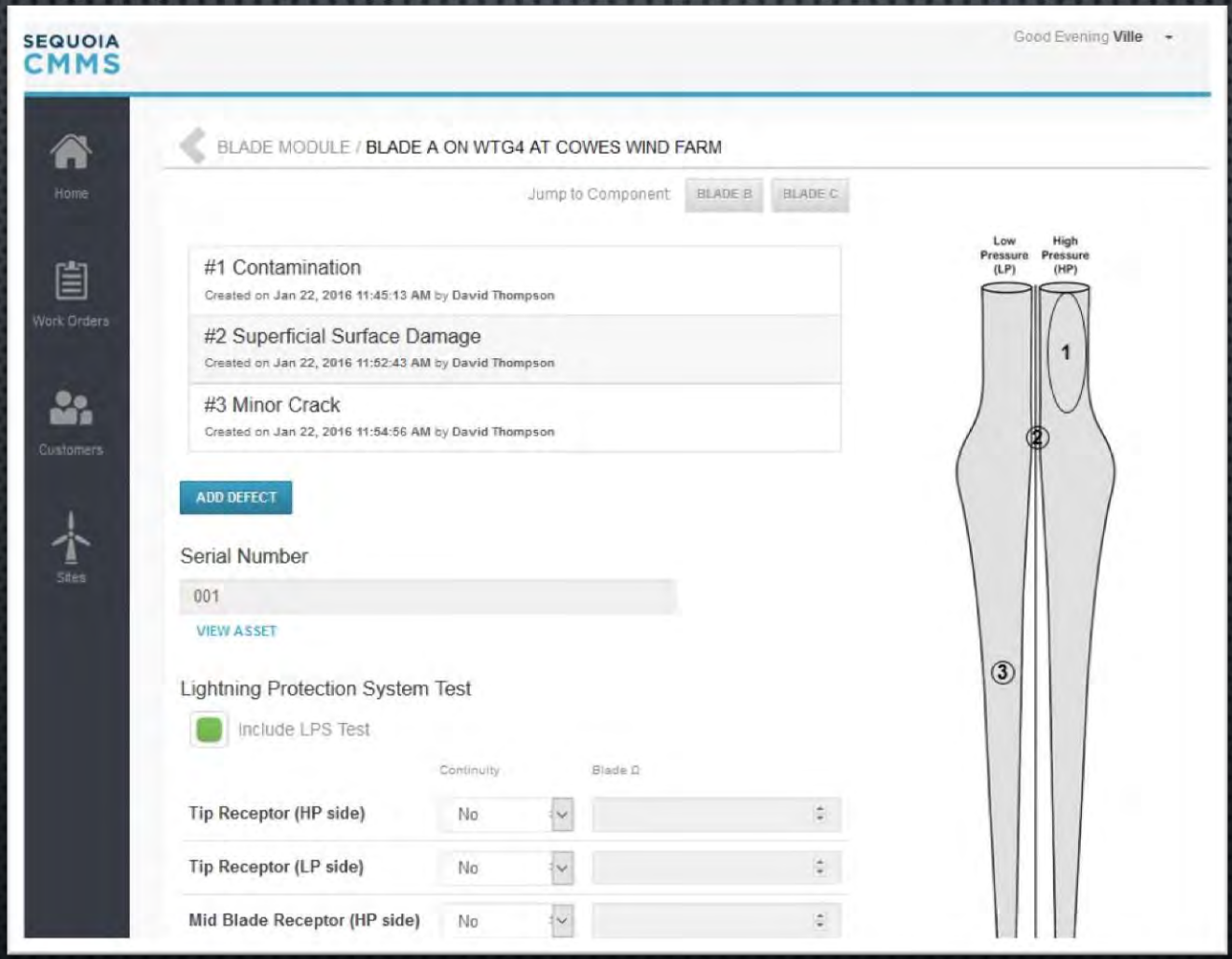
TOWARDS CONSISTENT DATA



SOURCE: MUIR DATA SYSTEMS

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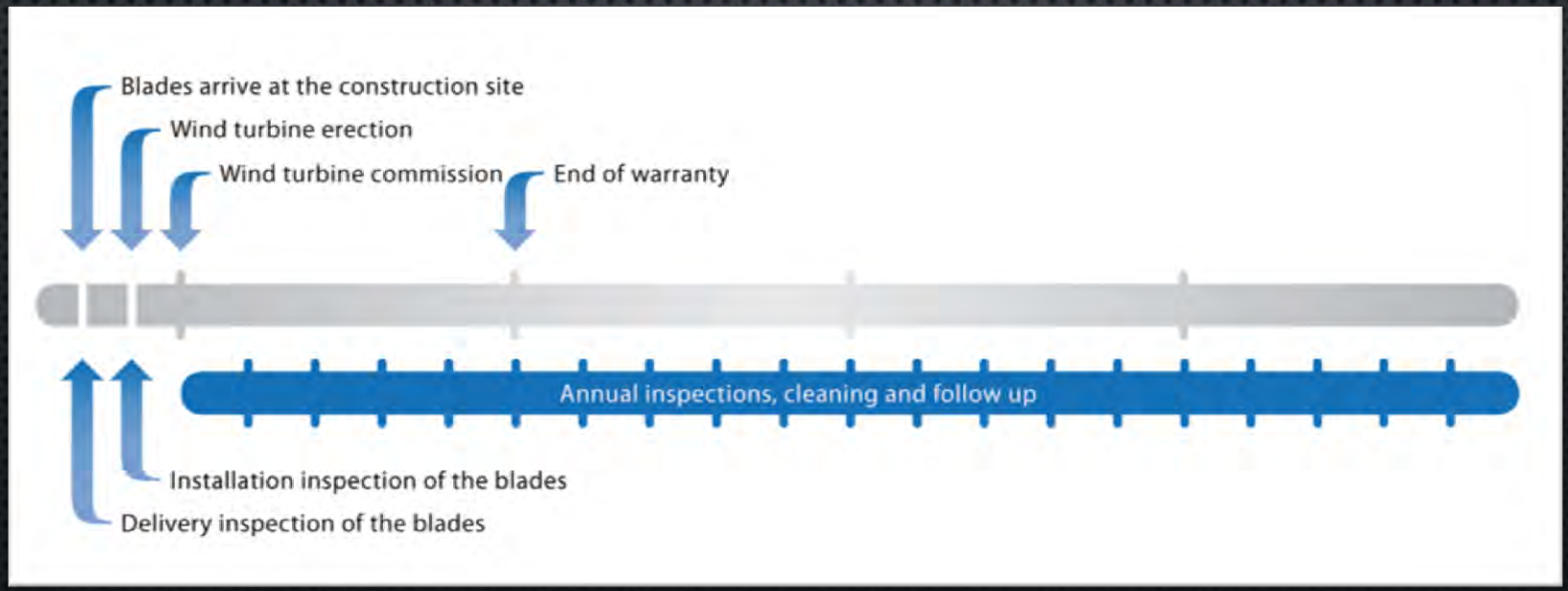
PREVENTIVE BLADE MAINTENANCE STRATEGY

- PREVENTIVE BLADE MAINTENANCE IS A SET OF PLANNED ACTIONS IN ORDER TO MITIGATE WEAR/TEAR, MANUFACTURING, INSURANCE AND OTHER ISSUES
- PREVENTIVE MAINTENANCE ALLOWS MOST ISSUES TO BE REPAIRED WHILE RELATIVELY SMALL AND REDUCES SECONDARY DAMAGES



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PREVENTIVE BLADE MAINTENANCE

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Wind Tunnel Studies at University of Illinois

- Test Location:
  - University of Illinois
    Applied Aerodynamics Group
  - Prof Michael Selig & Agrim Sareen
- Objective:
  - Determine impact of leading edge erosion on aerodynamics (lift and drag) at several different Reynolds numbers (here Re 1,850,000) on a DU 96-W-180 wind turbine airfoil profile
  - Estimate power output (AEP – Annual Energy Productio for each scenario using PROPID software

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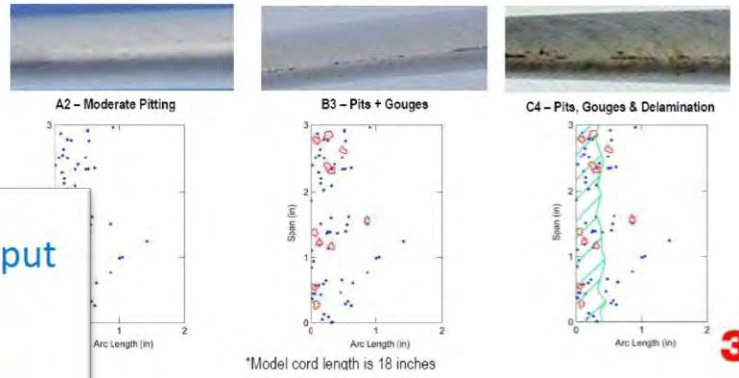
Erosion Conditions Evaluated

- Created subscale airfoils with leading edge damage using computer generated random Gaussian distributions
- 3 of the 9 levels of erosion evaluated are highlighted in this presentation



*Model cord length is 18 inches

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Effect of Leading Edge Erosion on Turbine Output

Leading Edge Status	△Drag (Measured)	△ Lift (Measured)	△AEP (Simulated)	△MWh / yr	△$$ / yr
A2 Erosion Moderate Pitting	↑80%	↓11%	↓4.2%	↓166	↓8,300€
B3 Erosion Pits & Gouges	↑200%	↓15%	↓9.8%	↓386	↓19,300€
C4 Erosion Pits, Gouges & Delam	↑400%	↓17%	↓20.5%	↓808	↓40,400€

Assumptions: 1.5 MW turbine, €50/ MWh, 30% capacity factor

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IS IT WORTH IT?

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CASE EXAMPLE

YES, IT IS.

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CASE EXAMPLE

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TRADITIONAL BLADE REPAIRS

- Traditional methods usually require an ambient temperature of +15 or more and relative humidity below 60%.
- Can be messy and creates a lot of waste
- On-site measurements for 2 component systems can be inaccurate -> quality issues
- The curing times are measured in hours
- Work season is limited to summer months

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ADVANCED UV CURING BLADE REPAIRS

- Modified epoxy based resin system with UV cure
- Mono-component resin and prepreg fabrics
- Very little waste
- GL certified product range
- Works in +5 temperature and up to 90% RH
- Cures in minutes using UVA light
- Compatible with polyester, epoxy and vinylester blades

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CASE EXAMPLE

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CASE EXAMPLE

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CASE STUDY: HORNBERGET WIND FARM

- CUSTOMER: JÄMTKRAFT
- SITE: HORNBERGET
- TURBINE: VESTAS V90
- TIME: JANUARY 2014
- AVERAGE TEMPERATURE:

  -10 TO -25 CELSIUS
- TYPE: SIGNIFICANT DELAMINATION OF APPROX. 2000MM * 300MM IN SIZE

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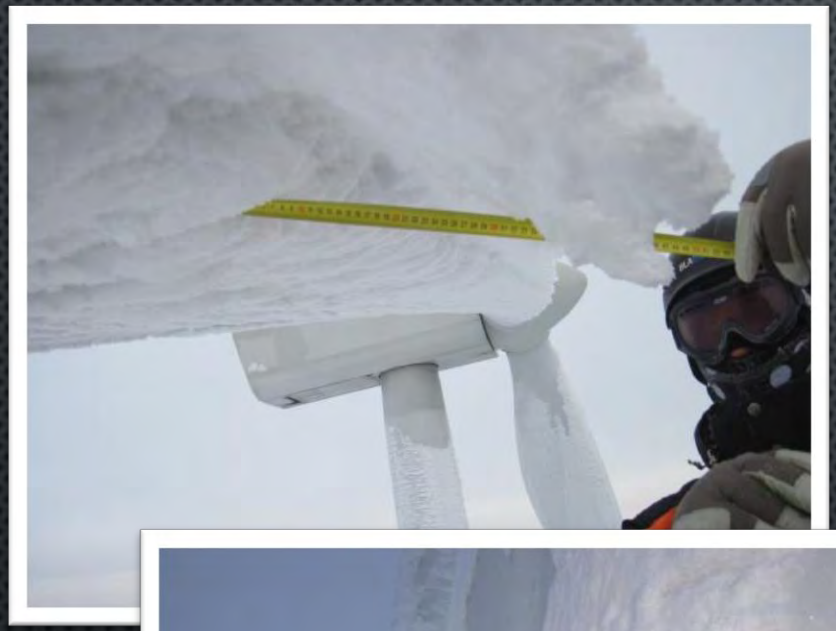
CASE STUDY: HORNBERGET WIND FARM



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CASE STUDY: HORNBERGET WIND FARM

- CUSTOM DESIGNED, FULLY INSULATED BLADE REPAIR MODULE WAS PREFABRICATED TO PROVIDE SUITABLE ENVIRONMENTAL CONDITIONS FOR THE WINTER REPAIR
- THE MODULE WAS INSTALLED IN ONE DAY USING SLINGS ATTACHED TO THE HARD POINTS IN THE NACELLE

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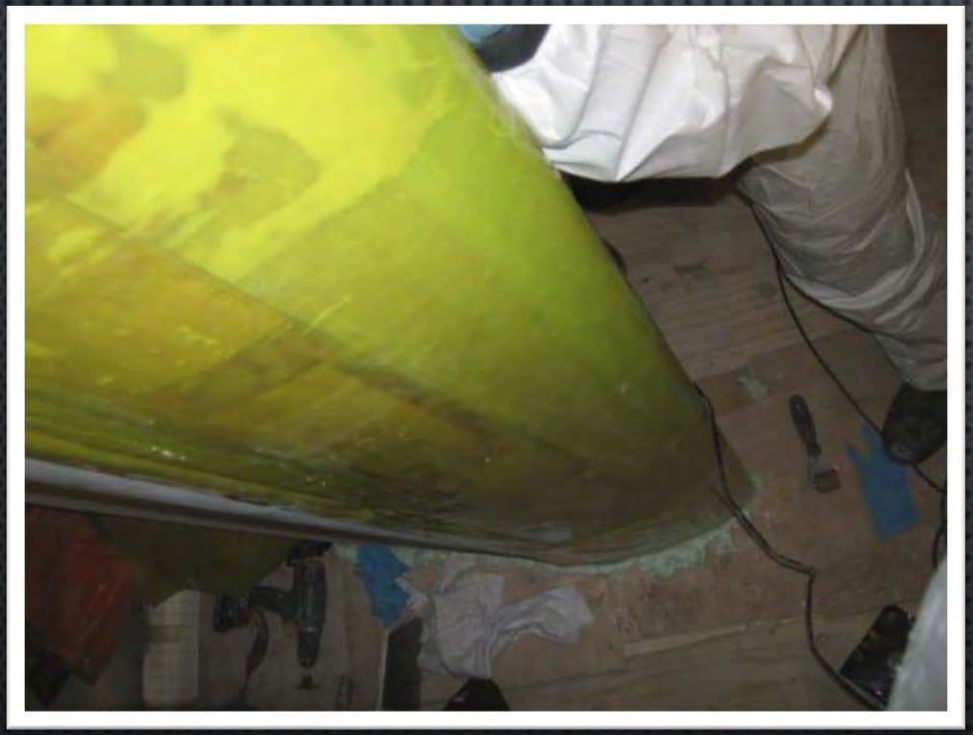
CASE STUDY: HORNBERGET WIND FARM



- THE ENTIRE PROJECT LASTED 7 DAYS INCLUDING SET-UP, BLADE DE-ICING, ACTUAL REPAIR, FINISHING WORKS AND DISMANTLING.

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Thank you!

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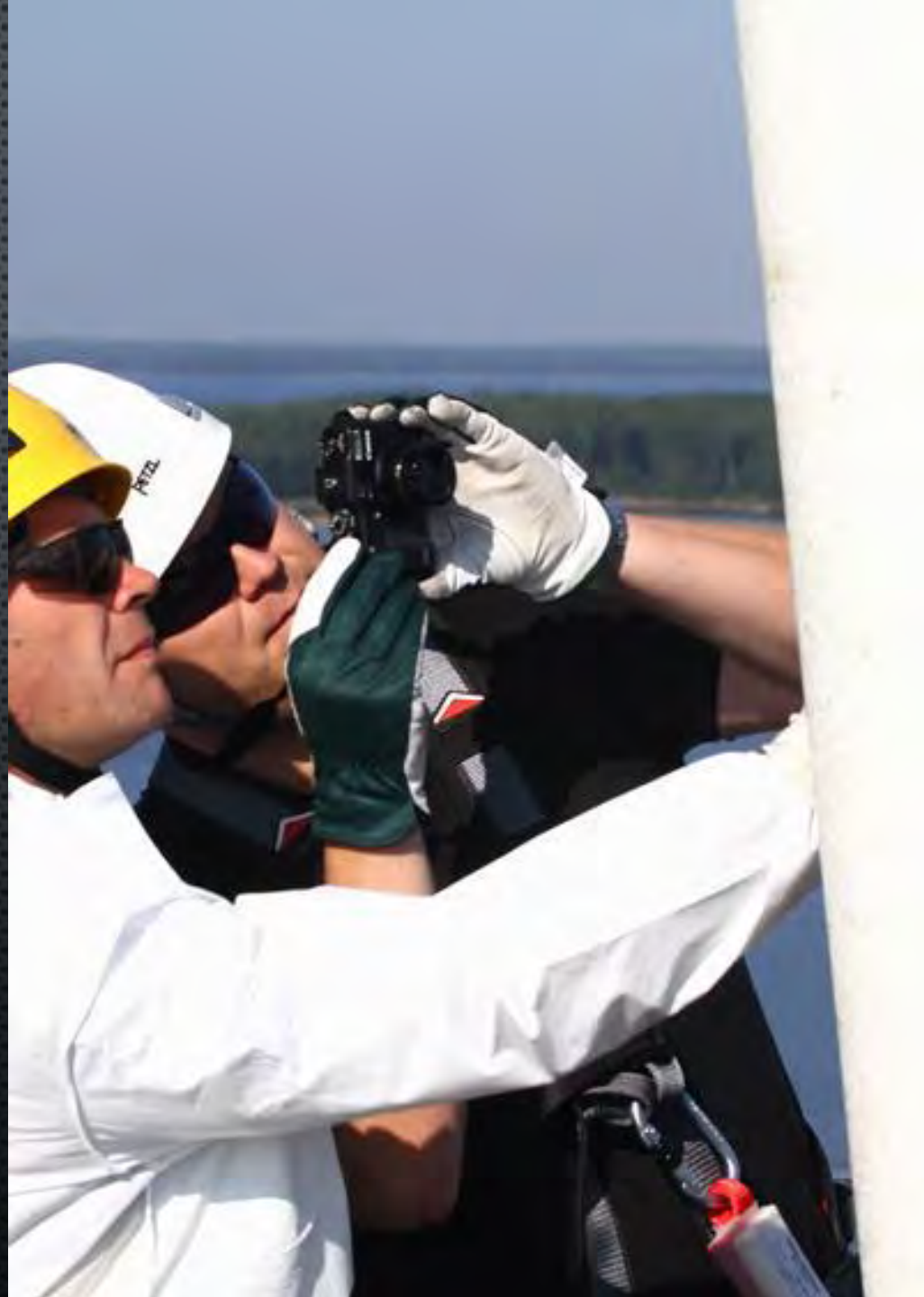

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For more details about getting involved at the conference, contact **adam@newenergyudpate.com** or visit **events.newenergyupdate.com/wind-operations-maintenance-canada**