Evaluation of ice detection systems for wind turbines
First experiences from field test

Saskia Bourgeois
René Cattin, Ulla Heikkilä

Winterwind 2017
Skellefteå - Sweden

Evaluation of ice detection systems for wind turbines
very First experiences from field test

Saskia Bourgeois
René Cattin, Ulla Heikkilä

Winterwind 2017
Skellefteå - Sweden

VGB PowerTech

- **European technical association for power and heat generation**
- **488 member companies from 34 countries**

Evaluation of ice detection systems - Part I

- **Independent overview** on commercially available ice detection systems for wind turbines (no data analysis)
- **Report for VGB members** to review and optimize the operation of wind parks under icing conditions
- Available since February 2016: https://www.vgb.org/vgbmultimedia/392_Final+report-p-10476.pdf

Evaluation of ice detection systems - Part II, Field test

- **Independent benchmark** of the four rotor blade systems: Weidmüller (formerly Bosch-Rexroth), fos4x, Wölfel, Eologix
- All installed on the same turbine

Ice detection systems – why?

Production

Safety

Ideal world

as **early** as possible
no false alarms!

as **short** as possible

as **early** as possible

«Ice» detection
Ice on the blades

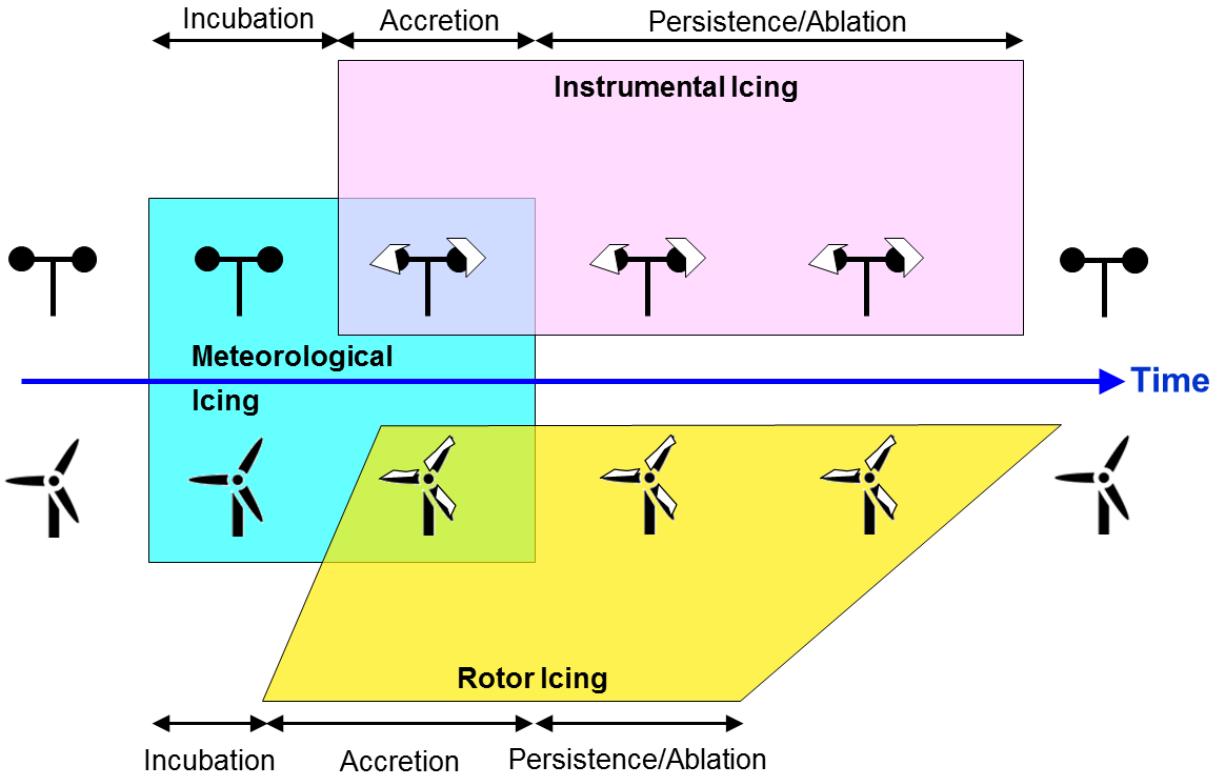
«No Ice» detection
Blades are icefree

Action:
- Stop turbine
- Start de-icing

Action:
- Restart turbine
- Stop de-icing

time

Icing basics



Icing basics

Instrumental Icing is NOT rotor Icing!

- Tip height >> hub height
- Different size/shape of structure (sensor vs. blade)
- Standstill structure vs. moving structure
  -> different wind speeds
  -> vibrations
  -> acceleration forces

→ **For safe and efficient operation of wind turbines under icing conditions, information on rotor icing is required**

Icing basics

Nacelle based systems

Blade based systems

Key content of the report

- **List** of all existing systems
- **Overview** on systems in operation today
- **Detailed evaluation**
  - Sensing technique, measured parameters
  - Technical specifications, recommended sensor position
  - Output data formats & protocols
  - Stage of development, technical maturity
  - Track record, no. of installed systems, certifications
  - Operational experiences
  - Cost of system
- Evaluation matrix: **comparison of systems**

Nacelle based approaches and systems

- Temperature & relative humidity (approach)
- Heated versus unheated anemometer (approach)
- Combitech IceMonitor (SWE)
- Goodrich 0871LH1, 0872F1 and 0872E3 (USA)
- HoloOptics T41 and T44 (SWE)
- New Avionics Ice Meister Model 9734 (USA)
- Labkotec LID-3300IP (FIN)
- Leine Linde Systems IPMS (GER)
- Meteorological Monitoring System PMS (CZE)
- Sommer Messtechnik: IDS-10 (AUT)

Blade based approaches and systems

- Power curve and pitch angle (approach)
- Weidmüller (Bosch Rexroth BladeControl) (GER)
- Eologix (AUT)
- fos4X fos4IceDetection (GER)
- Wölfel SHM.Blade / IDD.Blade (GER)
- Hainzl Haicmon$_{ice}$ (AUT)
- Infralytics (DE)
- MOOG Insensys RMS (UK)

1st questionnaire sent to VGB members

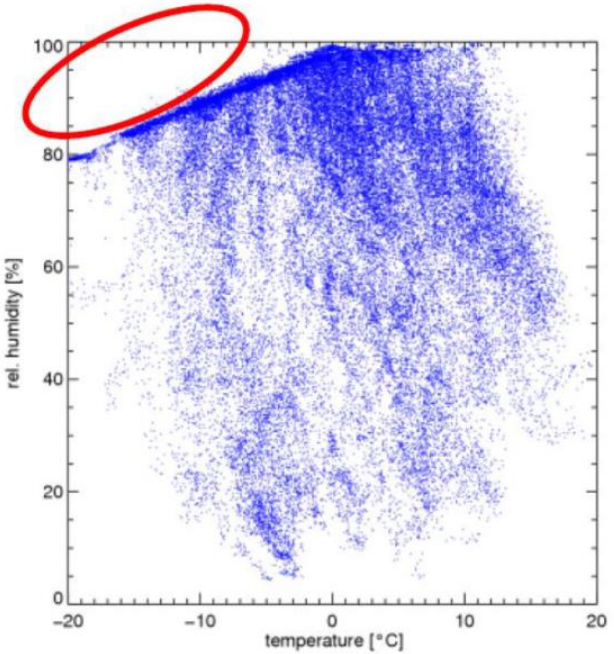
Key questions

- Is the list of ice detection systems complete?
- Available experiences among the VGB members?
- Which systems are most commonly in use?
- On which turbine types?

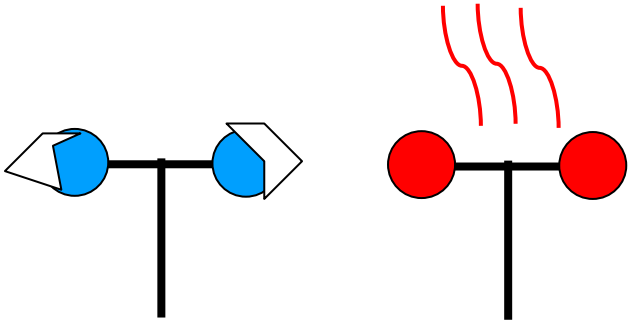
1st questionnaire - conclusions

- Two sensors added (Ice Meister and Sommer)
  → List complete
- Heated/unheated anemometer frequently used
  → Senvion
- Power Curve also very frequently used
  → Enercon
- Labkotec and Weidmüller most frequent systems
  → Vestas, Enercon, Senvion
- Other systems only rarely in operation by now

Nacelle based approaches



t/rh



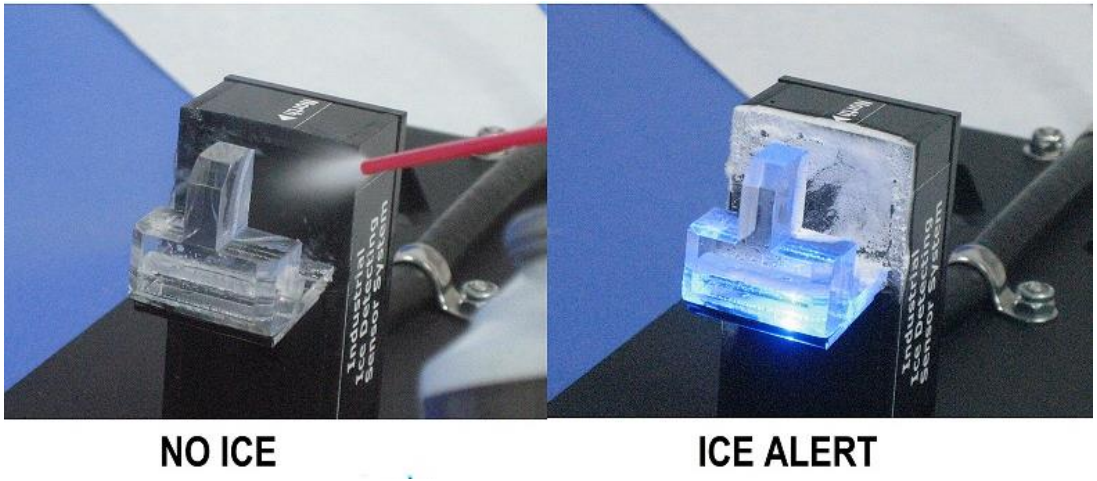
unheated / heated anemometer

Nacelle based systems I

Combitech

Goodrich

Nacelle based systems II

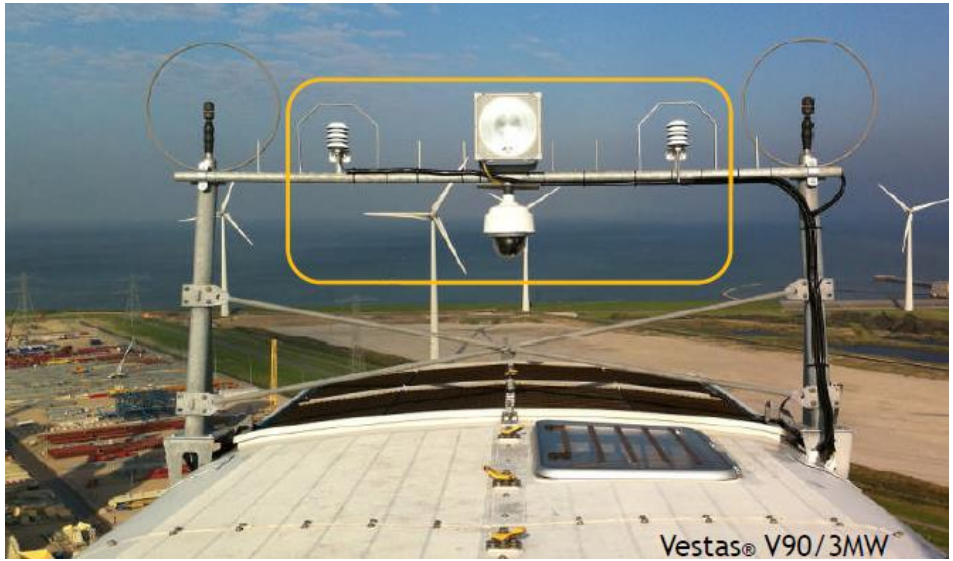


HoloOptics

New Avionics Ice Meister

Nacelle based systems III

Labkotec



Leine Linde System

Nacelle based systems IV

Meteorological Monitoring System PMS

Sommer IDS

Comparison nacelle systems

	Principle	Meteorological Icing	Instrumental Icing	Rotor Icing
Temperature & relative humidity	Temperature < xx°C Relative Humidity > xx%	No (potential)	No	No
Heated versus unheated anemometer	Significant deviation between heated and unheated anemometer	No	Yes	No
Combitech Ice Monitor	Vertical freely rotating cylinder Load Cell	Yes	Yes	No
Goodrich 0871LH1	Ultrasonic vibrating finger Decrease of amplitude during icing	Yes	No*	No
HoloOptics T40 series	Reduced infrared reflection when probe covered with ice	Yes	No*	No
New Avionics Ice Meister 9734	Change of opacity and index-of-fraction when probe iced	No	Yes	No
Labkotec LID-3300IP	Ultrasonic vibrating wire Decrease of amplitude during icing	Yes	No*	No
Leine Linde Systems IPMS	Temperature < xx°C Relative Humidity > xx% Video livestream	No (potential)	Yes (camera)	Yes (camera)
Meteorological Monitoring System PMS	Vertical non-rotating cylinder Load Cell	Yes	Yes	No
Sommer IDS-10	Change of impedance on surface when probe covered with ice	Yes	No*	No

* Yes if heating deactivated, but then no meteorological icing

Comparison nacelle systems

	Commercially available since	No. of systems (on turbines) sold	Stage of development
Temperature & relative humidity	long time	n/a	Serial
Heated versus unheated anemometer	long time	n/a	Serial
Combitech Ice Monitor	2005	50 (20)	Single pieces on demand
Goodrich 0871LH1	1994	250 in 2014	Serial
HoloOptics T40 series	2009	40 (20)	Small scale series
New Avionics Ice Meister 9734	2014	??	Serial
Labkotec LID-3300IP	2002	3000	Serial
Leine Linde Systems IPMS	2010	40 (40)	Small scale series
Meteorological Monitoring System PMS	1998	80(0)	Small scale series
Sommer IDS-10	2016	0	0-series

Comparison nacelle systems

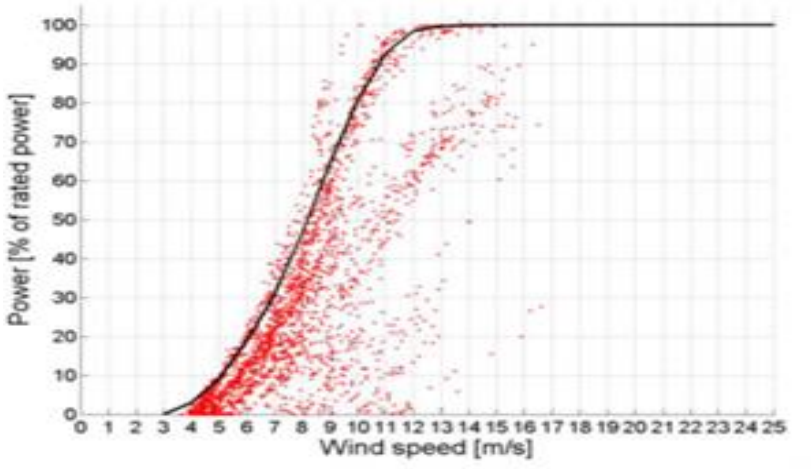
	Certification	Independent field studies	Operational Experiences
Temperature & relative humidity	n/a	Yes	strong overestimation, excessive false alarms
Heated versus unheated anemometer	n/a	Yes	Principle OK, robust, heated anemo gets iced too
Combitech Ice Monitor	designed according to ISO 12494	Yes	Principle OK, not robust, drift, noisy signal, heating too weak
Goodrich 0871LH1	cTUVus (USA)	Yes	Principle OK, robust, Igloo, partly false alarms
HoloOptics T40 series	No	Yes	Principle OK, not robust, heating too weak, partly false alarms
New Avionics Ice Meister 9734	??	No	n/a
Labkotec LID-3300IP	GL Component Certificate UL/CSA certificate VTT icing wind-tunnel	Yes	Principle OK, robust, heating too weak, partly false alarms, individual settings important
Leine Linde Systems IPMS	In process	No	n/a
Meteorological Monitoring System PMS	No	Yes	Principle OK, robust, stable signal
Sommer IDS-10	No	No	n/a

Comparison nacelle systems

Conlusions

- No nacelle system can measure rotor icing
- All systems have shortcomings
- Labkotec and Goodrich with highest technical maturity

Blade based approach



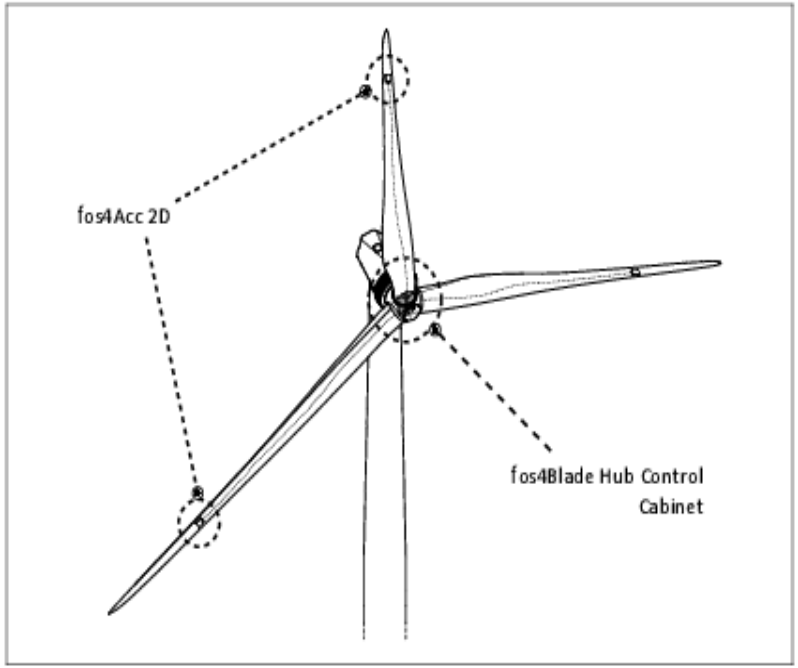
Power curve

Blade based systems I

Weidmüller (Bosch Rexroth)

eologix

Blade based systems II



fos4X

Wölfel

Comparison blade systems

		Principle	Meteorological Icing	Instrumental Icing	Rotor Icing
BLADE BASED SYSTEMS	Power curve	Deviation between produced power and power curve at low temperatures	No	No	Yes
	fos4 Ice Detection	Fibre-optic Accelerators Change in Eigenfrequency when blade is iced	Yes	No	Yes
	Bosch Rexroth BladeControl	Piezo-Electric Accelerators Change in natural oscillation frequencies 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
BLADE BASED SYSTEMS	Power curve	Yes	No	3 m/s	Yes	Yes
	fos4 Ice Detection	Yes	Yes	3 m/s	Yes	Yes
	Bosch Rexroth BladeControl	Yes	Yes	2 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
BLADE BASED SYSTEMS	Power curve	none	n/a	No	n/a	n/a
	fos4 Ice Detection	Minimum 1 per blade	1/3 of the blade radius	No	inside glued	Yes
	Bosch Rexroth BladeControl	Minimum 1 per blade	1/3 of the blade radius	Yes	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
BLADE BASED SYSTEMS	Power curve	n/a	Enercon: > 1690 turbines	serial
	fos4 Ice Detection	2013	50-70 by end of winter 2015/16 (~40 x Senvion)	Small scale series all turbine types
	Bosch Rexroth BladeControl	2005	> 1500 (300 in 2015)	Serial all turbine types
	Wölfel SHM.Blade/ IDD.Blade	2012	100 (mainly Nordex)	Serial for Nordex Available for all turbine types in 2016
	Eologix	2015	~20	Small scale series all turbine types

Comparison blade systems

		Certifications	Independent field studies	Field tests
BLADE BASED SYSTEMS	Power curve	n/a	(Yes)	
	fos4 Ice Detection	GL Type Certificate GL Condition Monitoring	No	2014/2015 results available on request
	Bosch Rexroth BladeControl	GL Type Certificate GL Condition Monitoring	No	own evaluations
	Wölfel SHM.Blade/ IDD.Blade	GL Type Certificate GL Condition Monitoring	No	Nordex Sweden 2011/12 Nordex Germany 2014/15
	Eologix	GL Component Certificate	No	Winter 2015/16 results at Winterwind 2016

Comparison blade systems

Conlusions

- All systems can measure rotor icing
- Power curve robust but doesn’t work at standstill
- Weidmüller (Bosch Rexroth) with longest experience
- Three new and promising systems
- No independent evaluations / field tests available
- No real winner

Field test: blade systems

Main objectives:

- Independent benchmark of the four blade based systems
  - Eologix (AUT)
  - Fos4X fos4IceDetection (GER)
  - Weidmüller (Bosch Rexroth) BladeControl (GER)
  - Wölfel SHM.Blade / IDD.Blade (GER)
  -> All systems installed in the same wind turbine
- Camera system + SCADA data as additional reference
- Winters ~~2016/17 and~~ 2017/18 and 2018/19
- Validation against camera images and SCADA data

Data base for study

The following data will be **collected** from the wind turbine:

- SCADA data and operational status data
- Output of ice detection systems (signals, frequencies, ice thickness etc.)
- Webcam images

All data **stored in data base** at Meteotest, camera images (live/archive) on **protected website.**

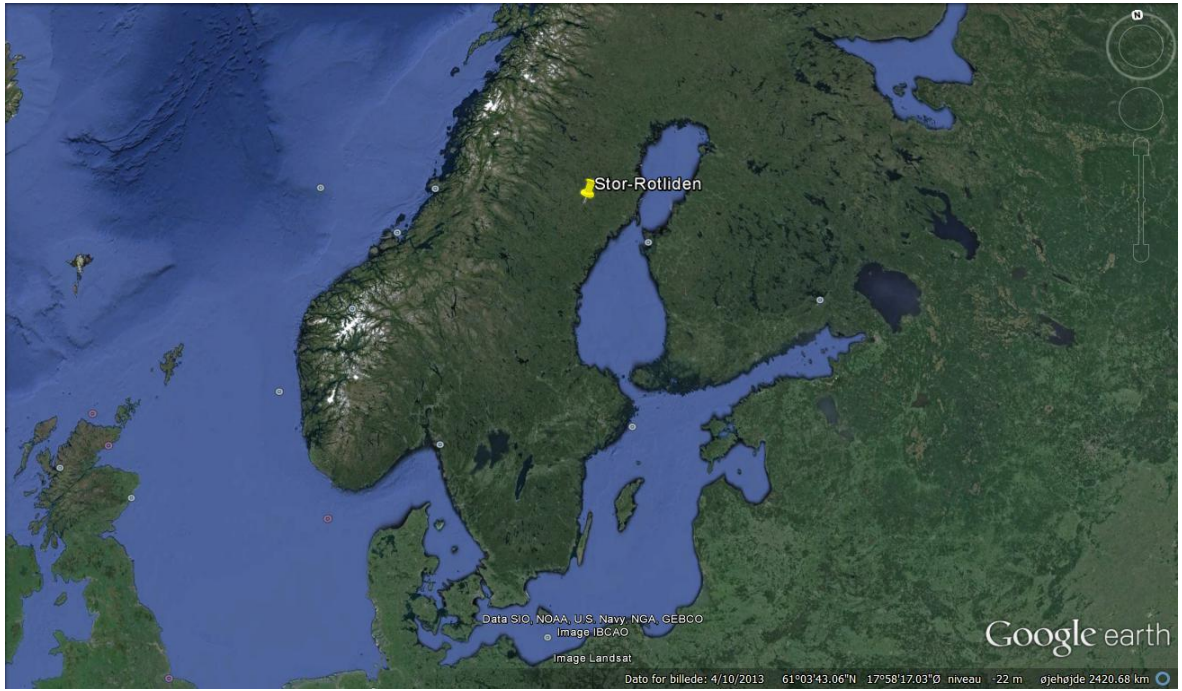
Challenge: Independent data transfer from wind turbine for every manufacturer separately

Data analysis

- Hit rate of the system
- False alarm rate of the system (and related conditions)
- Missed events (and related conditions)
- Time difference against webcam ice detection
- Time difference compared to other systems
- Time difference to T19 IceLossMethod
- Representation of different ice thicknesses on the blade
- Reliability of "no ice" signal“ for restart
- Detection of meteorological icing (growth) and icing intensity (load)
- Data availability
- ...

Test site

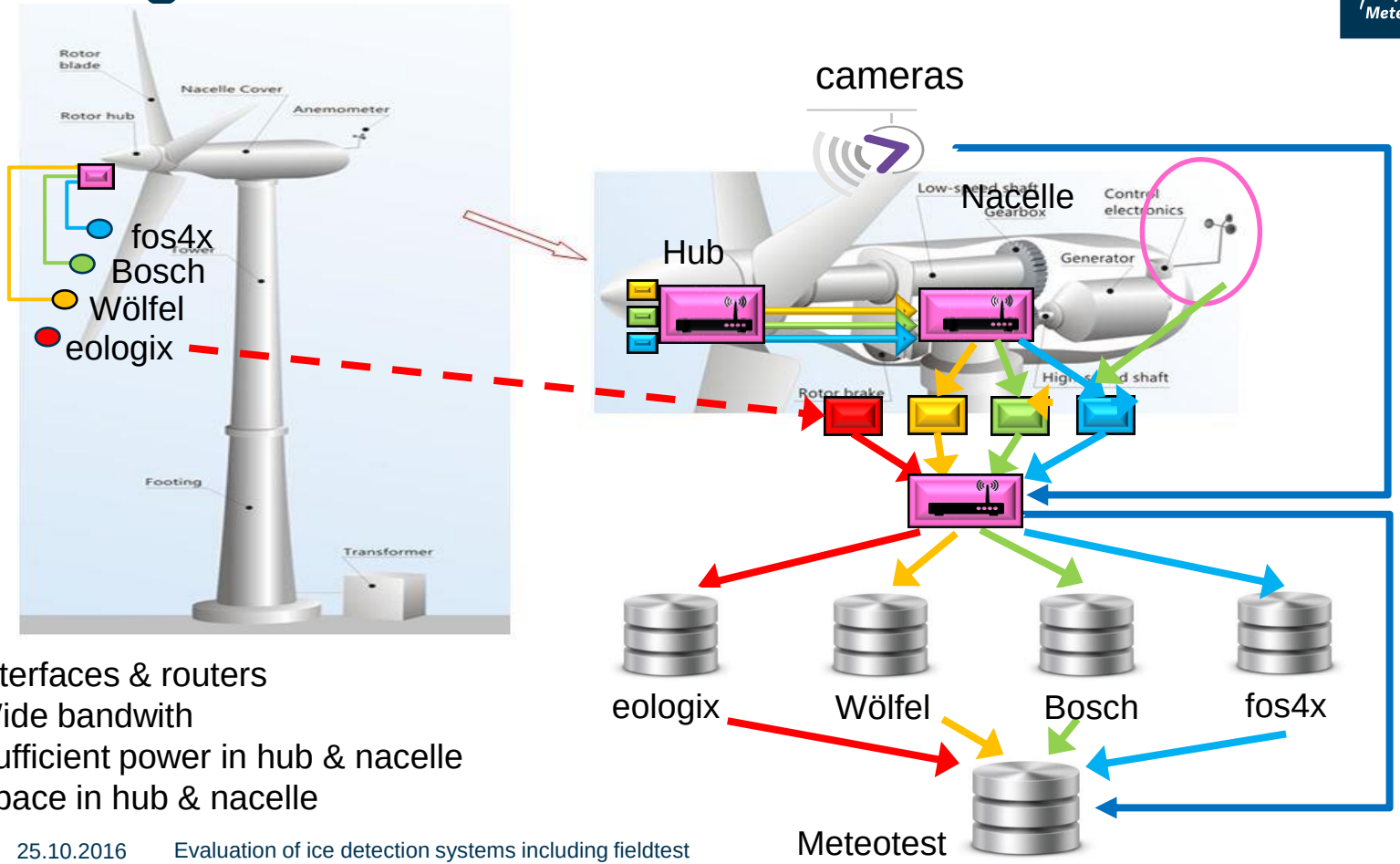
- **Windpark Stor Rotliden, Sweden**
  Vestas V90, non-heated



Experienced challenges during installation

- Communication between many players (park operator, sensor suppliers, turbine manufacturer, Meteotest) -> very time consuming
- Collecting information on existing system
  - power supply, network connections, space in hub and nacelle
- Finding ideal locations for sensors and control cabinets
- Fos4X, Wölfel and Bosch Rexroth need access to turbine data -> upgrade of communication network necessary
- Ice detection systems installed by manufacturers -> country specific requirements for service technicians
- Confidential treatment of all data – individual data streams
- Avoiding too many downtimes of turbine for installation of the IDS
- Cold temperatures / weather days / technical failures - broken elevator inside turbine

Challenges: data transfer



- Interfaces & routers
- Wide bandwith
- Sufficient power in hub & nacelle
- Space in hub & nacelle

Thank you for your attention!