# Intercomparison of blade-based ice detection systems

Winterwind 2019
Umea, 6 February 2019

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# Motivation

**Ice detection systems, review study**

Meteotest AG, 2016 in VGB PowerTech Journal

**Nacelle-based ice detectors: 10 systems**

some with long experience, well tested

**Blade-based ice detectors: 4 systems (beside power curve)**

More recent, no quantitative intercomparison so far

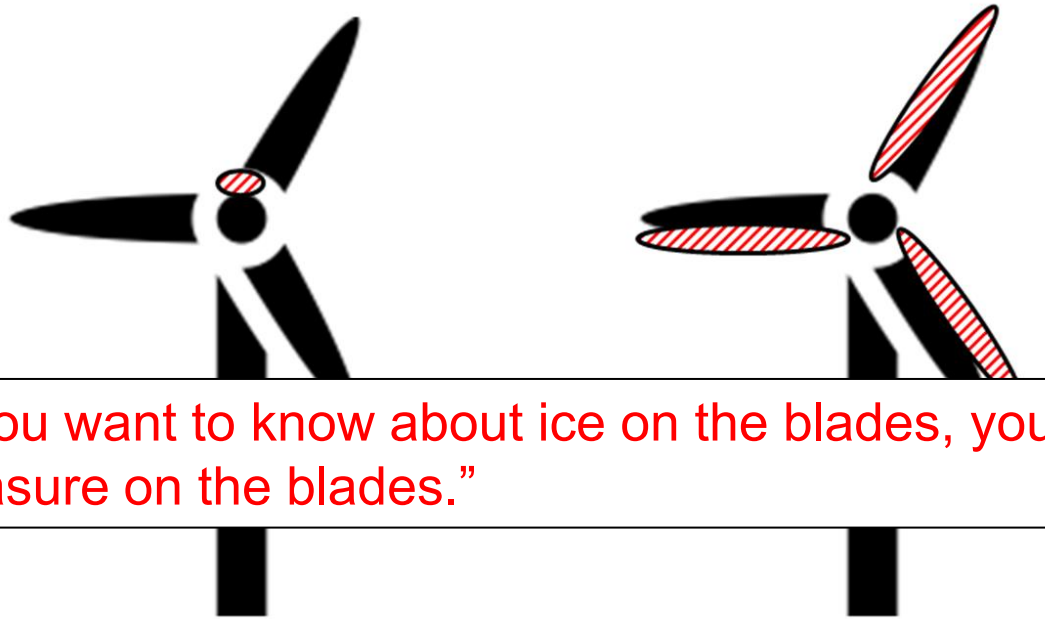
# Motivation

**Instrumental icing is NOT blade icing**

- Standstill structure vs. moving structure
  - blades may cross several air layers
  - different wind speeds
  - vibrations and acceleration forces

- Different size/shape of structure (sensor vs. blade)

# Motivation



"If you want to know about ice on the blades, you will have to measure on the blades."

Nacelle based systems

Blade based systems

# Experiment

## Idea

- Install commercially-available blade-based ice detectors **on the same turbine**
- Compare results, use webcams as a reference
- Winters 2017/18 and 2018/19

## Financing

- Financed by the **VGB research foundation**
- Additional contribution from 11 VGB member companies

# Experiment: blade-based ice detectors

- **weidmüller,** BLADEcontrol (GER, 2005)
- **wölfel,** IDD.Blade (GER, 2012)
- **fos4X,** fos4Ice (GER, 2013)
- **eologix** (AUT, 2015)

Vibration sensors
inside-glued

Impedance sensors
outside-taped

# Experiment: test turbine

Vestas V90,1.8 MW, 95 m hub
no heating, no restrictions due to icing

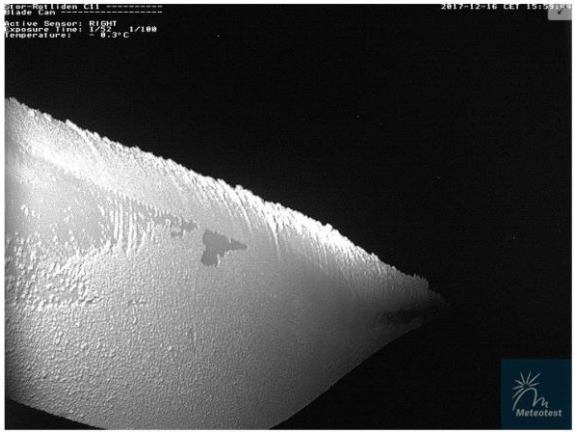
**Harsh conditions**
**No risk, No gain !**

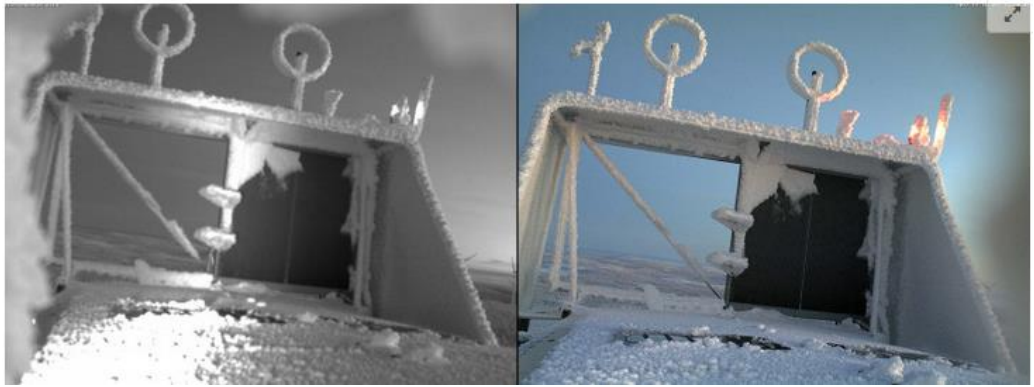
Stor-Rotliden, Sweden
~ 500 m.a.s.l.


VATTENFALL
Owner and operator

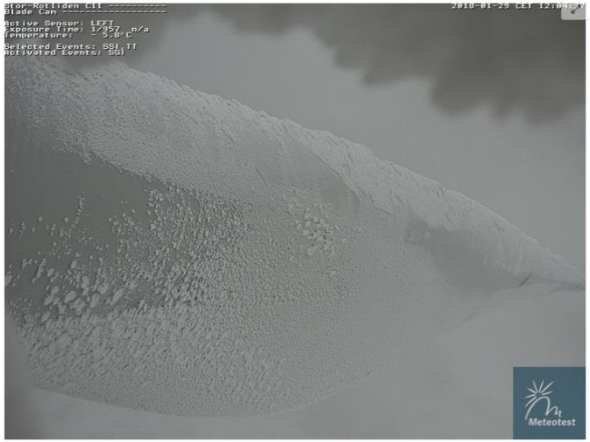
# Experiment: webcams

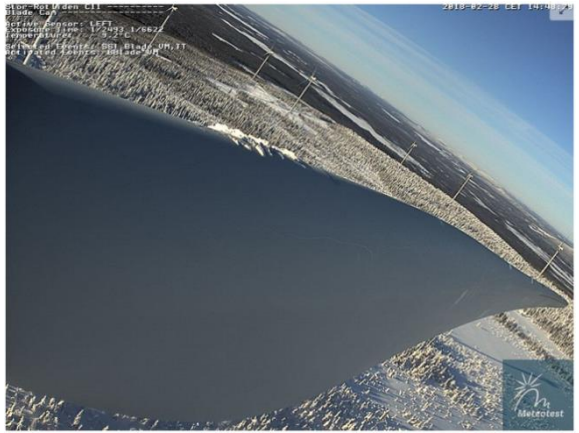
- Nacelle and blades
- Vis and IR sensors
- Heated
- IR projector

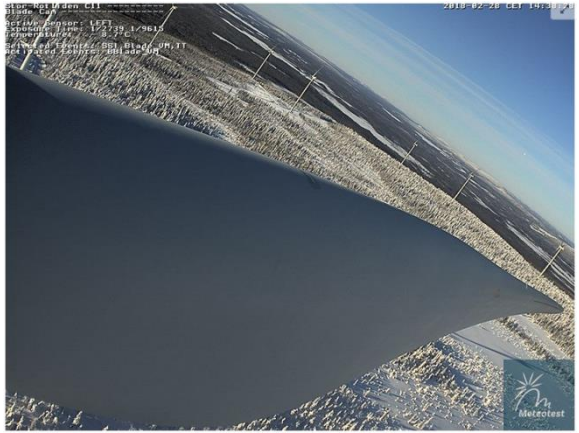




# Experiment: webcams limitation







# Preliminary results: intercomparison

| | Numerical signals | Alarm/warning signals | Icing levels | Minimum wind speed |
|---|---|---|---|---|
| Woelfel | 3<br>one per blade | 4<br>one per blade and summary | 3<br>icing levels | 2-3 m/s |
| Weidmueller | 1 | 1 | 2<br>icing levels | 2 m/s |
| Eologix | no | 16<br>one per sensor | 3<br>icing thicknesses | 0 m/s |
| Fos4x | 3<br>one per blade | 4<br>one per blade and summary | 2<br>icing levels | 2 m/s |

**Standardized:**

- No icing
- Warning
- Alarm
- Missing data

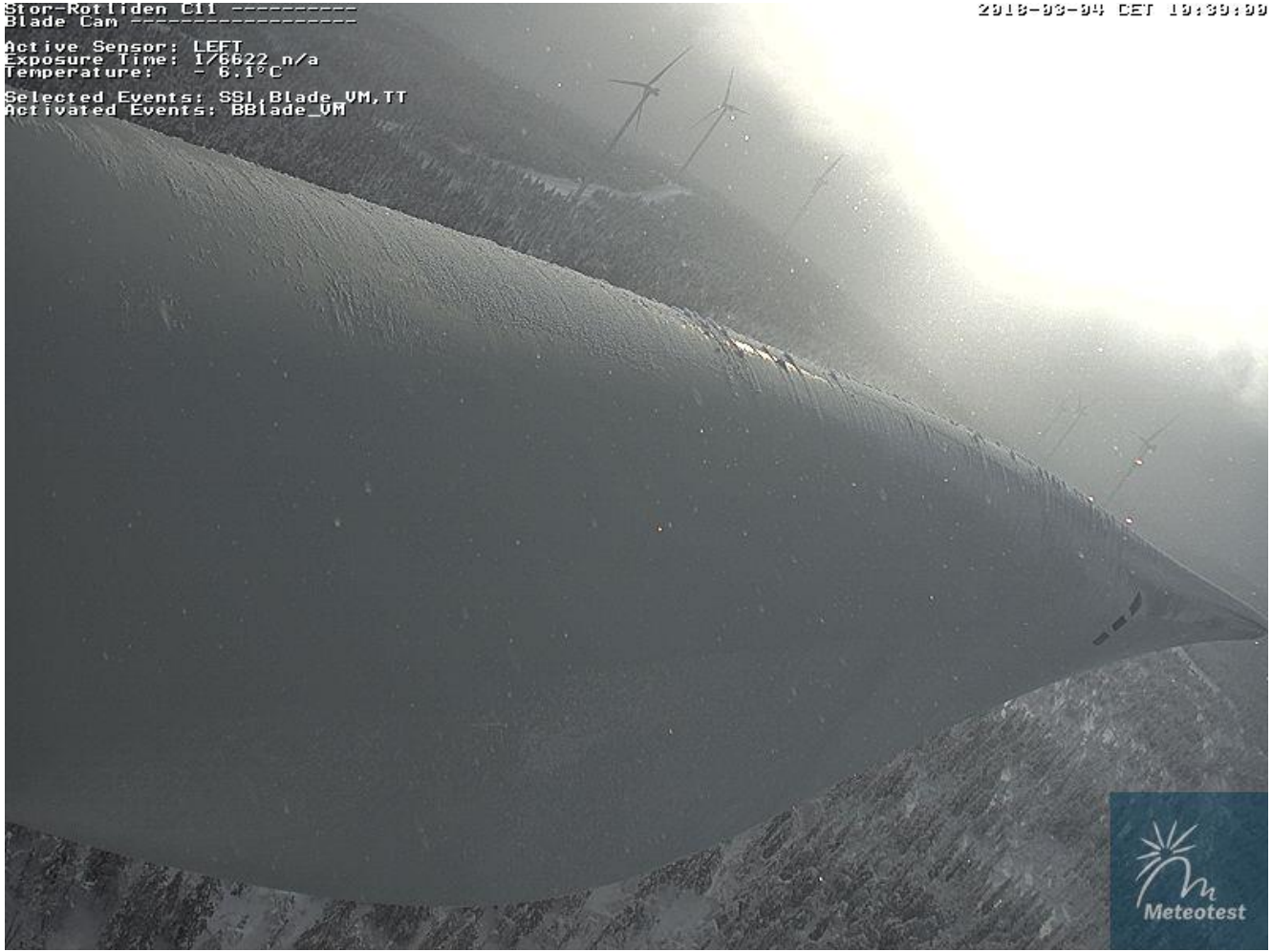
# Preliminary results: case studies


29 Jan 2018 14:00 CET

-7° C
7.9 m/s
0 kW, **-100%**

Ice Detector A: **Alarm**
Ice Detector B: **Alarm**
Ice Detector C: **Alarm**

hereafter
A,B,C
= weidmueller, eologix, woelfel
! In random order !




Meteotest

04 March 2018 10:30 CET

-8° C
5.8 m/s
106 kW, **-70%**

Ice Detector A : **Alarm**
Ice Detector B : **Alarm**
Ice Detector C : **Warning**


05 March 2018 12:00 CET

-10° C
6.2 m/s
330 kW, **-24%**

Ice Detector A : **Warning**
Ice Detector B : **No icing**
Ice Detector C : **No icing**


Meteotest

06 March 2018 12:00 CET

-10° C
5.5 m/s
190 kW, **-33%**

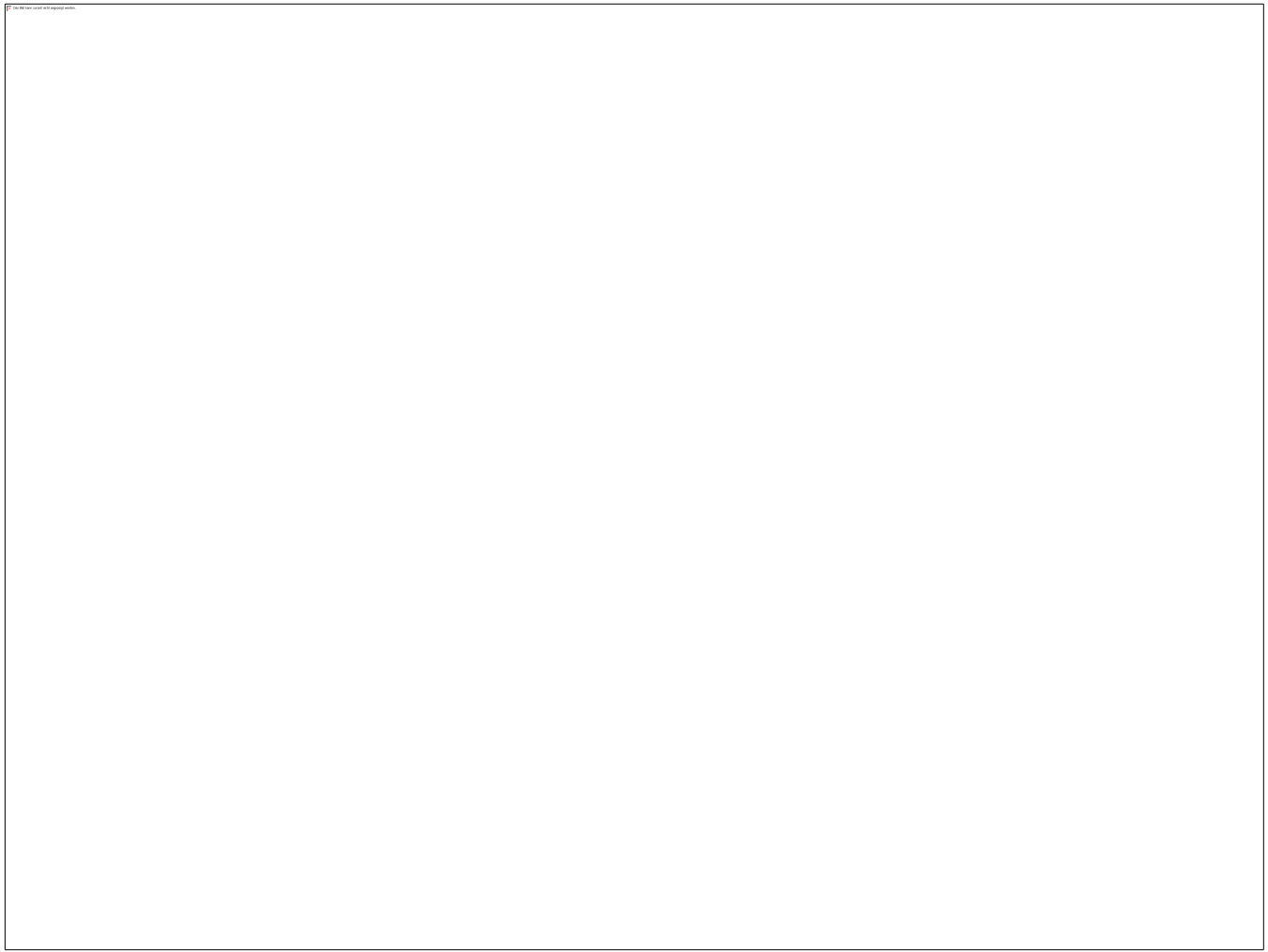
Ice Detector A : **Warning**
Ice Detector B : **No icing**
Ice Detector C : **No icing**


Meteotest

10 March 2018 04:00 CET

-6° C
5.3 m/s
110 kW, **-58%**

Ice Detector A: **Alarm** 5h13
Ice Detector B: **Alarm** 4h29
Ice Detector C: **Alarm** 4h04



11 March 2018 10:00 CET

-7° C
4.7 m/s
80 kW, **-50%**

Ice Detector A: **Alarm**
Ice Detector B: **Alarm**
Ice Detector C: **Alarm**

# Preliminary results: case studies

- Ice detectors do not always agree, especially during light to medium icing
- Some «missed events» identified, «false alarms» are more difficult to detect
- How important is the sensitivity of the thresholds?
- Webcam doesn’t show everything at any time

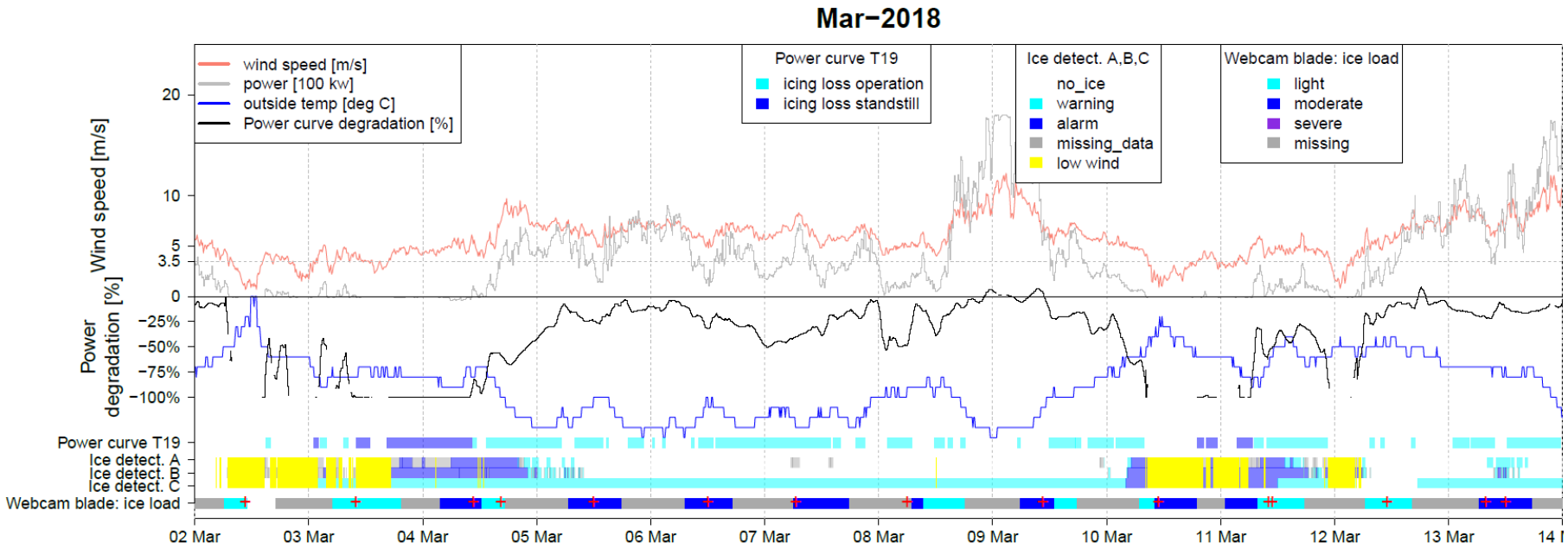
# Coming soon…

- More case studies: **winter 2018/19 with all 4 ice detectors**
- Statistics: availability, icing time, icing severity, accuracy (skill score hit rate, false alarms, etc).
- **Collaboration with Nergica, similar study. Standardisation of thresholds. ”When do we want a warning / an alarm ?”**

- Detailed results for financially contributing VGB members in 2019
- Public report will follow

# Thank you !


# Preliminary results: case studies



# Meteotest

- Private independent company, located in Bern, Switzerland
- Founded in 1981, University spin-off
- 25-30 scientist, engineers and technicians
- Business fields: wind energy, solar energy, geo informatics, air pollution monitoring, climatology, web and software applications
- Wind energy specialists for complex terrain and icing climate
  - Measurement campaigns in cold climate
  - Production loss calculation due to icing
  - Icing forecasts for wind energy
  - Ice throw studies and risk assessments
- Long experience with wind energy in cold climate
- Elaboration of independent studies for ENERCON since 2009 looking at performance of blade heating and ice detection system

# Comparison blade systems

| | Principle | Meteorological Icing | Instrumental Icing | Rotor Icing |
|---|---|---|---|---|
| Power curve | Deviation between produced power and power curve at low temperatures | No | No | Yes |
| Weidmüller Blade Control | Piezo-Electric Accelerators Change in natural oscillation frequencies when blade is iced | Yes | No | Yes |
| fos4 Ice Detection | Fibre-optic Accelerators Change in Eigenfrequency when blade is iced | Yes | No | Yes |
| Wölfel SHM.Blade/ IDD.Blade | Structural Noise Sensors (accelerators), change in Eigenfrequency when blade is iced | Yes | No | Yes |
| Eologix | Change of impedance/capacitance on sensor surface when probe iced | No | No | Yes |

# Comparison blade systems

| | Operation | Standstill | Minimum wind speed | SCADA data required | Anywhere on blade |
|---|---|---|---|---|---|
| Power curve | Yes | No | 3 m/s | Yes | Yes |
| Weidmüller BladeControl | Yes | Yes | 2 m/s | Yes | Yes |
| fos4 Ice Detection | Yes | Yes | 3 m/s | Yes | Yes |
| Wölfel SHM.Blade/ IDD.Blade | Yes | Yes | 2-3 m/s | Yes | Yes |
| Eologix | Yes | Yes | 0 m/s | No | No |

# Comparison blade systems

| | No. of sensors | Sensor position | Electrical wires in blade | Blade sensor Installation | Retrofit |
|---|---|---|---|---|---|
| Power curve | none | n/a | No | n/a | n/a |
| Weidmüller BladeControl | Minimum 1 per blade | 1/3 of the blade radius | Yes | inside glued | Yes |
| fos4 Ice Detection | Minimum 1 per blade | 1/3 of the blade radius | No | inside glued | Yes |
| Wölfel SHM.Blade/ IDD.Blade | Minimum 1 per blade | 12- 18 m from root | Yes | inside glued | Yes |
| Eologix | Minimum 2 per blade every 10 m recommended | leading edge | No | outside taped | Yes |

# Comparison blade systems

| | Commercially available since | No. of systems sold | Stage of development |
|---|---|---|---|
| Power curve | n/a | n/a | serial |
| Weidmüller Blade Control | 2005 | > 2000 | Small scale series all turbine types |
| fos4 Ice Detection | 2013 | >100 ~ 200 after 2017/18 | Serial all turbine types |
| Wölfel SHM.Blade/ IDD.Blade | 2012 | 150 IDD.Blade 400 SHM.Blade | Serial all turbine types |
| Eologix | 2015 | ~100 | Small scale series all turbine types |