BLADEcontrol®

Jenseits der Eiserkennung:
Wie Rotorblattüberwachung den Anlagenbetrieb unterstützt

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Weidmüller

BLADEcontrol®
CONDITION MONITORING SYSTEM

HMU

Access Point Nacelle
APNAC

Evaluation and
Communication Unit
ECU

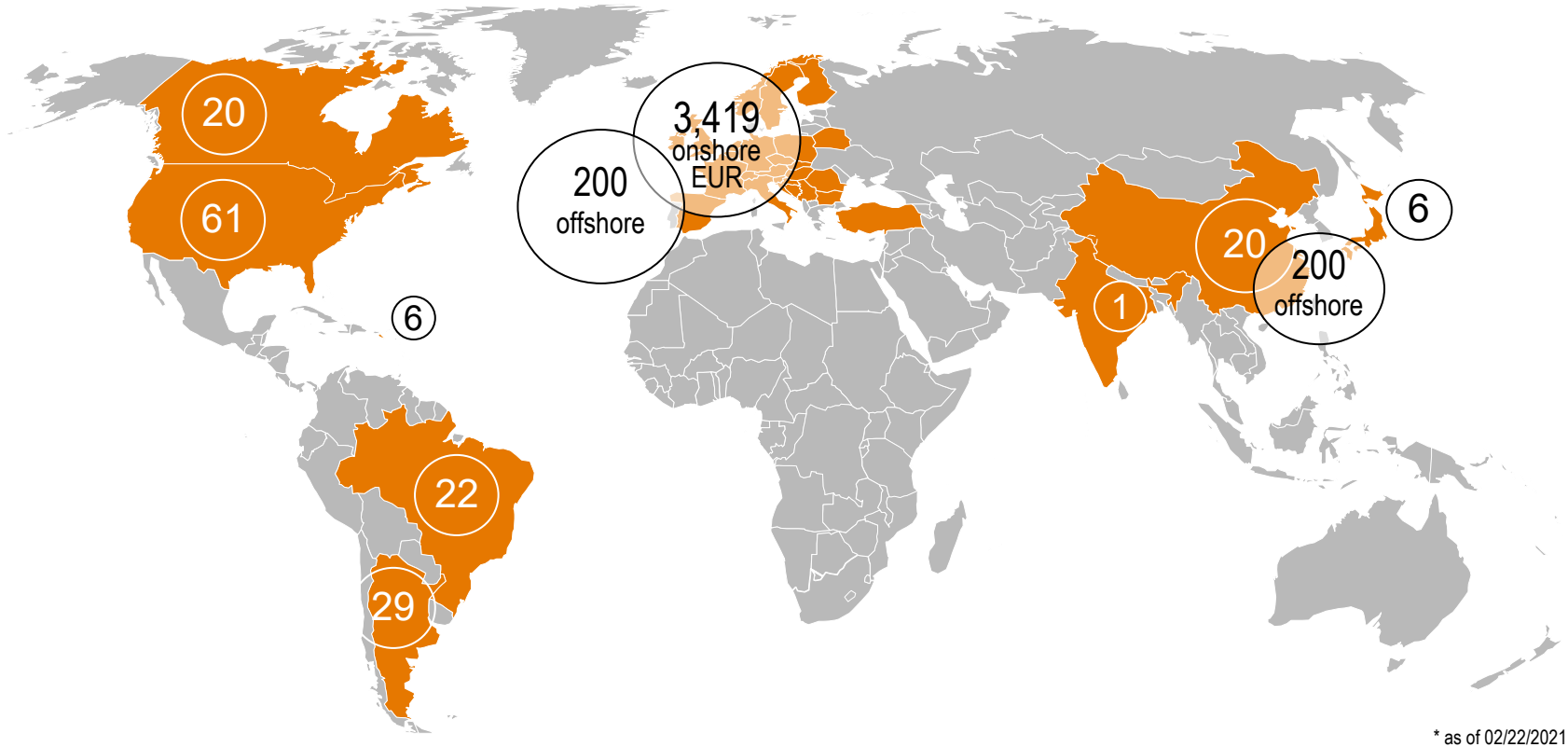
Blade Sensor

Monitoring Center

Turbine Controller

Weidmüller

Global Deployment



* as of 02/22/2021

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BLADEcontrol®
CONDITION MONITORING SYSTEM

Structural Health Monitoring

- **Blade Deterioration / Damage**
- **Main or Pitch Bearing Deterioration / Damage**
- **Loose Components**
- **Bolt / Nut Damage**

Ice Detection

- **Formation of Ice on Blades**
- **Conditional Stop**
- **Auto-Restart**

Optimization

- **Aerodynamic Imbalances**
- **Yaw Misalignment**
- **Wake Effect**

Improvement of Operation in Ice Detection

Master-Slave configuration of ice detectors:

- Master turbines are equipped with BLADEcontrol
- Slave turbines are triggered by the Master turbine signal
- Automatic restart not allowed for slave turbines

Real case example: Three years of Master-Slave

- 3 out of 27 turbines detect ice → **Ø 120 MWh standstill**
- 24 turbines triggered switch-off without automatic restart → **Ø 171 MWh standstill**
- **Result:**
  - ✓ Approx. 4,500 € additional yield per turbine
  - ✓ ROI <3 years
  - ✓ > 1.5 Mio. € additional yield in 15 years

Ice Build-up in Wind Farms

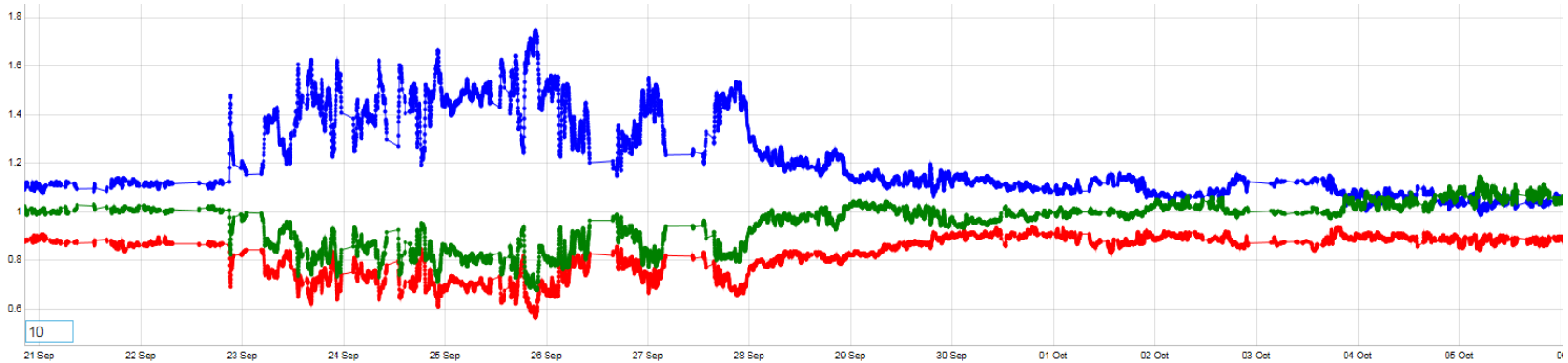
Five hours from first (WTG 2) to last ice alarm (WTG 3)

→ individual measurement needed

Combination with Anti-Icing Systems

Reliable damage detection at heating mats to ensure a secure anti-icing system outside on the rotor blades

- Re-calibration of **BLADE**control® after installation of heating mats necessary
- Damage indicator clearly indicated a defect at the heating mat at blade 2 (blue)



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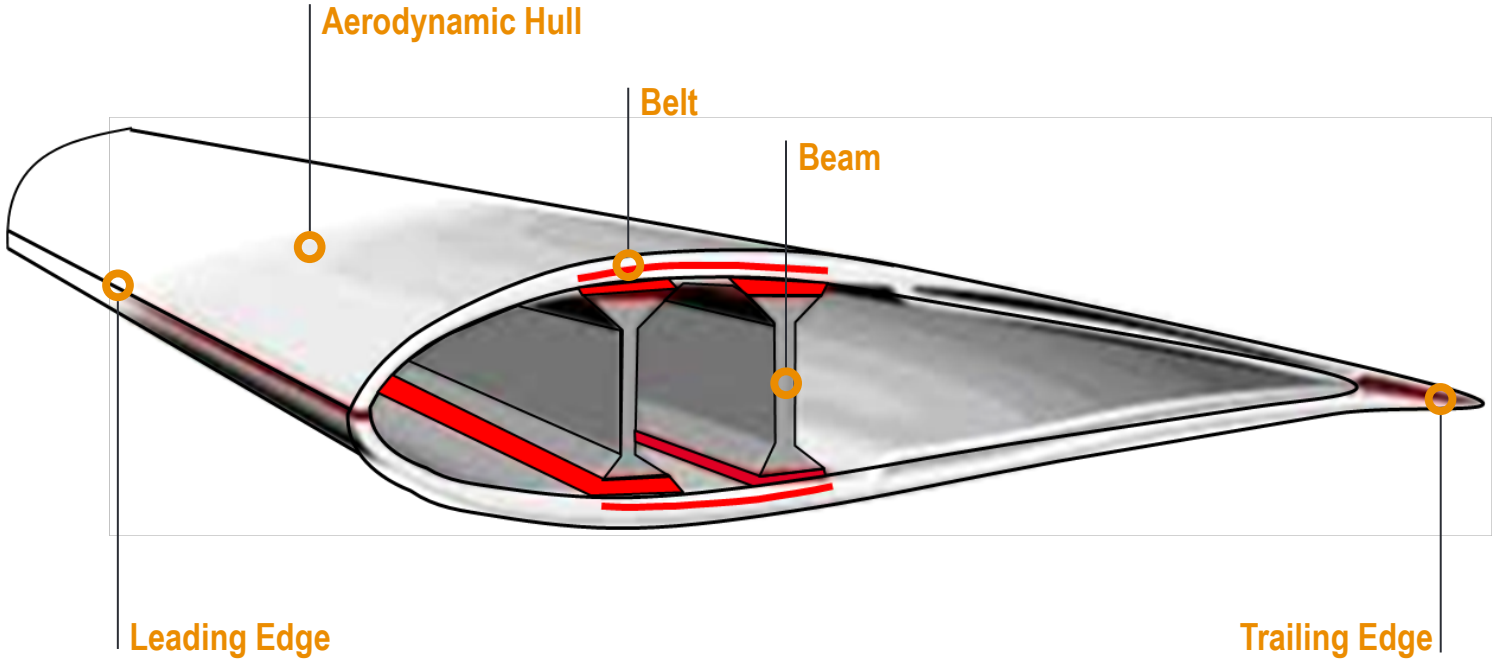
Rotor Blade Damages



Trailing edge debonding

Problem:

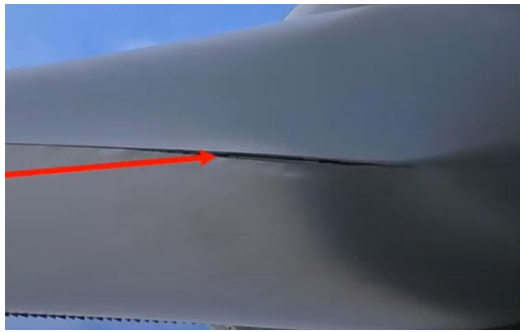
- Trailing edge opens in root section
- It turned out that the root cause is a spar web debonding that can lead to blade loss

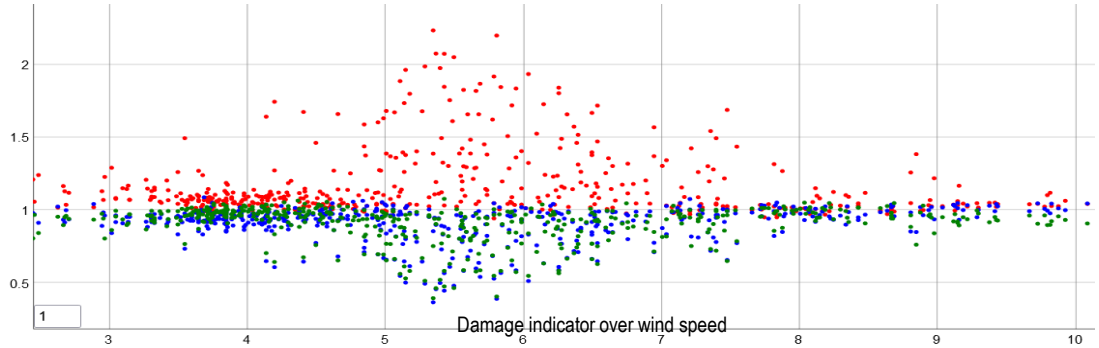
Solution:

- Detection of the root cause rather than the secondary damage

Benefits for customer:

- Avoidance of blade loss
- Avoidance of critical size of damage
- Lower repair cost





Spar Web Separation

Problem:

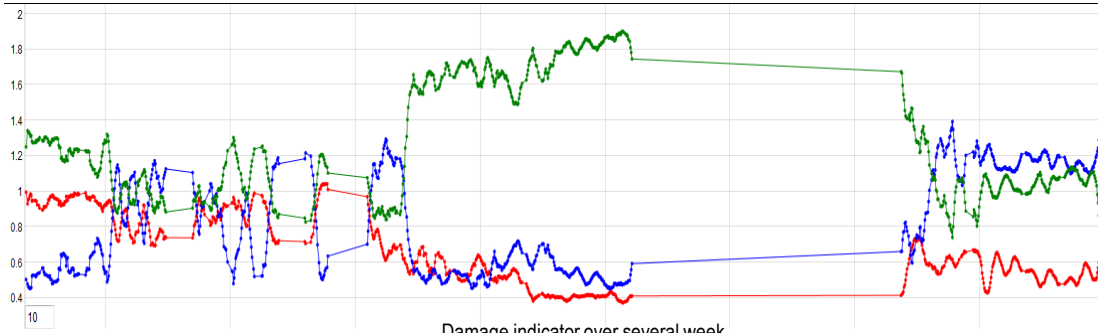
- Spar web separates from hull
- Critical size of damage during several weeks
- In case of non-detection, damage will lead to loss of blade

Solution:

- Early detection by analysing specific frequency ranges of all three blades
- Automatic & permanent monitoring

Benefits for customer:

- Avoidance of blade loss
- Avoidance of critical size of damage



Damage indicator over several week

Blade Root Damage

Problem:

- Different blade damages on several turbines in a wind farm
- Blade types not available on market anymore
- Manual blade inspection every 6 months (costs: 1,000 $/turb.)

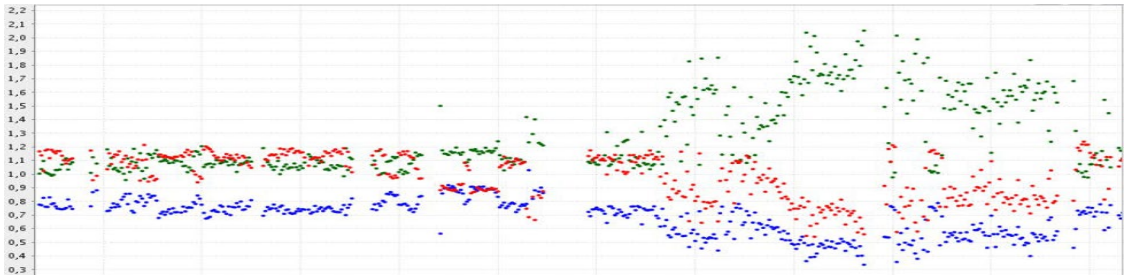
Solution:

- Detection of small deviations in early stage results in timely detection of different damage types at the wind farm
- Automatic & permanent monitoring

Benefits for customer:

- Saving blades that are no longer available
- Lower repair costs
- Longer inspection intervals

Source: Brenner & Gollee, 2014



Damage indicator over several week

Cracks

Problem:

- Crack at leading edge of blade
- Critical size of damage during several weeks!
- In case of non-detection damage will lead to blade loss

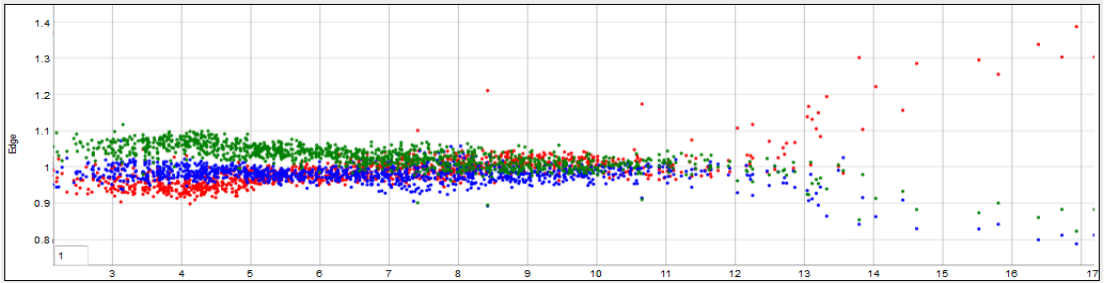
Solution:

- Analysis of blade-specific frequency ranges plotted over wind speed
- Detailed evaluation of externals (e.g. wind speed, pitch angle,…)

Benefits for customer:

- Significantly lower repair costs due to early damage detection
- No risk of losing the blade


Source: Cerbe & Rische, 2018



Damage indicator over wind speed

Split Tip

Problem:

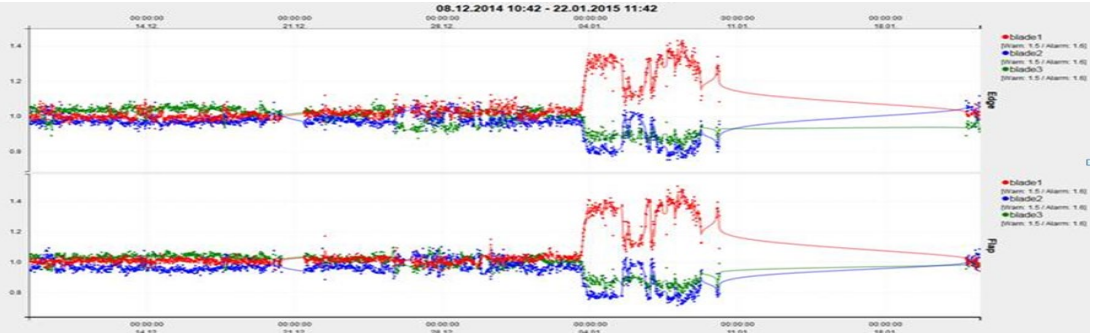
- Split tip due to lightning strike at offshore turbine
- In case damage is not detected in early stage significantly higher repair costs will occur

Solution:

- Integration of special offshore CMS solution incl. stainless steel housing
- Automatic & permanent monitoring

Benefits for customer:

- Significantly lower repair costs due to early damage detection
- Repair onsite without crane safes high repair costs
- No risk of losing the blade
- Hugh savings due to no new blade will be needed! (offshore blades are significantly more expensive than onshore blades)
- Reduction of regular inspections offshore



Damage indicator over several week

Tip Loss after Lightning Strike

Problem:

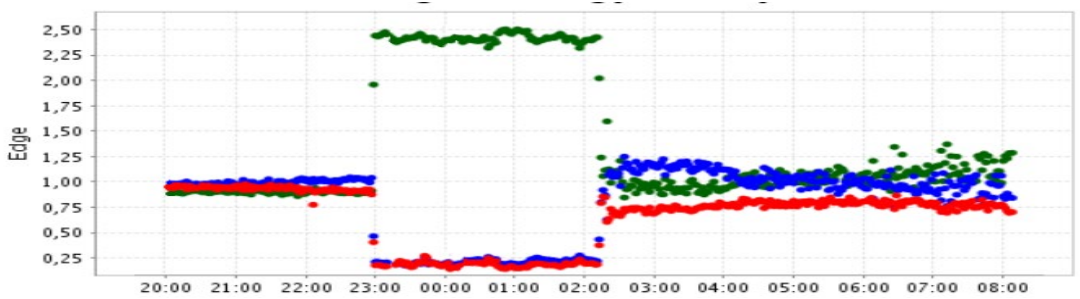
- Tip loss 3 m length
- Turbine was running for more than three hours with damage

Solution:

- Analysis of heavy damages due to lightning strikes within seconds to ensure a quick stop
- Automatic & permanent monitoring

Benefits for customer:

- Significantly lower repair costs due to early damage detection
- No additional stress for other components of the turbine (e.g. bearings, drive train)
- No risk of consequential damages
- Prolonging of lifetime to turbine and turbine components



Damage indicator over several hours

Split Tip causing Blade Loss

Problem:

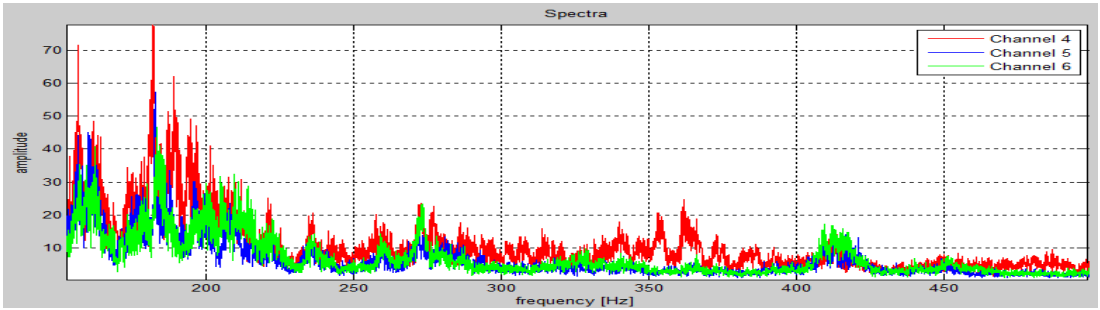
- Split tip due to lightning strike
- Turbine was still running by approx. 25 m/s wind speed
- Blade lost after 30 minutes

Solution:

- Analysis of heavy damages due to lightning strikes within seconds to ensure stop
- Automatic & permanent monitoring

Benefits for customer:

- Significantly lower repair costs due to early damage detection
- No additional stress for other components of the turbine (e.g. bearings, drive train)
- No risk of consequential damages
- No damages at the tower or complete Loss of the turbine
- Prolonging of lifetime to turbine and turbine components



Damage indicator over several frequencies

Erosion Protection Foil

Problem:

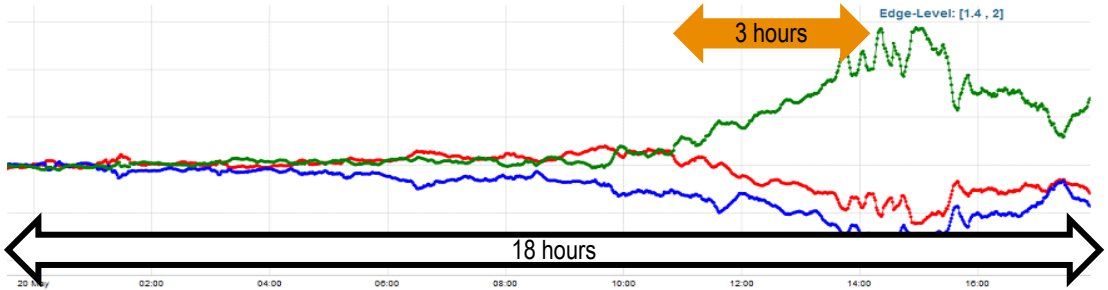
- Loss of an erosion protection foil while the turbine is running
- Owner and operator don´t recognize the loss. Only while regular maintenance missing foils will be detected!

Solution:

- Analysis even of small blade specific frequency changes in short times of an event
- Automatic & permanent monitoring

Benefits for customer:

- Early ensures recognition and repair planning
- No need to shut down turbine, as replacement during next maintenance can be realized



Damage indicator over several hours

Blade Bearing

Problem:

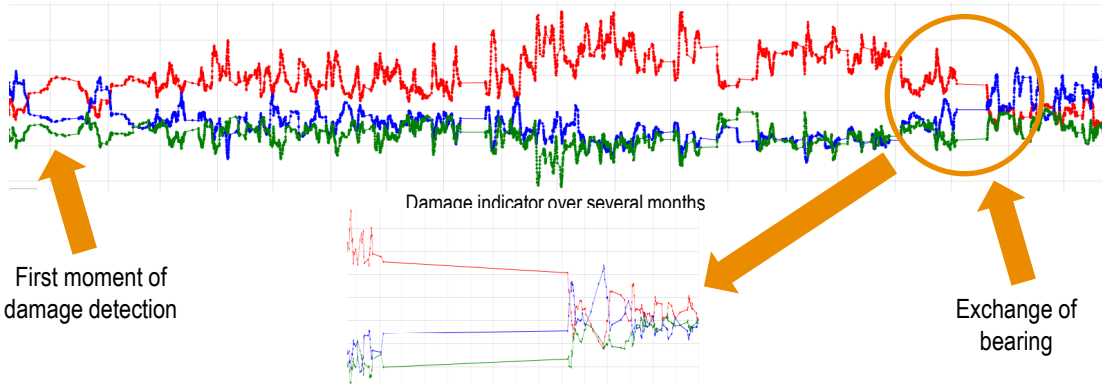
- Damage of blade bearing
- Late detection of failure of bearing caused less time for ordering spare parts and repair

Solution:

- Specific analysis of frequency ranges in the blades which are caused by bearing problems
- Automatic & permanent monitoring

Benefits for customer:

- Order of spare parts can be done immediately after first deviations are detected which leads to reduced losses in energy production!
- Early detection prevents blade loss
- Detection up to 15 months in advance to exchange of bearing



Main Bearing

Problem:

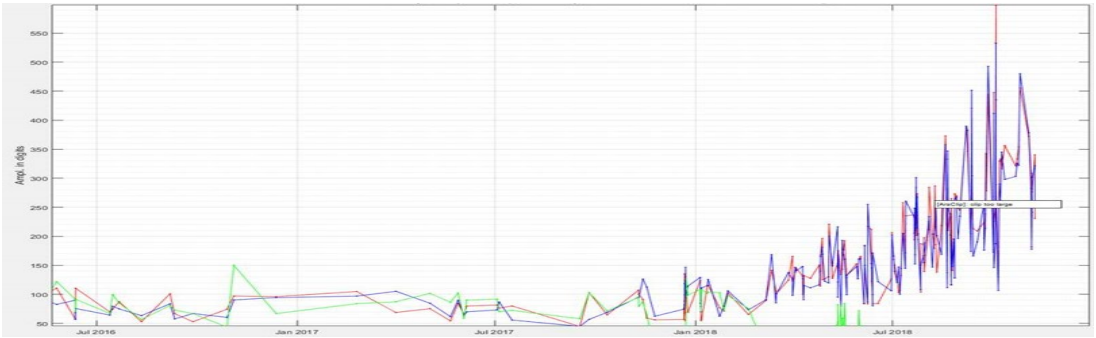
- Damage of main bearing
- Late detection of failure of bearing caused less time for ordering spare parts and repair

Solution:

- Specific analysis of frequency ranges in the blades which are caused by bearing problems!
- Automatic & permanent monitoring

Benefits for customer:

- Order of spare parts can be done immediately after first deviations are detected
- Early detection prevents consequential damages
- Detection up to 10 months in advance of damage detection by operator/customer



Damage indicator over several months

Pitch Error

Problem:

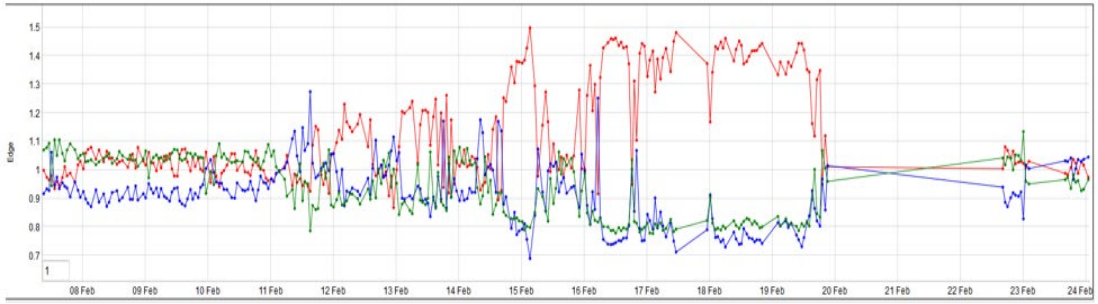
- Defective pitch angel sensor leads to a random malposition of a rotor blade
- Pitch misalignments reduce possible energy power output of turbine

Solution:

- Analysis of blade specific frequencies compared with wind speeds and information of externals of turbine
- Automatic & permanent monitoring

Benefits for customer:

- No Pitch misalignment means no yield loss
- Early detection reduces lifetime consumption



Damage indicator over several weeks

Drivetrain Torsion

Problem:

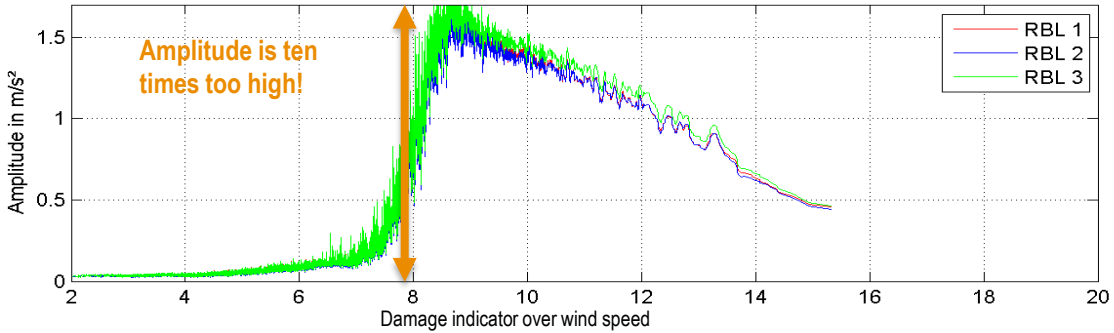
- High vibration amplitudes at blades detected based on increased drivetrain torsion
- Wrong parameter settings caused increased torsion of drivetrain!

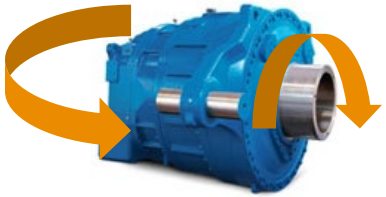
Solution:

- Amplitude of the drivetrain torsion vibration plotted over wind speed
- By cooperating with producer of drivetrain parameters of damping system adjusted

Benefits for customer:

- Correction of control parameters for drivetrain damping reduced amplitude to 10%
- Gearbox lifetime extended
- Costly repair avoided





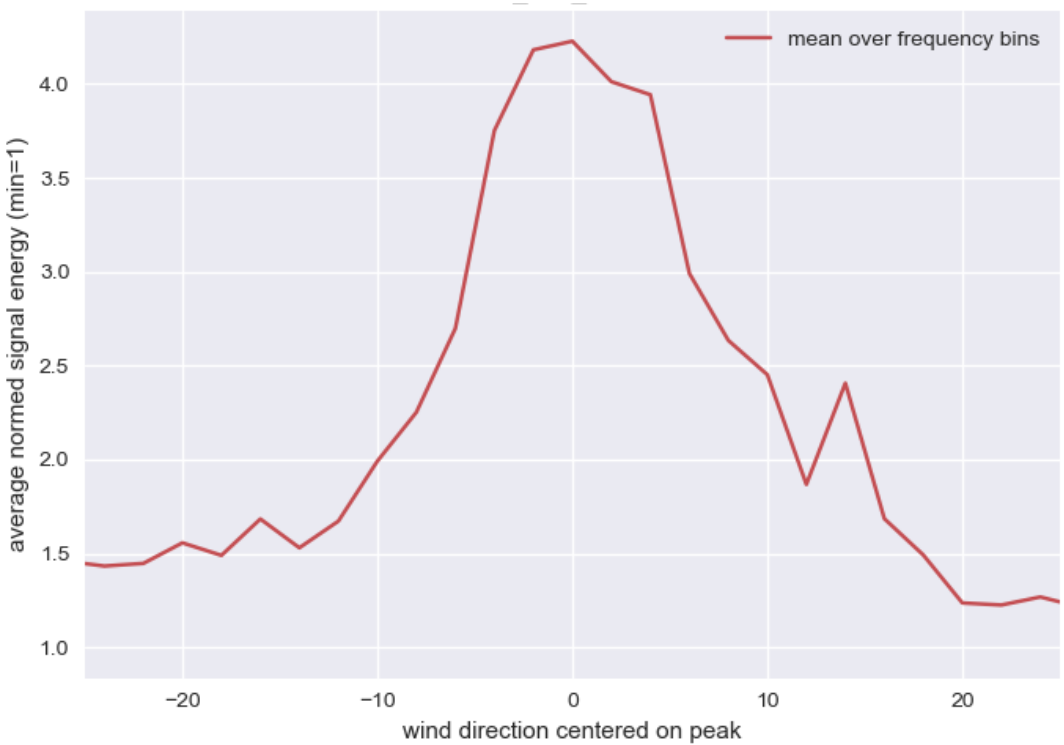
Wake Effect

Problem:

- Increased turbulence and turbine wear caused by front row turbines

Solution:

- Wake effect detection
- Change of operation mode in case of detection



Damage indicator over several months

Galloping

Problem:

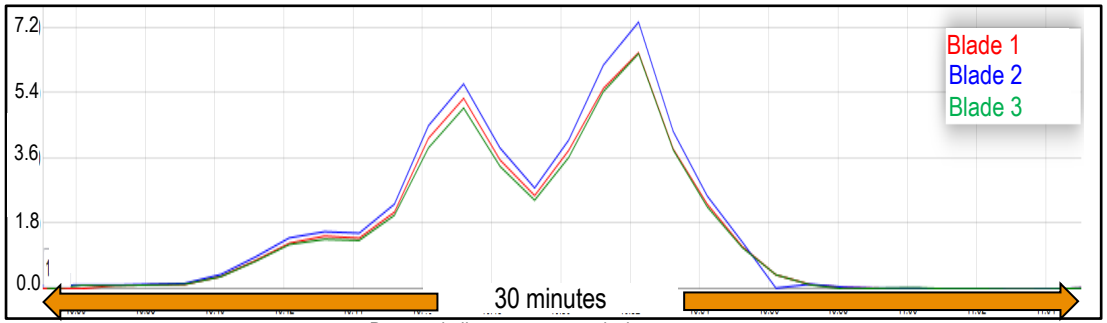
- Galloping event (edgewise vibration of the blade) during standstill of turbine
- Extreme stress for blade for short periods can lead to reduced lifetime of turbine

Solution:

- Fast analysis of blade-specific frequency even while standstill of turbine
- Automatic & permanent monitoring

Benefits for customer:

- Avoidance of extreme stress for blades
- Detection of possible damage events when nobody expects stress for components
- Fast detection ensures a just-in-time reaction by turbine operator to yaw the turbine for reduction of galloping
- Ensure estimated lifetime of the turbine



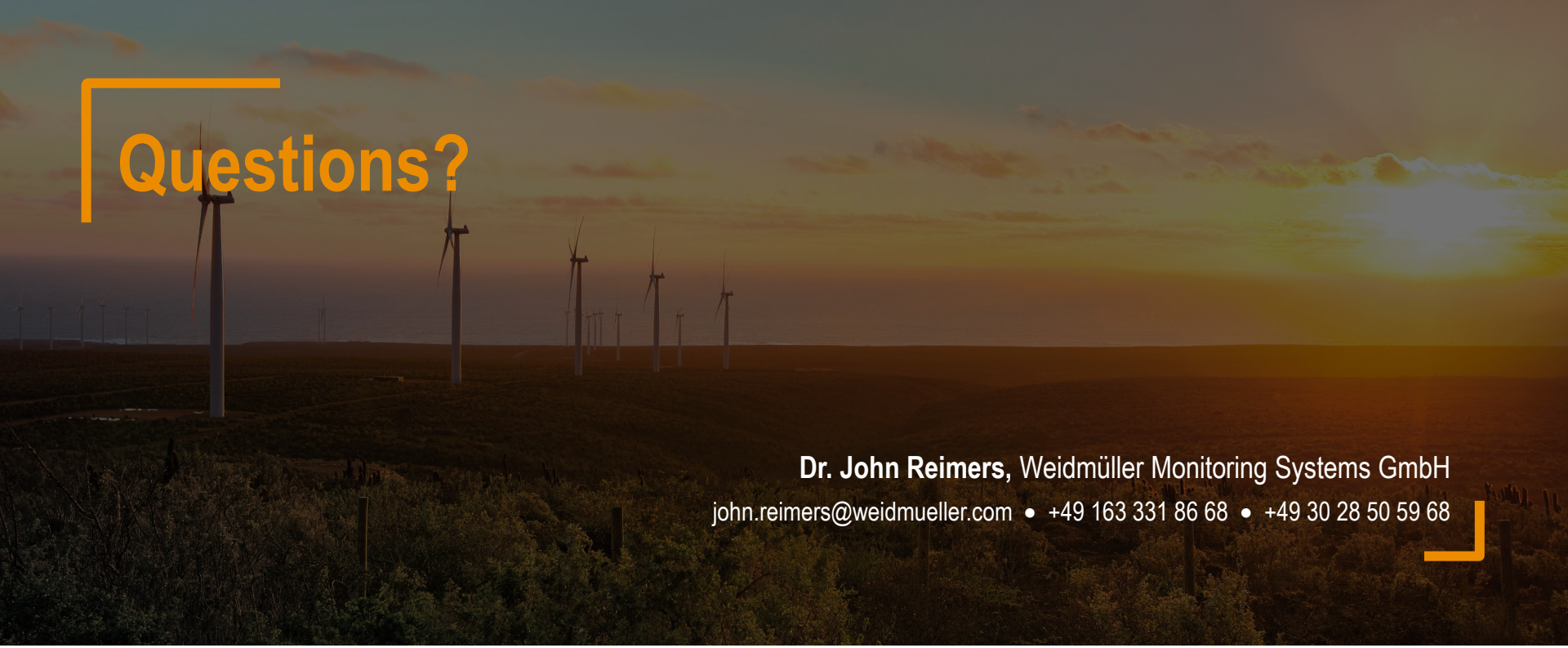
Damage indicator over several minutes

This does not happen to my turbine!

- Weidmüller has more than 14,000 machine years of monitoring experiences
- >1,800 tickets of detected damages were created

➔ Every 7.5 years, it's your turn

With every turbine



Questions?

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