



Vestas Cold Climate Solutions

Vestas Wind Systems A/S

Winterwind 2017

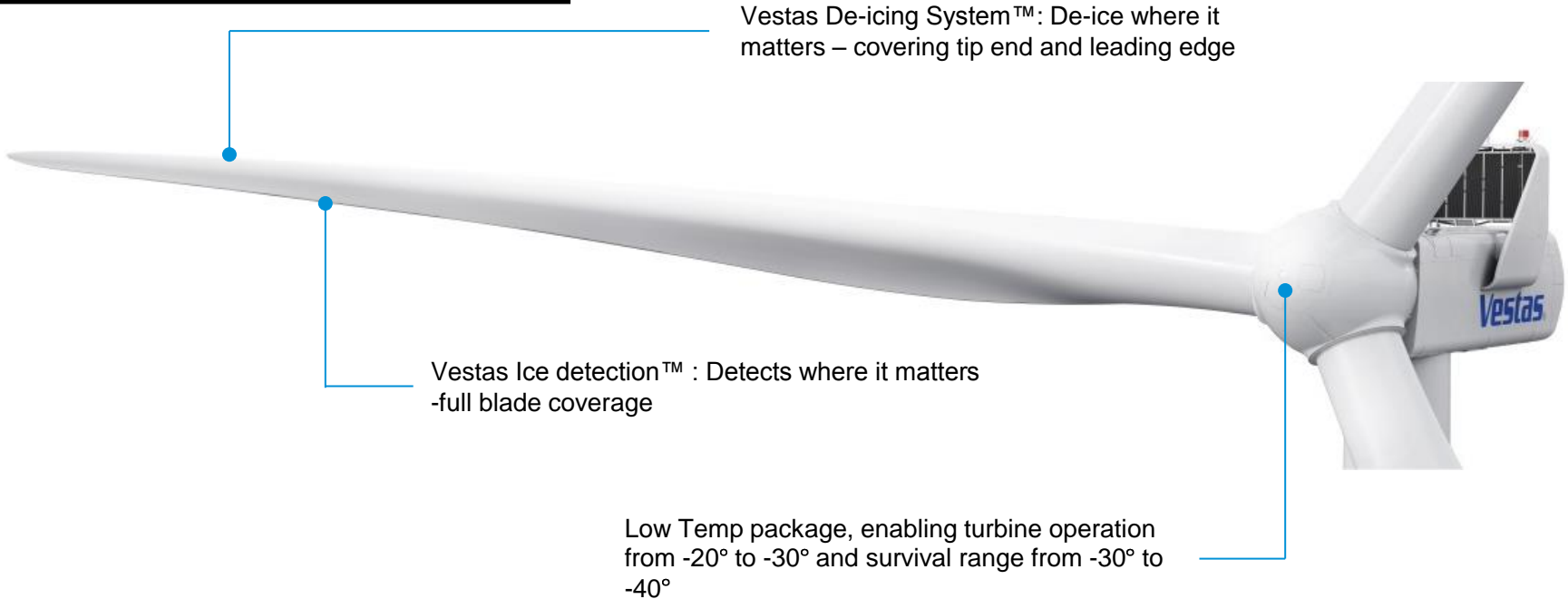
Brian Daugbjerg Nielsen, Product Management

Agenda

1. Vestas cold climate solutions
2. Vestas technical and commercial outlook
3. Vestas Ice detection R&D & ice forecasting

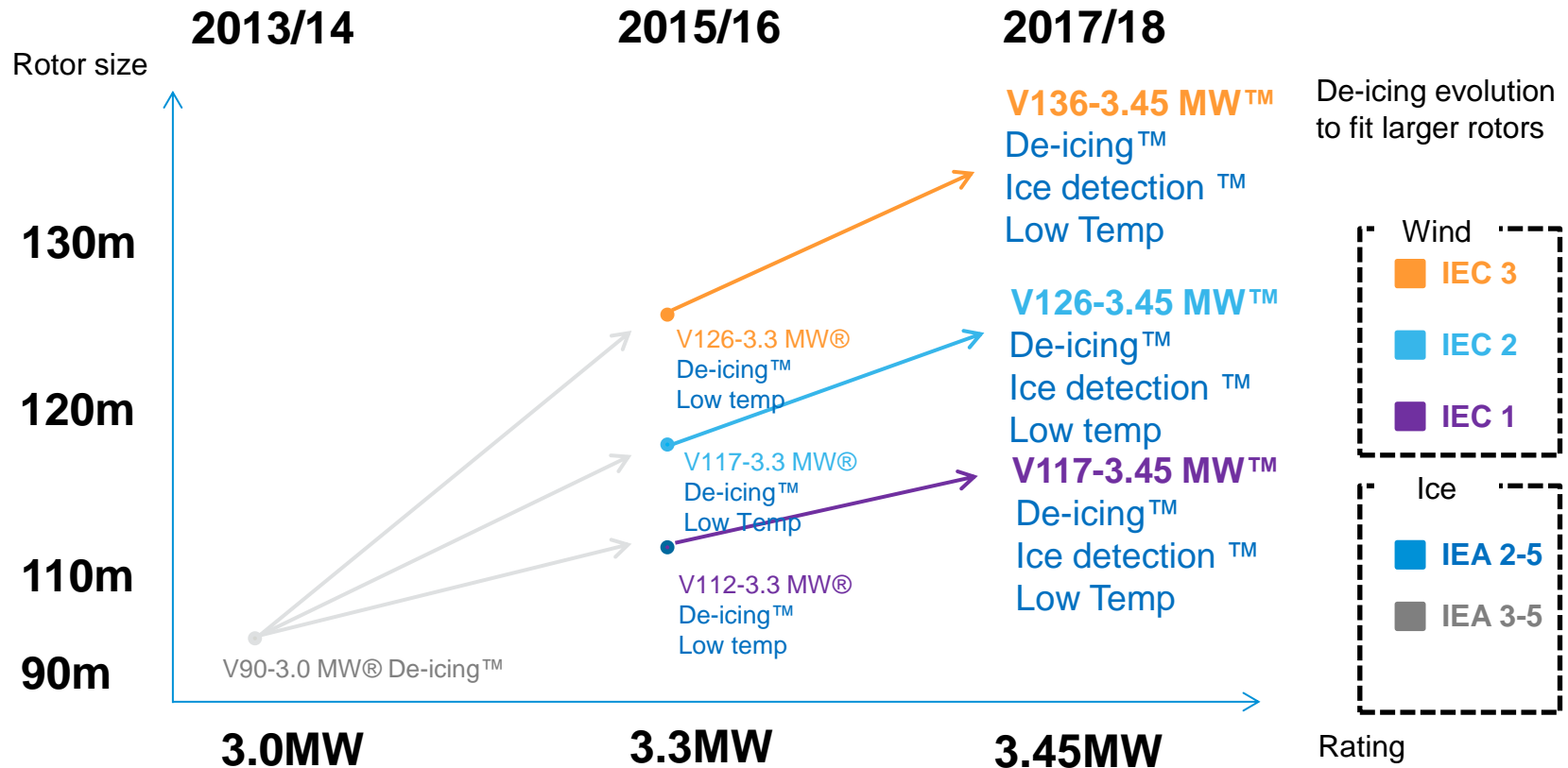
Vestas cold climate solutions

3.45-3.60MW™ turbines features Vestas' cold climate package, designed specifically to endure low temp, and icing with HSE risk and production concerns, thereby **improving AEP performance without adding risk to the turbine.**



Vestas Cold Climate availability to 3MW platform

Platform upgrade and de-icing evolution is enabling cold climate market



*AEP=Annual Energy Production. Actual figures depend on site specific conditions.

Vestas De-icing System: Track record

25 projects firmed: >1GW with De-icing in Sweden, Norway, Finland, Japan, Canada & Austria.
Up to date: 105 turbines installed



Vestas De-icing : System at a glance for V112→V136

Designed for production optimization

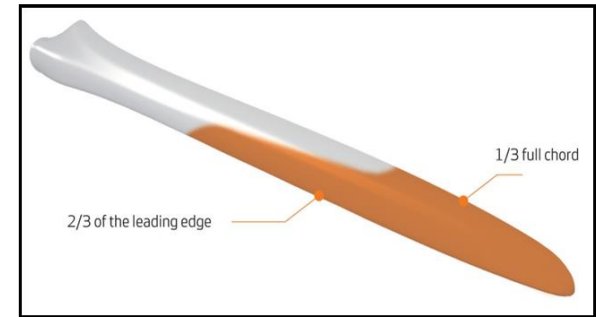
Solution is based on hot air flow methodology in the blades

De-icing time under 2 hours for complete rotor set

Nominal power consumption is approx. 105 kW , peak power consumption is 150 kW



Stop during de-icing in Y position, with simultaneous de-icing cycles of the rotor set



Blade heating target area

Power curve based ice detection, monitored and controllable from SCADA, with option settings to improve site performance

Vestas De-icing: Designed for reliability and service

Functional overview

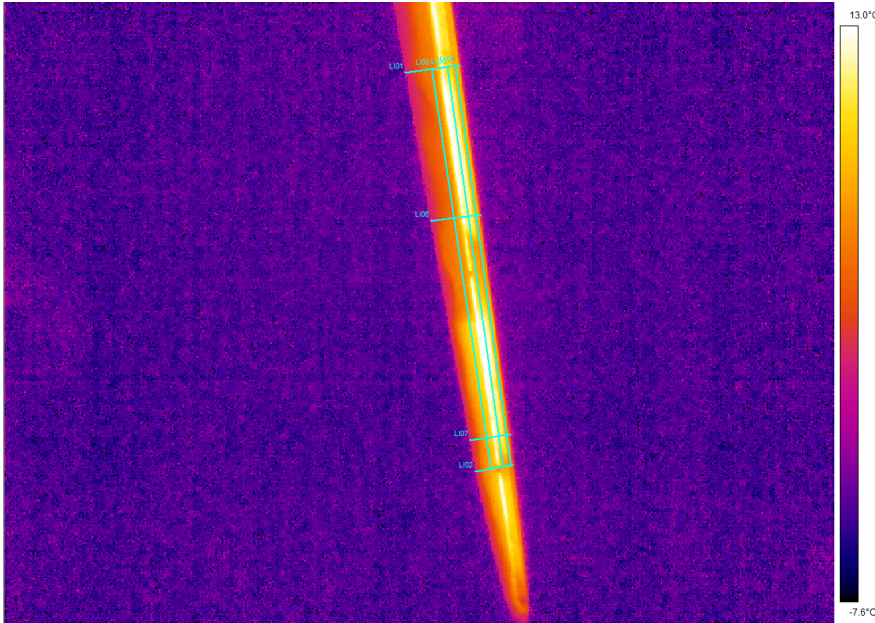
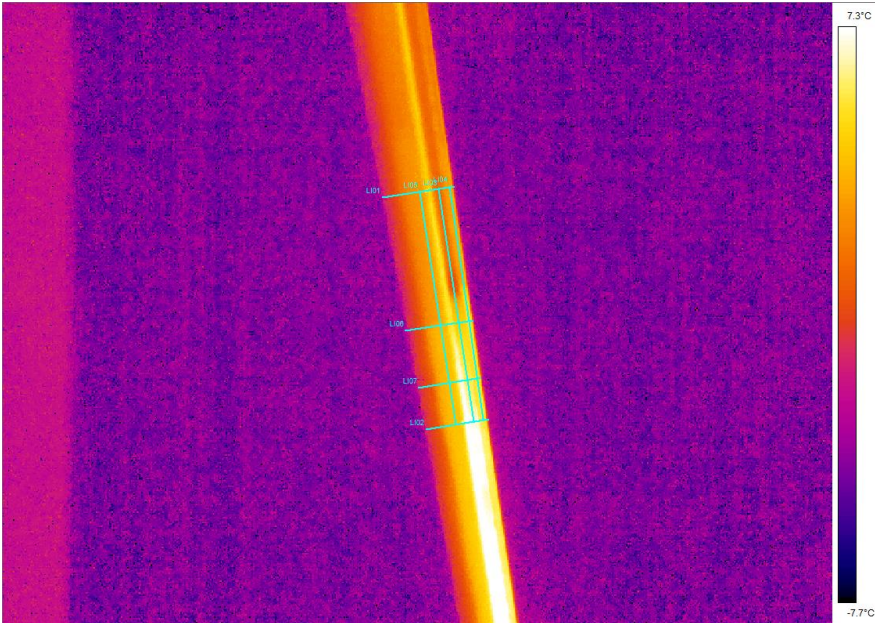
- No impact on turbine



- Fully integrated solution in the turbine
- Statement of Compliance on turbine type certificate
- No additional lightning risk
- No impact on overall turbine performance – 20 year lifetime maintained
- Serviceable from hub and blade root end

Vestas De-icing: Field Performance through IR images

Conditions during test: Ambient temperature -4°C, Wind speed 9m/s



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De-icing warranty **concept selection**

How will customers evaluate the warranty vs risk exposure to Vestas vs differentiation

Buyer perspective:



Translate the warranty into money



How costly to Test and easiness



Is the penalty sum accordingly to ice losses?



Can the AEP losses be reduced?



Benchmark the value to other offerings



Performance documentation

De-icing warranty **concept selection**

How will customers evaluate the warranty vs risk exposure to Vestas vs differentiation

Supplier
perspective:



How to differentiate, should we do it?



What is the risk of failing the test?



What does the track record/data show?



Do we remain a positive business case?



What is the exposure/likelihood for test?

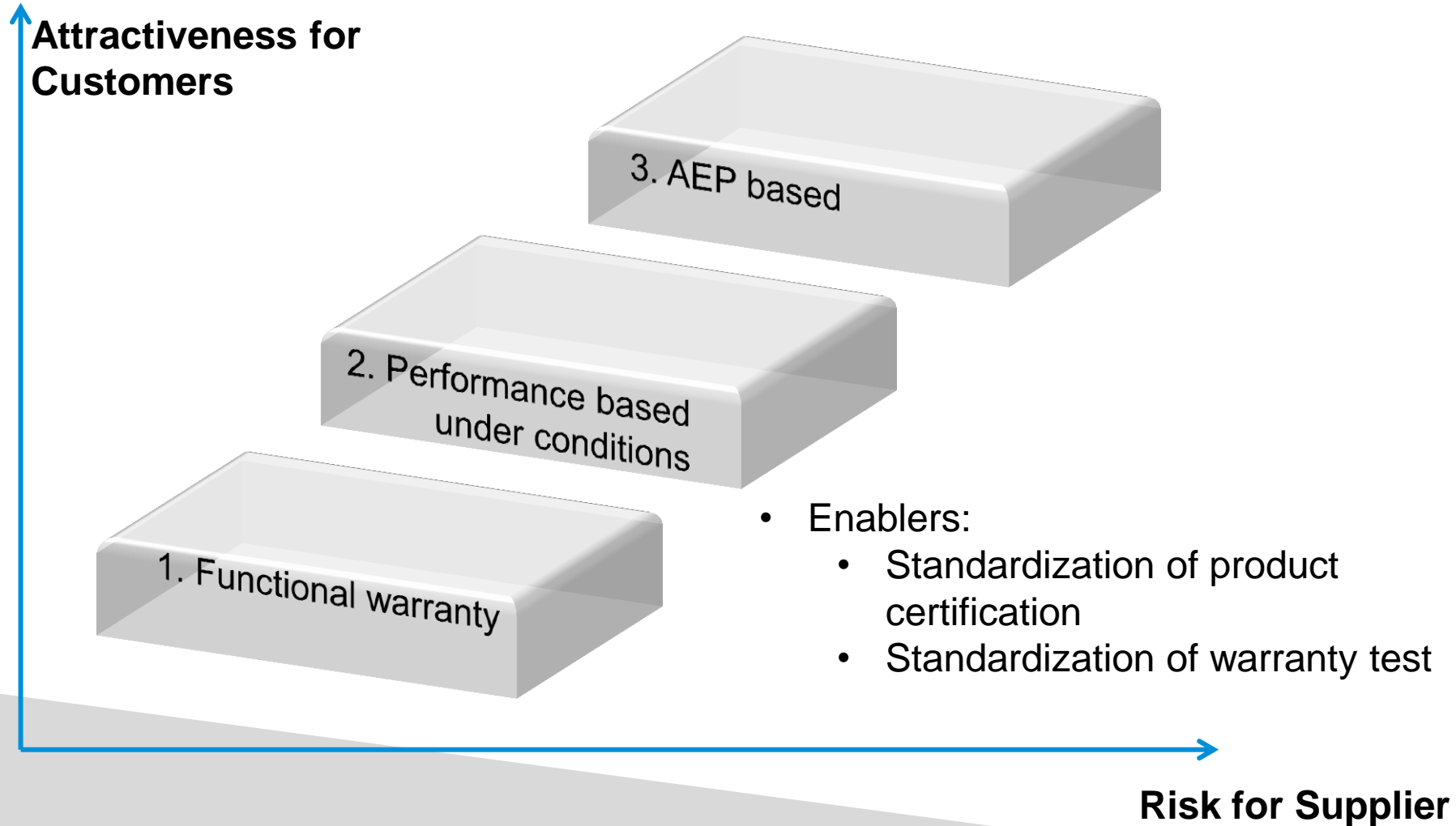


What can be re-done if failing the test?

Wind. It means the world to us.™

De-icing Warranty: **Attractiveness vs risk**

Market conceptual warranty plan; Supplier path to meet Customers requirements



Vestas De-icing **Focus areas**

- Improved Ice detection and blade ice removal measures.
 - Fine tuning triggering of the system to site optimize
- Alternative control strategies to be less ice prone
- Optimize heating cycle to reduce period of standstill

Agenda

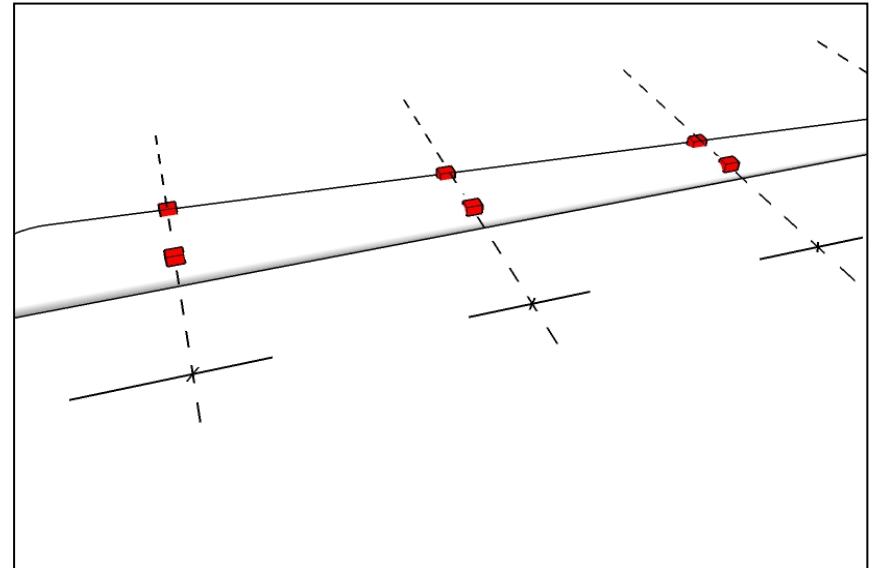
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Vestas and Aarhus University – Ice Detection

Test rig & setup



- Test rig for simulation of **ice mass**
- Different **mass** and **location** tested with sandbags
- Sensors located at different places along the blade

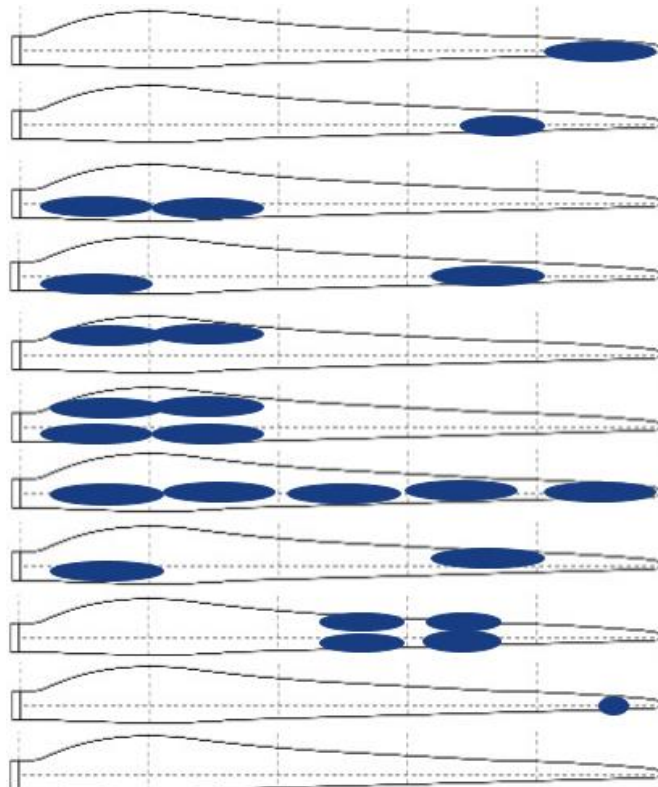


Test done at Bleast test center, Aalborg, Denmark

Vestas and Aarhus University – Ice Detection

Test Setup and simulation of ice event

- Test done with 11 different scenarios of location and mass
- Test was done as ‘blind test’, researchers had no knowledge about placement and mass



Vestas and Aarhus University – Ice Detection

Results

- Test of several algorithms
- Test of different sensor setups; sensor types and locations

- Possible to detect mass below 10kg (location depended)
- Possible to detect mass in 5 different sections along the blade

- Indications of final setup; a few sensors along the blade

Reference:

J.B. Hansen ¹, R. Brincker ², L. Glavind ³, T.B. Olsen ¹, L. Colone ¹, “APPLICATION OF AMODAL-DRIVEN DAMAGE ASSESSMENT FRAMEWORK FOR ICE LOCALIZATION AND QUANTIFICATION ON WIND TURBINE BLADES.”, IOMAC'17

¹ Department of Engineering, Aarhus University, Denmark

² Department of Civil Engineering, Technical University of Denmark, Denmark

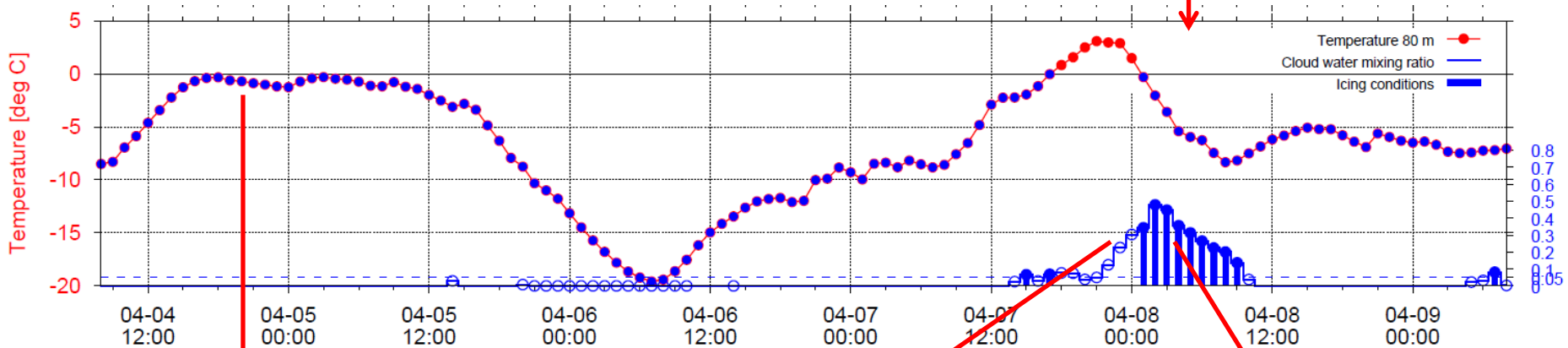
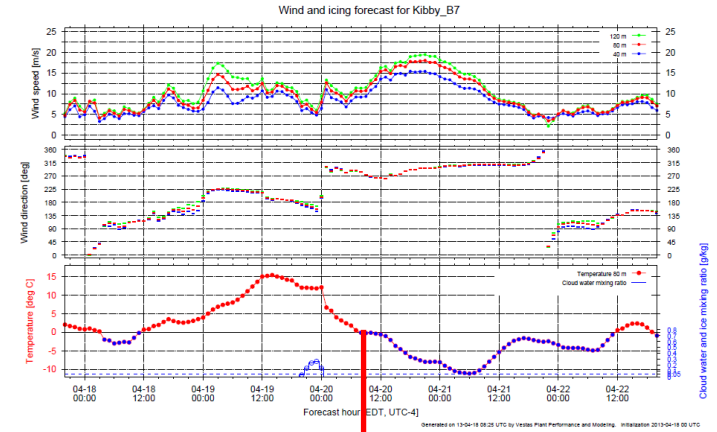
³ Vestas Wind Systems A/S, Aarhus, Denmark

Vestas Icing Forecast – the model

Introduction and description

Icing forecast contains hourly values of:

- Temperature, cloud water content
- Active icing conditions
- Wind speed and direction



Temperature

Cloud water content

Active icing conditions

Vestas Icing Forecast – understanding the data

Introduction and description

Possible scenarios to consider when interpreting the icing forecast:

1. No active icing, but ice exists on blades

- Forecast shows no active icing, but there is ice leftover from previous episode
- *Scenario:*
 - Icing conditions had existed for several hours
 - Ice has deposited on the blades
 - Active icing conditions no longer exist (e.g., cloud is gone)
- It may take several hours for the ice to shed/melt/evaporate, depending on temperature

2. Active icing, but no effect on turbines

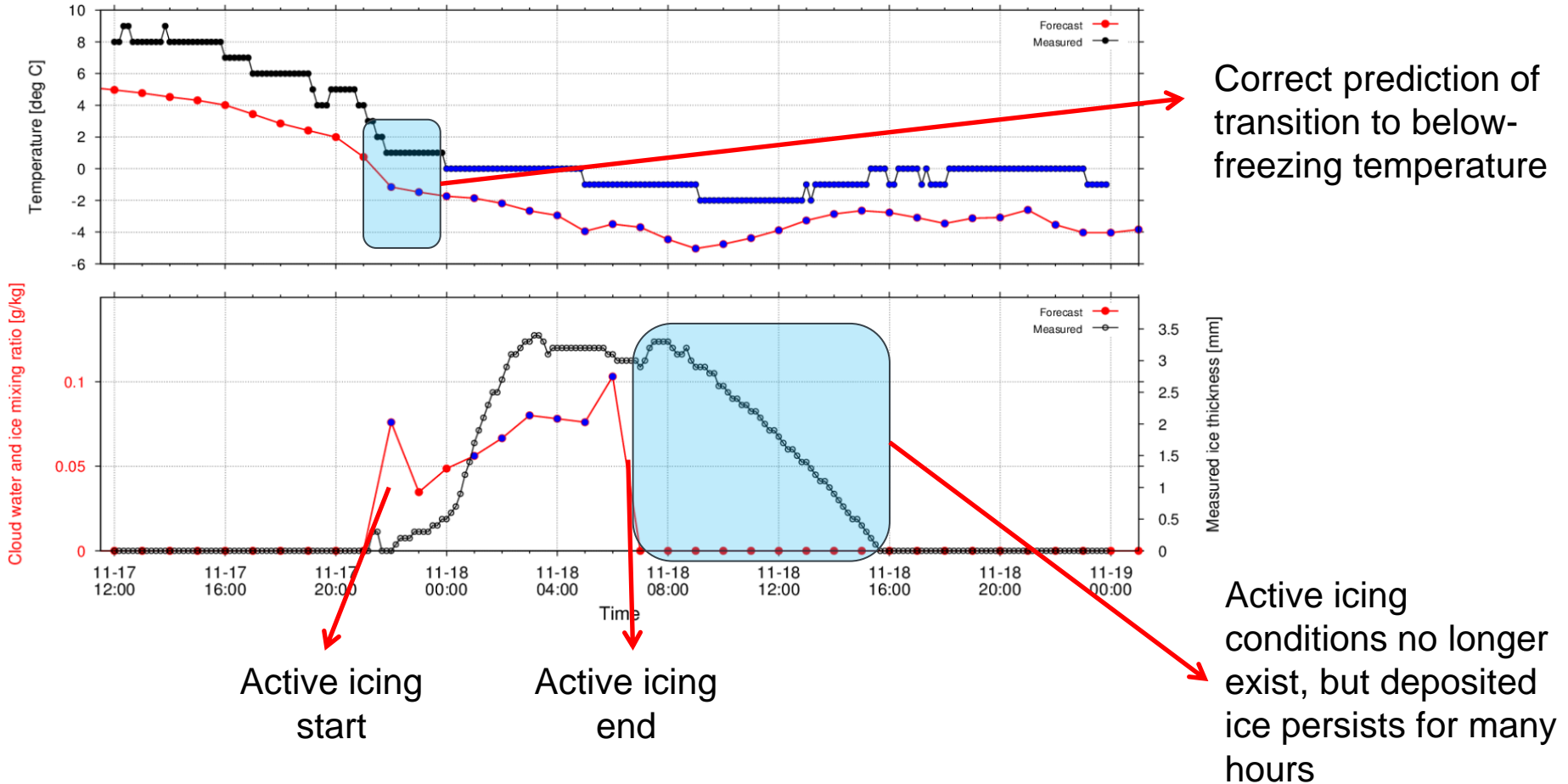
- Forecast shows active icing, but there is no measurable effect on turbines
- *Scenario:*
 - *Very weak icing event*

Vestas Icing Forecast – understanding the data

Introduction and description

Icing event 17 – 18 Nov 2011, Kent Hills wind park, Canada

- Comparison of forecast with ice-thickness measured on met-mast icing sensor



Vestas Icing Forecast – reliability

Introduction and description

Verification of active icing forecasts:

- Ice thickness sensor from Kent Hills wind park, Canada
- Period: Jan 2011 – April 2013
- Icing season: Nov – April

- Measure skill of categorical prediction of daily active icing event
 - From measurement:
 - Active icing exist if ice thickness grows during at least on hour in a day
 - From forecast:
 - Active icing exist if predicted for at least one hour in a day

		Observed		
		Yes	No	Total
Forecast		Yes	No	Total
	Yes	205	65	270
	No	101	112	213
	Total	306	177	483

Success ratio = 76 %

76 % of forecasted active icing events were actually observed

Probability of detection = 67 %

67 % of icing events were correctly predicted

False alarm ratio = 24 %

24 % of forecast icing events were not observed

Vestas Icing Forecast - user experience

Kent Hills wind farm 50xV90-3MW, owned and operated by TransAlta

- Extensive icing and significant production loss
- Majority of downtime after icing events with low temperatures
- Loss of AEP due to icing estimated correctly, but cold weather following icing events extends losses and downtime

Proactive curtailment as operational strategy for minimizing ice losses

- Stop turbines before a severe icing event
- Significantly less ice accumulates (from 100 mm down to 2-3 mm)
- Turbine can start operating immediately after the event
- Decision based on observed current conditions and Vestas Icing Forecast

Applying proactive curtailment strategy, Transalta was able to reduce icing related losses by 15%¹



1. Jeff Nelson (2010): *TransAlta's Experience with Blade Icing*

The Vestas logo is displayed in the top left corner of the slide. It consists of the word "Vestas" in a white, italicized, sans-serif font, followed by a registered trademark symbol (®). The background of the top half of the slide is a blue sky with wispy white clouds.

Wind. It means the world to us.™

Thank you for your attention

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