Blattmonitoring an der Spitze des Rotorblattes

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Condition Monitoring at the Tip of a Rotor Blade

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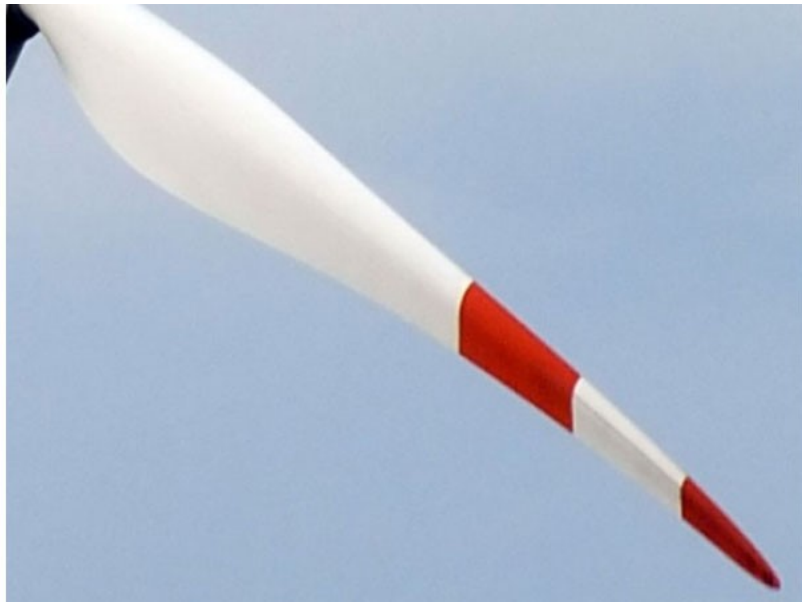
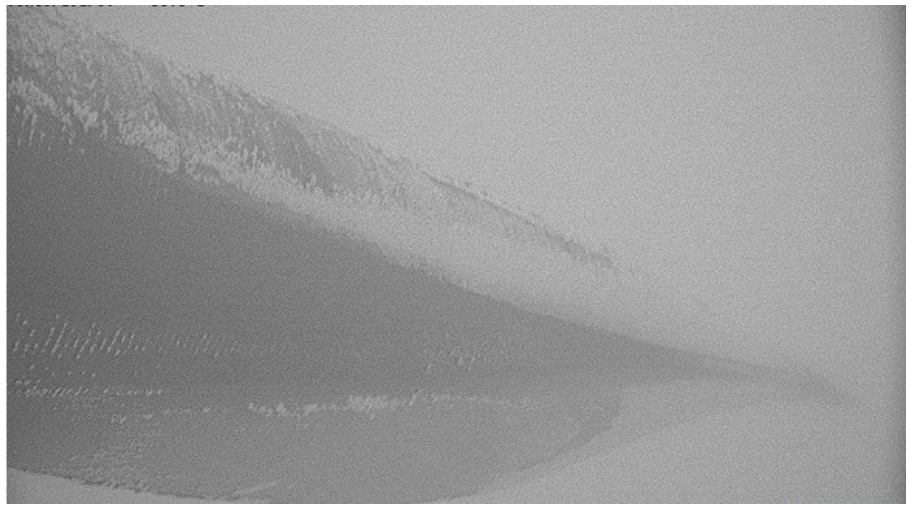
Blattmonitoring



Different interesting things going on on the blade surface

- Icing
- Heating Results
- Vibration & Loads

Große Verluste durch Vereisungen



Huge losses due to unreliable ice detection:

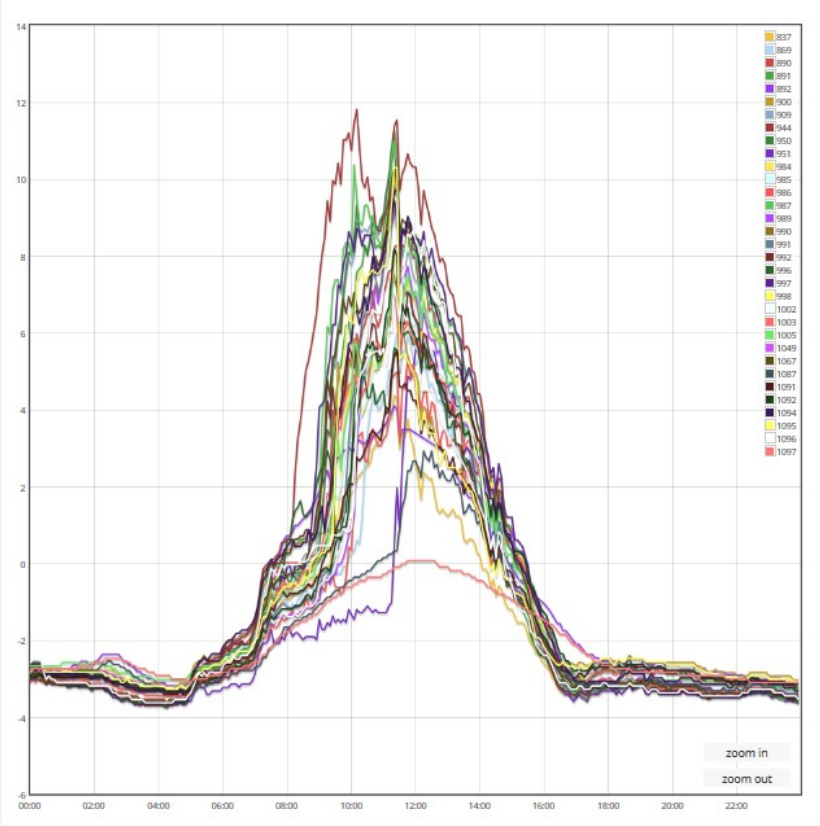
- Stopped operation although no ice on the blades
- Delayed re-start (ice on the blades already disappeared)
- Saftey and load issues in case there is undetected ice

Blattbasierte Eisdetektion

Ice Detection where it occurs:

- Directly on the blades
- Thin as well as thick layers of ice should be differentiated
- Special customer needs:
  - “No ice at all on the blades”
  - “Want to keep the blades ice free / Control heating solution”

Temperatur der Blattoberfläche



Temperatur measurement

- directly on the blade surface
- accuracy +/- 0.25° C
- fully calibrated
- excellent long term stability (< 0.04 °C/yr)

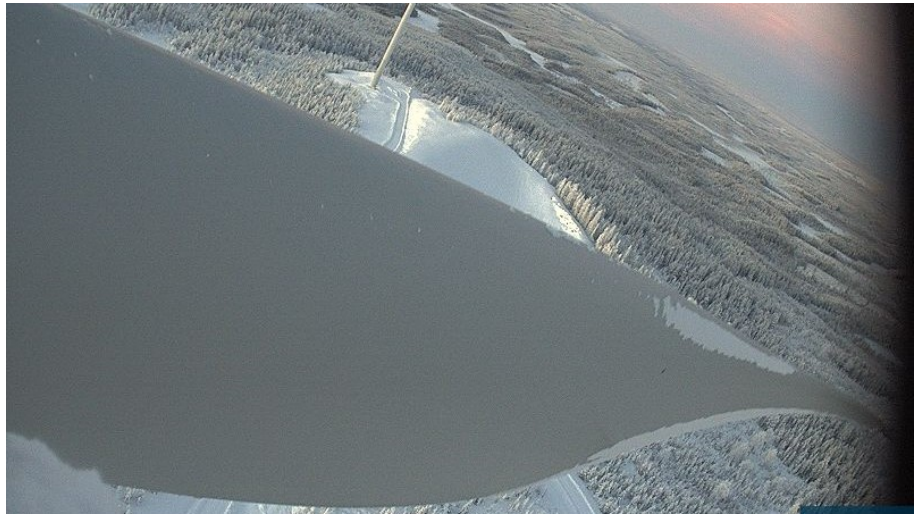
Heizungssteuerung

Heating solution should be used to

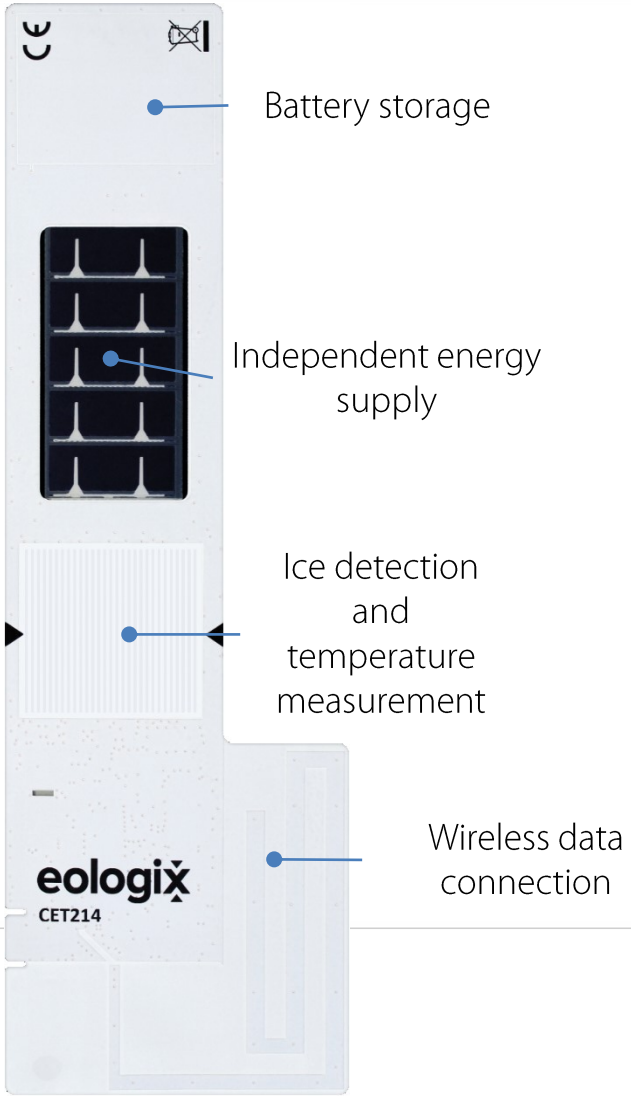
- Keep blades ice free
- In severe conditions, icing of blades should be delayed
- Ice should be detected just before it occurs and when it is gone
  - Predictive Ice Detection
  - Turn on/off heating at correct times

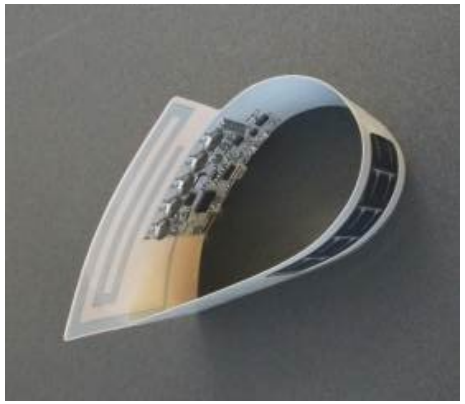
Heated Turbine:
Ice Creation & Heater Control

Turbine with heating solution



Sensor

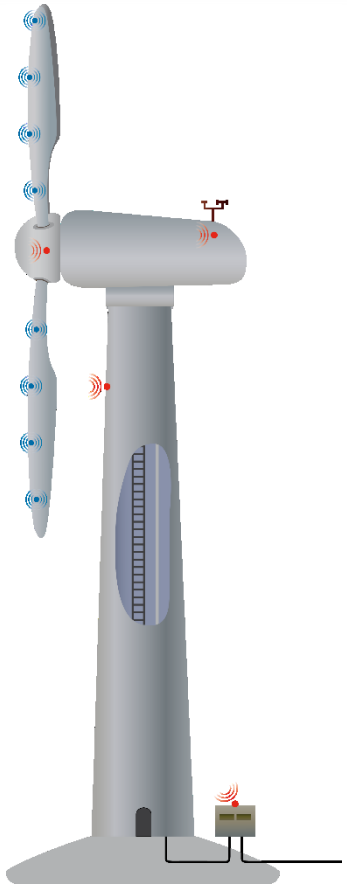


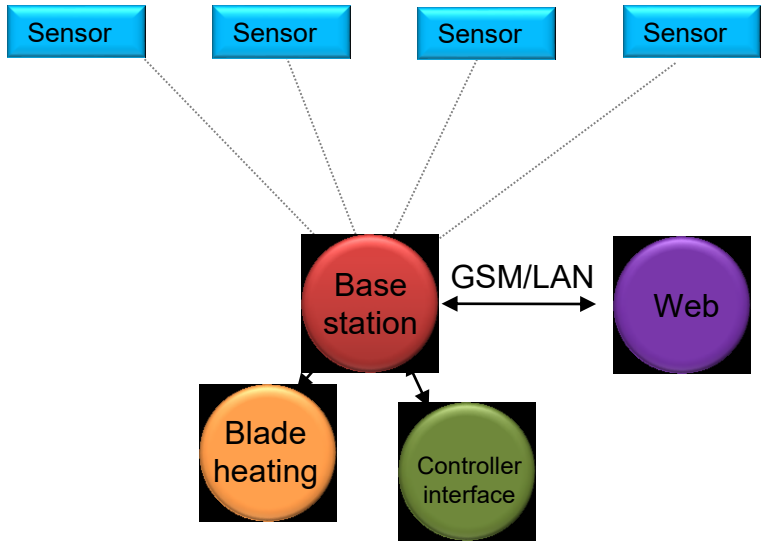


Sensors

- Wireless
- Integrated power supply and storage
- Thin & flexible foil
- Direct ice detection on the blade surface
- Detects thin ice layers as well as thick ones
- Distinguishes ice layer thicknesses
- Surface temperature measurement
- Robust & reliable
- Decoupled & isolated from internal wiring
- No influences on or from lightning
- Easy to apply even as retro-fit
- Inexpensive solution
- DNV GL certified

Empfangsstation



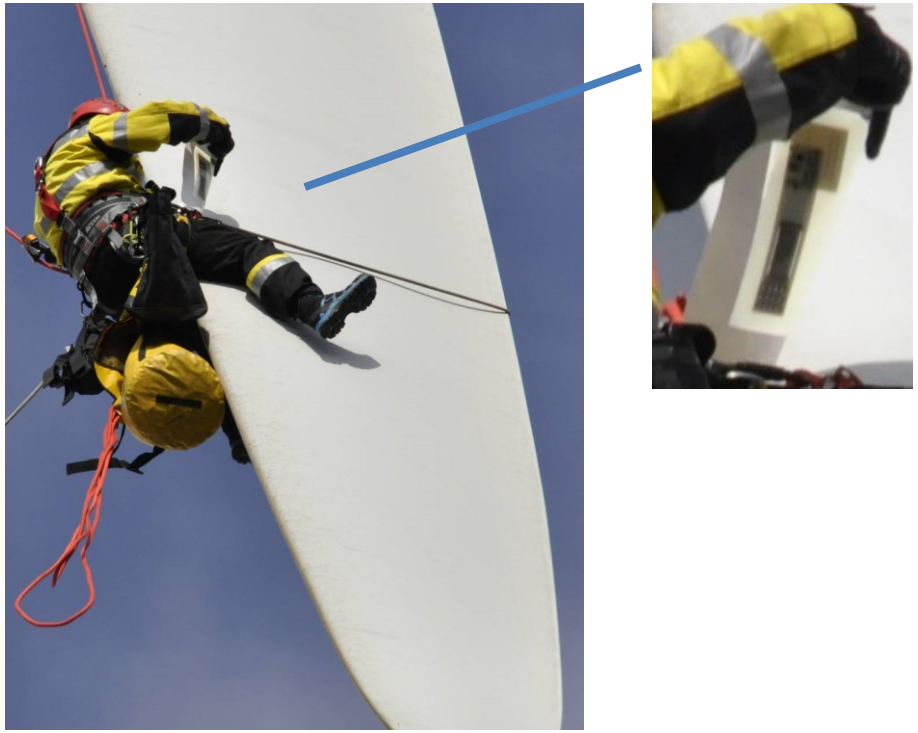


Data acquisition unit

- Measurement data acquisition & analysis
- Autonomous offline fully functional
- Optional controller integration
- Optional data transfer LAN or wireless via GSM
- Automatic stop & restart function DNV GL certified
- Mounted in the nacelle or else where

Installation Examples:
Ground based installation

Installation Examples:
In-air installation by rope-climbers

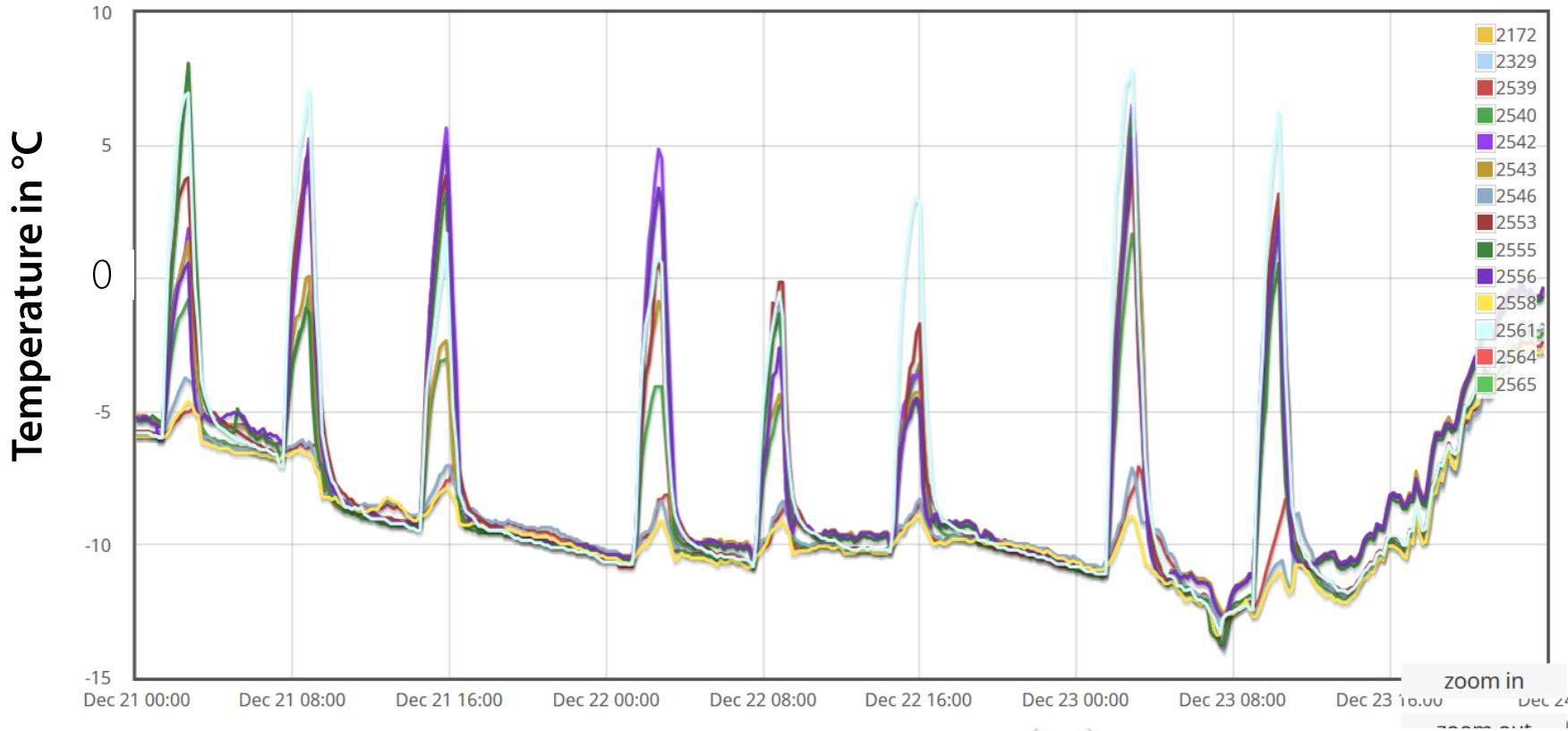


Stoppage of turbines for installation purpose: usually 1-2 days

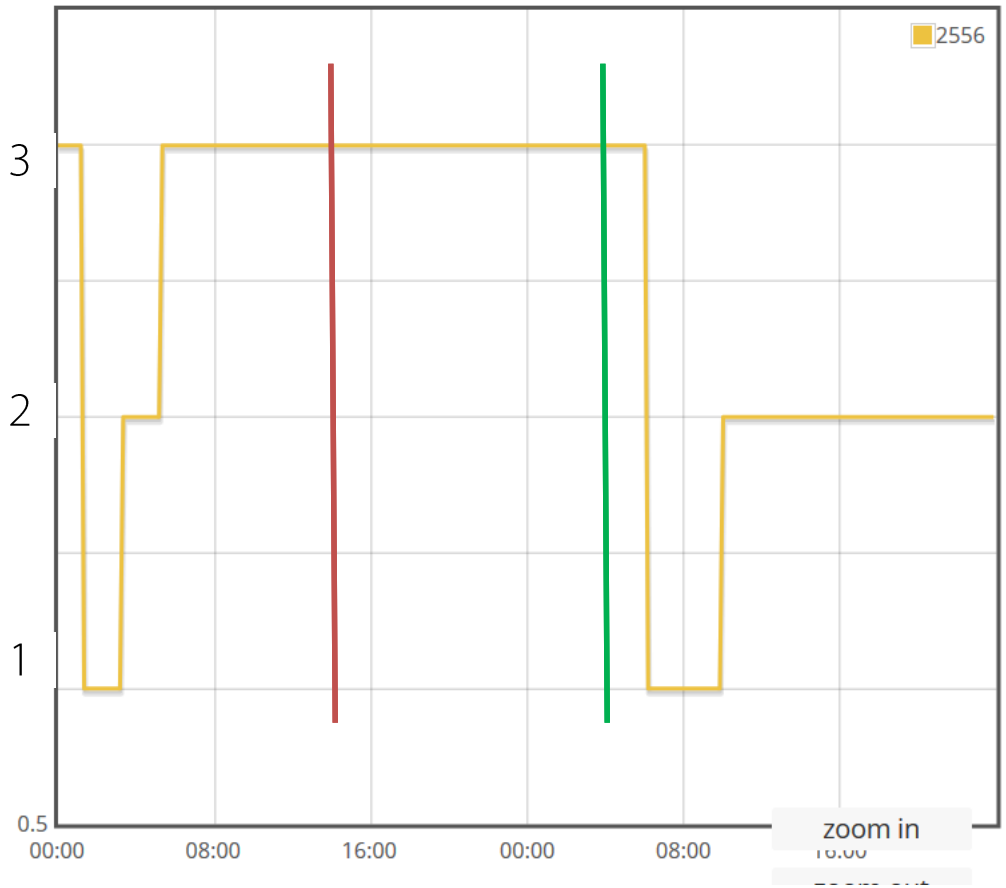
Heated Turbine:
Ice creation & Heater Control

- Temperature from

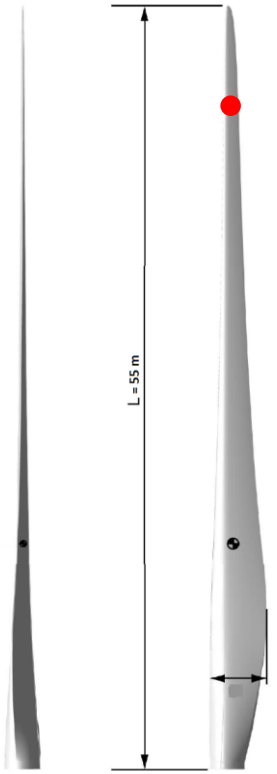
  Dec 21st – 24th

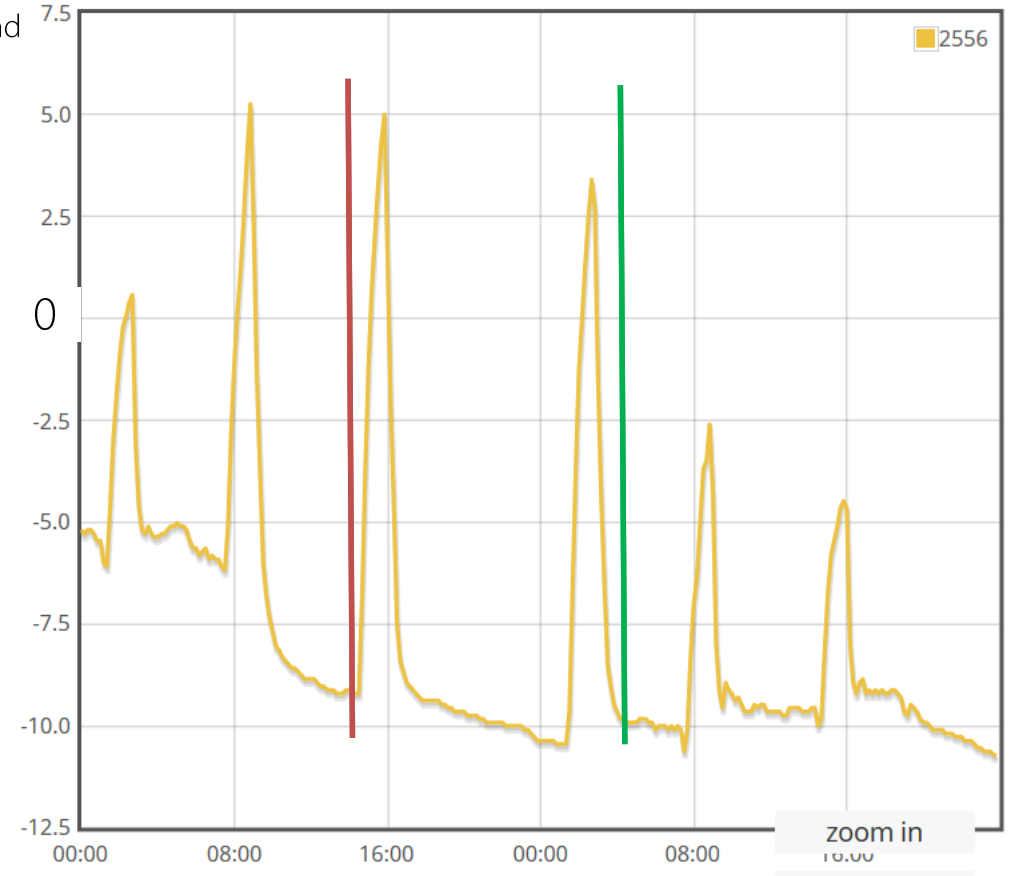


Heated Turbine:
Ice creation & Heater Control

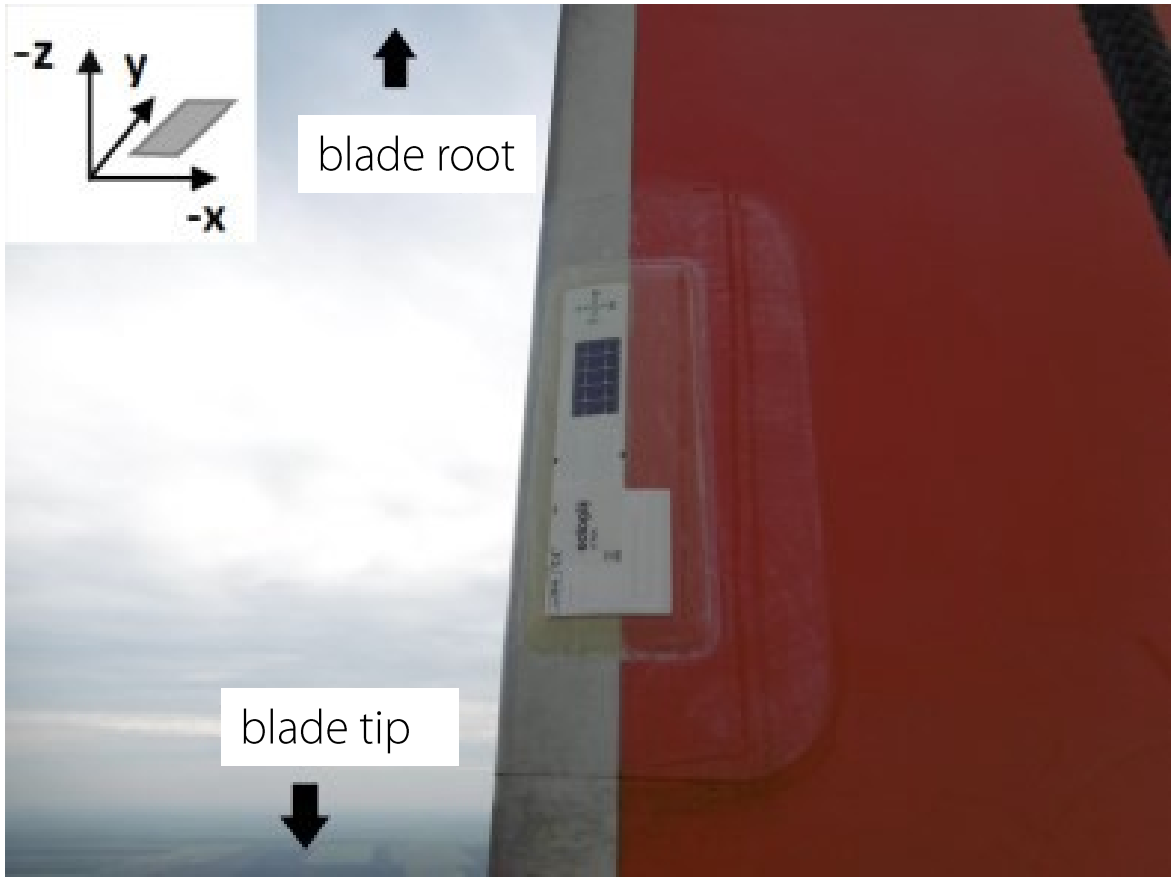


Dec 21st – 22nd





Vibrationsmessung am Tip



Sensor Placement:

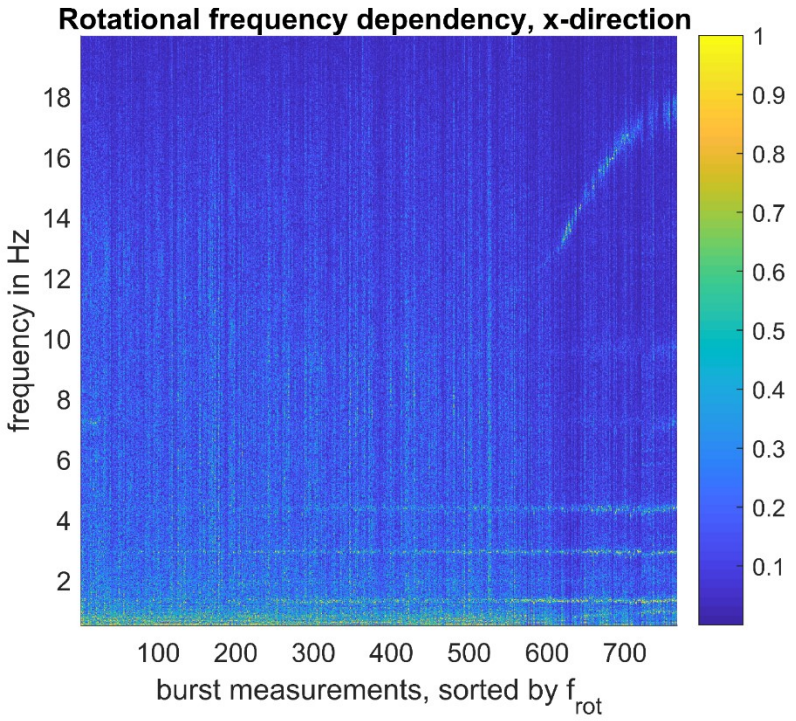
- > 90% of the blade length
- On the outside (no space limitations, easy maintenance)
- Placing accelerometers on the blade tip→ Maximum deflection

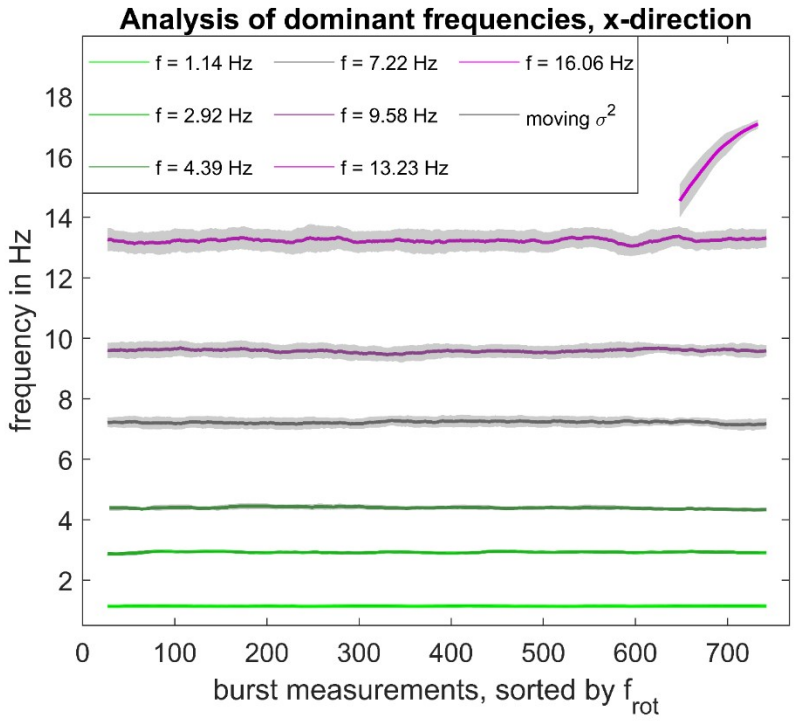
How ?

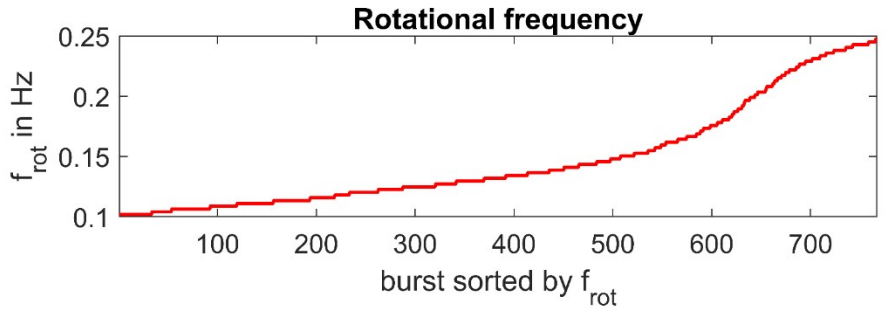
- Integration of MEMS sensor element into sensor
- Thin and flexible design
- Wireless power supply and data transmission
- Burst measurements of 26s @ ~150 Hz

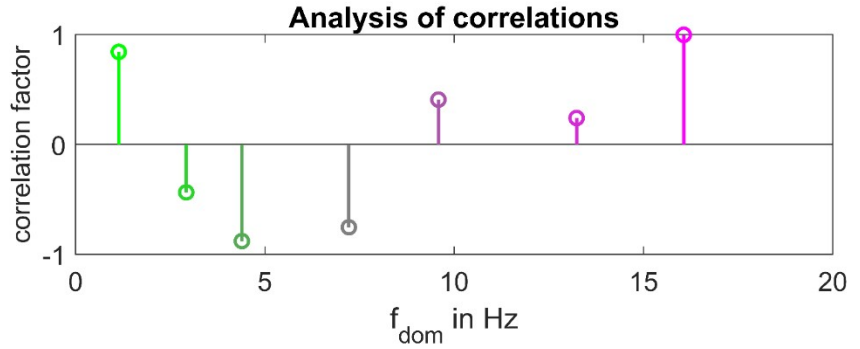
Loss, T., Gerler, O., & Bergmann, A. (2018, October). Using MEMS Acceleration Sensors for Monitoring Blade Tip Movement of Wind Turbines. In *2018 IEEE SENSORS* (pp. 1-4). IEEE

Messdaten – Charakterisierung v. Vibrationsdaten





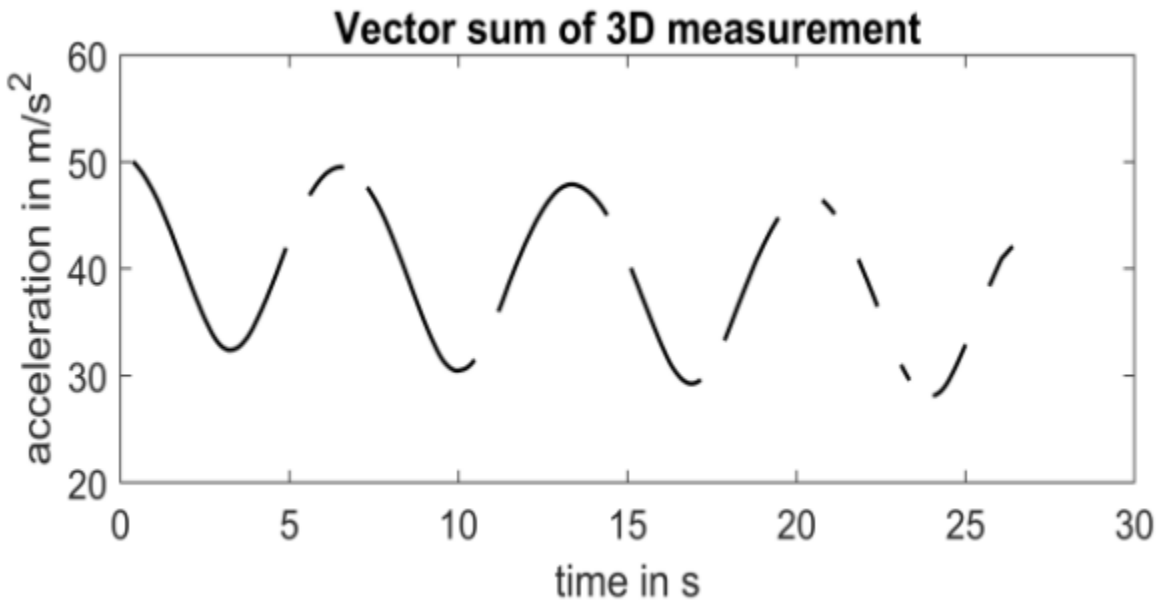


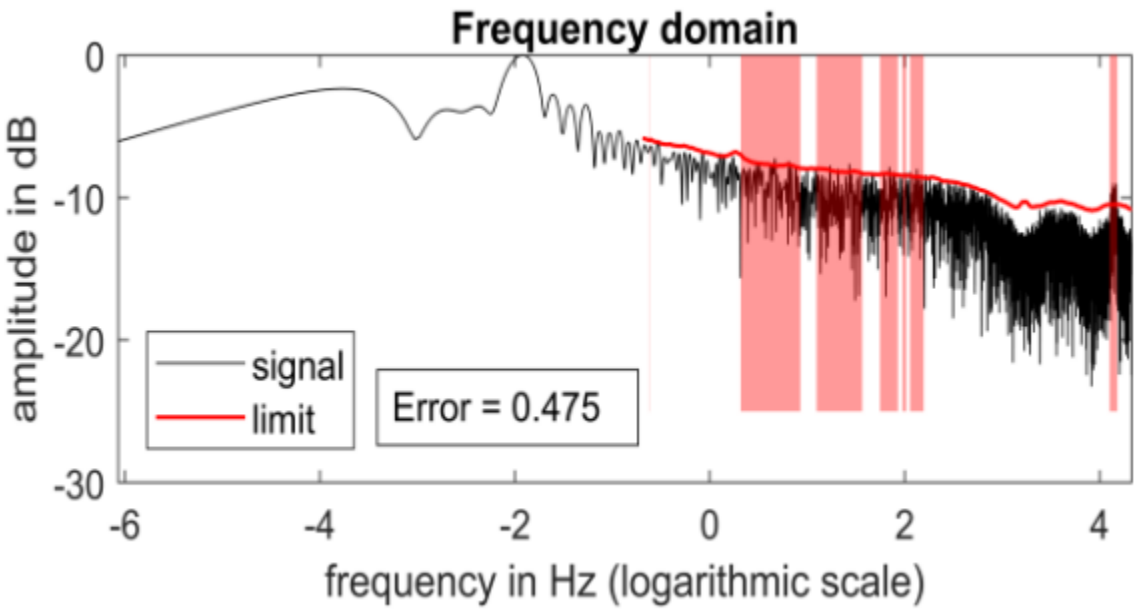


- Increased vibrations for high rotational frequencies (DF at f=16.1 Hz, f_{rot}> 0.2 Hz)
- Increasing DFs with increasing f_{rot} (stiffening effect of the blades)
- Few DFs with a very small or even negative correlation

Loss, T., Moser. M, Bergmann, A.: Load and Vibration Monitoring of Wind Turbine Blade Tips Using 3D Accelerometers. Proceedings Eurosensors 2018.

Turbine Setting Monitoring





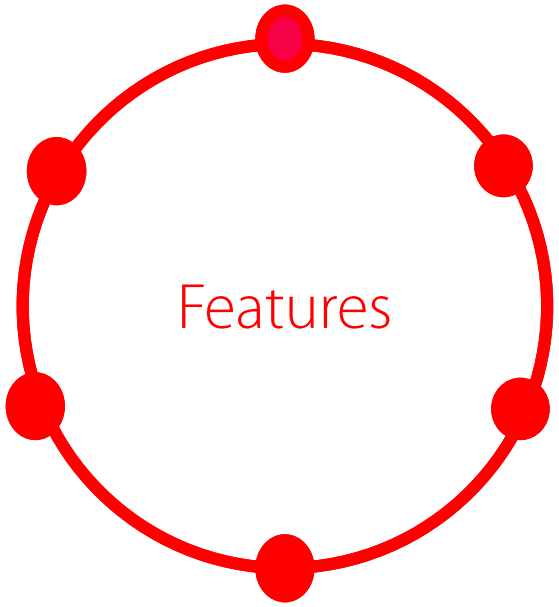
Loss, T., Moser. M, Bergmann, A.: Load and Vibration Monitoring of Wind Turbine Blade Tips Using 3D Accelerometers. Proceedings Eurosensors 2018.

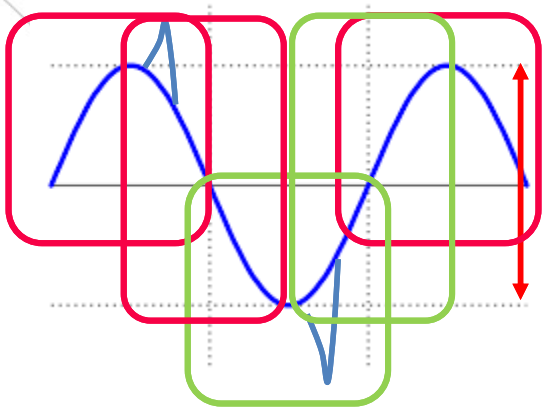
Feature Development

Rotational frequency f0,
estimated from FFT

Non-ideal circular movement,
Split into right/left half-circle
Difference in rotational frequencies:
F_{RL}

Non-ideal circular movement,
Split into top/bottom half-circle
Difference in rotational frequencies:
F_{TB}





Periodic deviations from
ideal sine wave
(top / bottom)
Peak widths: F_{PW1} /F_{PW2}

Periodic deviations from
ideal sine wave (top / bottom)
Peak distances: F_{PD1} /F_{PD2}

AC amplitude F_{SC}

Blattspitzenbewegungen

Settings:

- 4 week real world data set
- MEMS sensor mounted on the blade tip
- Wind turbine with a diameter of 101 m
- Preprocessing: interpolation of missing values (transmission errors)

Real Data Evaluation

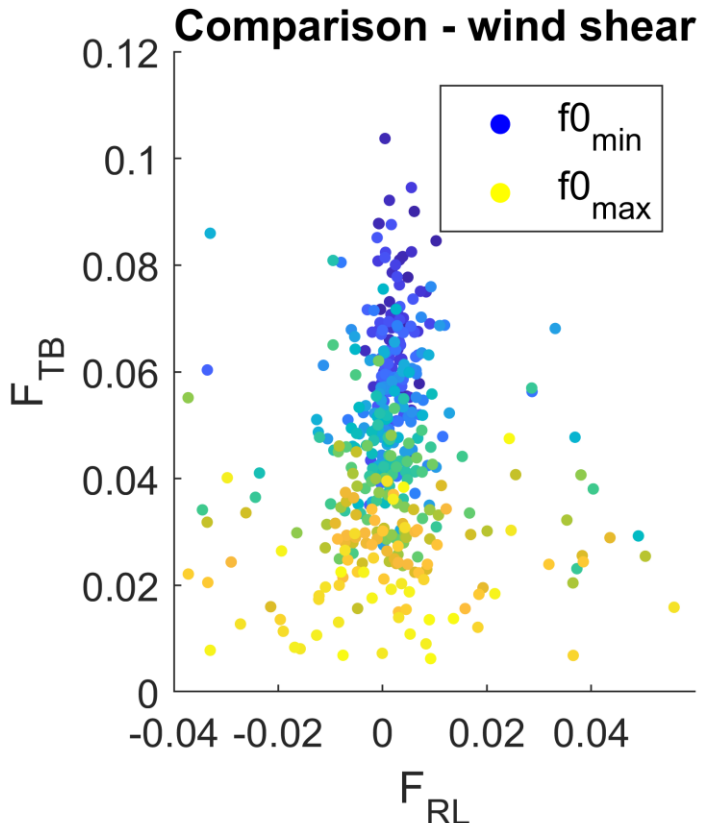
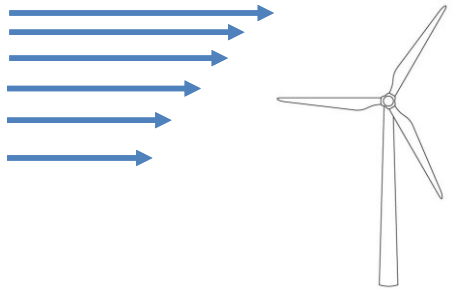


Figure 12: Evaluation of wind shear features

- Decrease of F_{TB} with increasing f_{rot} (balanced rotation, stiffening)
- Spread of F_{RL} at higher f_{rot} (difficult alignment at higher windspeeds)



Real Data Evaluation

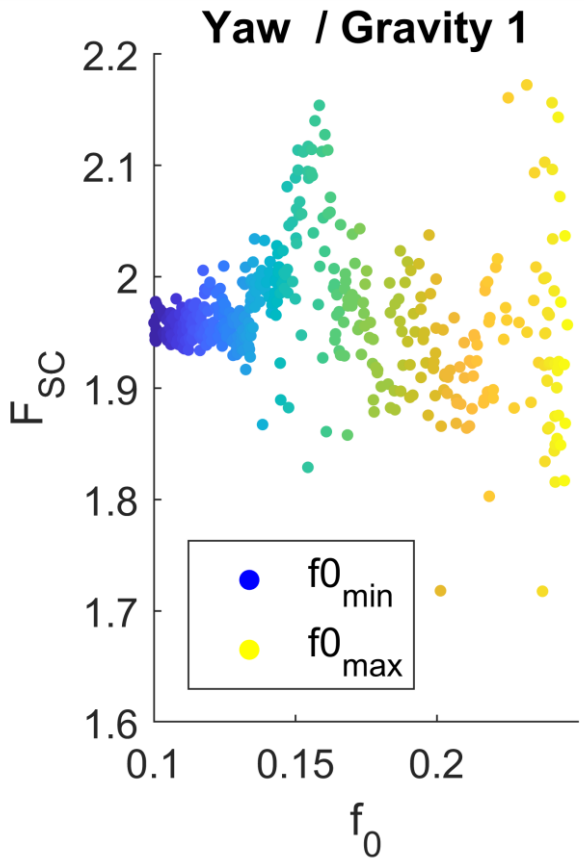


Figure 13: Evaluation yaw features

- Increased variance of F_{SC} at 0.15 Hz (imperfect alignment of turbine and wind direction)
- Decrease of F_{SC} at higher f_{rot} (difficult alignment at higher windspeeds)

Selected References

eologix sensor technology

OEM:

ENERCON ENERGIE FÜR DIE WELT · Vestas · SIEMENS Gamesa RENEWABLE ENERGY · NORDEX · SENVION · GE

Austria:

WIEN ENERGIE · Verbund · EVN · energie BURGENLAND · ÖSTERREICHISCHE BUNDESFORSTE

International:

e·on · VATTENFALL · vleemo · ALPIQ · PLANET ENERGY Greenpeace Energy Kraftwerke · ENGIE

Zusammenfassung & Ausblick

- Einfach nachrüstbar
- Keine externen Daten nötig
- Messung an der Blattspitze essentiell für Eis, Temperatur und Bewegungsmonitoring
- Vibrationsmessung an der Blattspitze wurden das erste Mal überhaupt in Betrieb gemessen
- Höhere Lasten und Vibrationen können gemessen und erkannt werden

Vielen Dank!

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