Allianz Global Corporate & Specialty SE

LESSONS LEARNED FROM CLAIMS AND RISK ENGINEERING

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AZT / Thomas Gellermann
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VGB Conference
“Maintenance of Wind Power Plants”

Allianz

CONTENT TOPICS

01 LESSONS LEARNED PROCESS @ AGCS

02 EVALUATION OF CLAIMS DATA

03 CLAIMS EXAMPLES

04 CURRENT MAIN DAMAGE AREAS

05 MAINTENANCE STRATEGY AND BEST PRACTICE

06 CONCLUSIONS

LESSONS LEARNED PROCESS @ AGCS

Internal systematic approach using AGCS technical know-how and capabilities to identify and multiply lessons learned internally and externally

Summary

- **Learning** from **individual losses** as well as from **loss statistics**
- **Internal discussion** and **clustering** lessons learned in different categories

Minimising the risk together with our clients!

02

EVALUATION OF CLAIMS DATA @ WIND ONSHORE

Analysis from insurance perspective provide

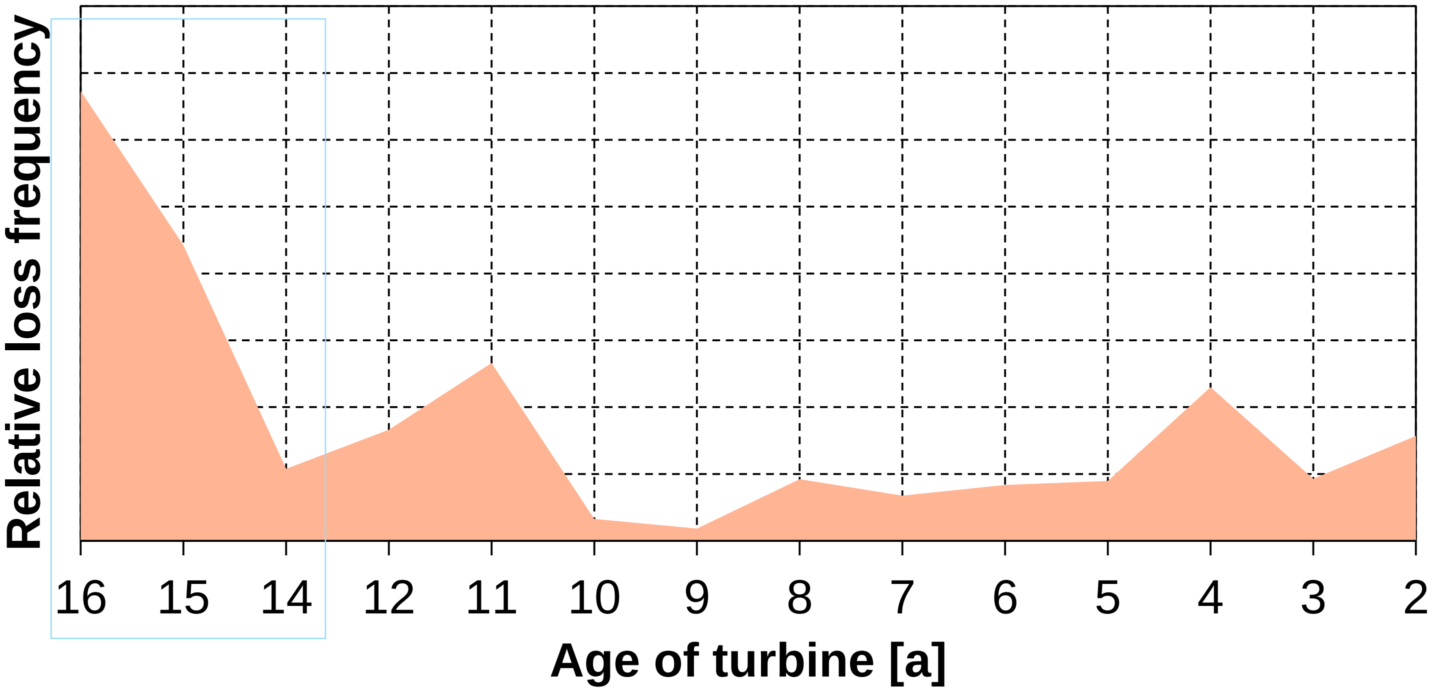
- a glimpse and
- not a holistic scientific view

because of the different policies involved and respective policy conditions.

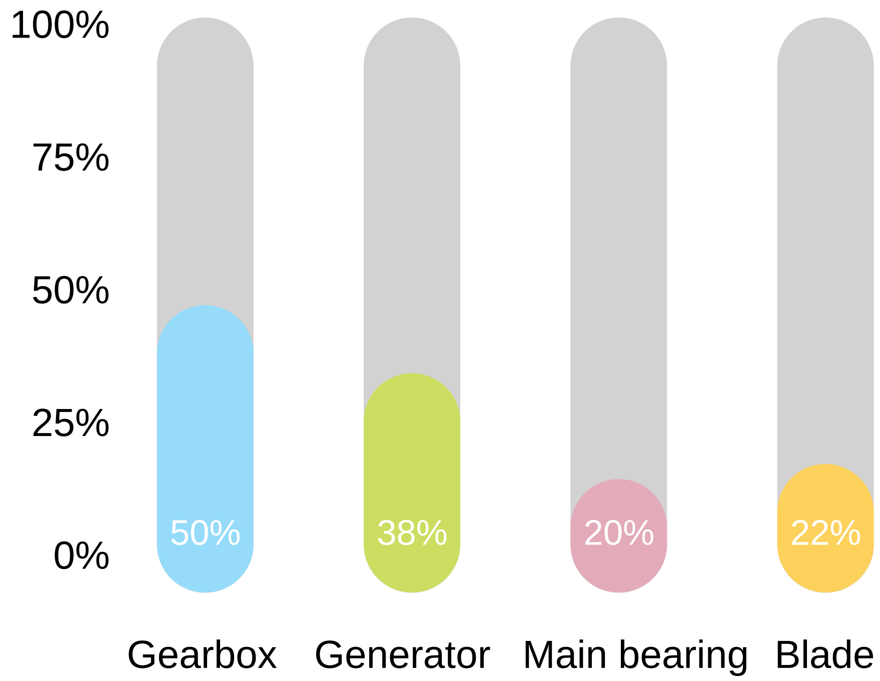
Basis for our claims evaluation

- Subset of AGCS open/closed claims from operational policies (excluding losses paid via guarantee)
- Subset chosen to represent a typical portfolio of a wind onshore investor/operator
- Subset consists of over 3,500 turbines with ¾ of wind turbines being not older than 10 years

WIND TURBINES AND AGE



Relative frequency of losses at old age to losses over total operational time



- Older turbines show higher frequency for unscheduled maintenance
- Especially gearbox and generators failures at higher age
- In total 40 % of losses at aged turbines happen at blades (70% due to lightning)

DAMAGE SEVERITY OFFSHORE TO ONSHORE

Relation of loss amount Offshore : Onshore

>10:1

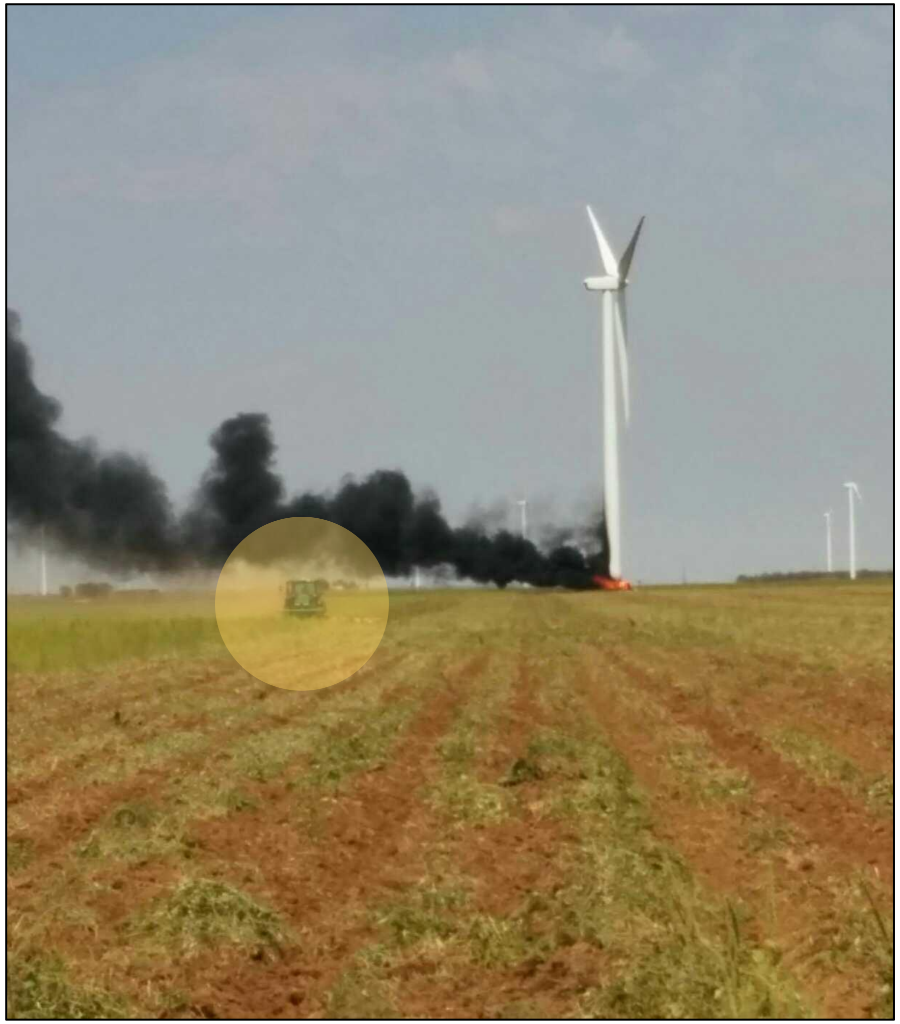
03

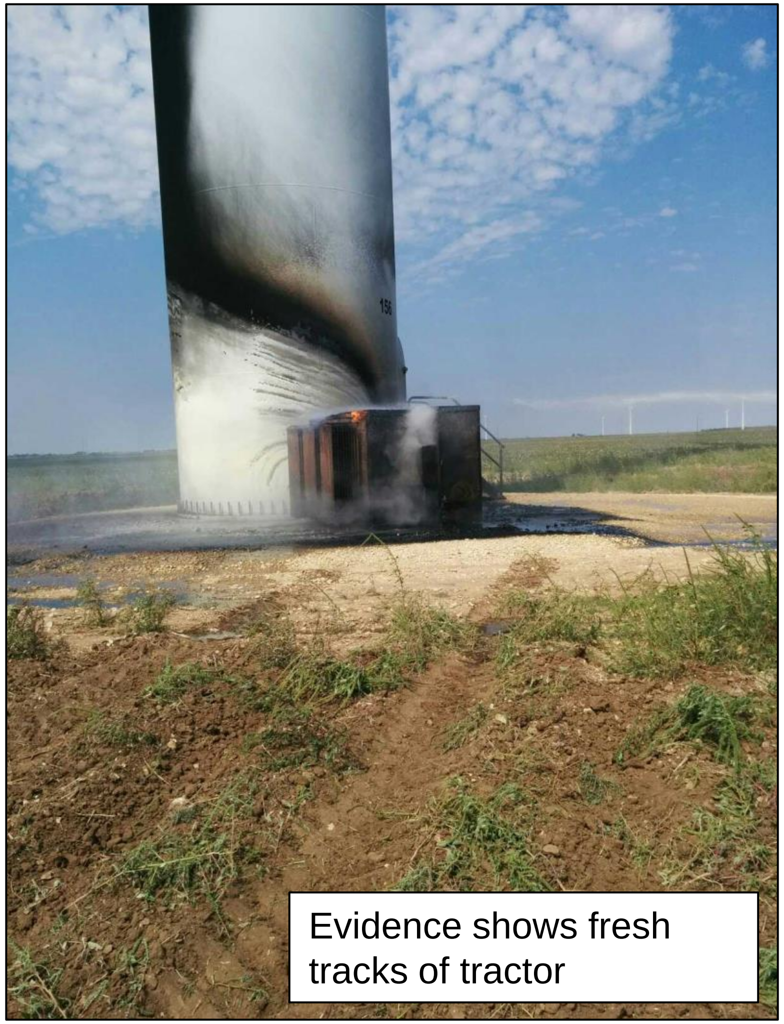
CLAIMS EXAMPLES
@ ONSHORE WIND FARMS

FIRE DAMAGE No1

Three phase transformer

FIRE DAMAGE No1





Evidence shows fresh tracks of tractor

- During maneuvering tractor hit transformer
- Escaping dielectric oil was ignited by arcing
- Fire engulfed and destroyed the entire transformer with flames reaching the adjacent tower
- Fire caused internal heat damage to components within the converter cabinets and low voltage control cables running from the cabinet to the nacelle

➢ Structural integrity of tower was in question
➢ Extremely long downtime of nearly ¾ of a year

FIRE DAMAGE No2

Filter cabinet with electrical components

Inside of tower

- A fire due to electrical component failure
- Fortunately, the fire has extinguished itself in the close cabinet
- Smoke detector in the cabinet was a Ionization smoke detector, which contains an radioactive substance (Americium-241) for detection
- Radioactive contamination led to involvement of authorities and extensive decontamination and cleaning efforts

➢ Extremely long downtime of nearly a year
➢ Due to the long time further damage has occurred due to corrosion

- All installed ionization smoke detectors have been replaced by optical smoke detectors
- Concept of fire safety should be analyzed in detail (e.g. Fire in bottom of tower affects the whole tower, fire in cables of generator)

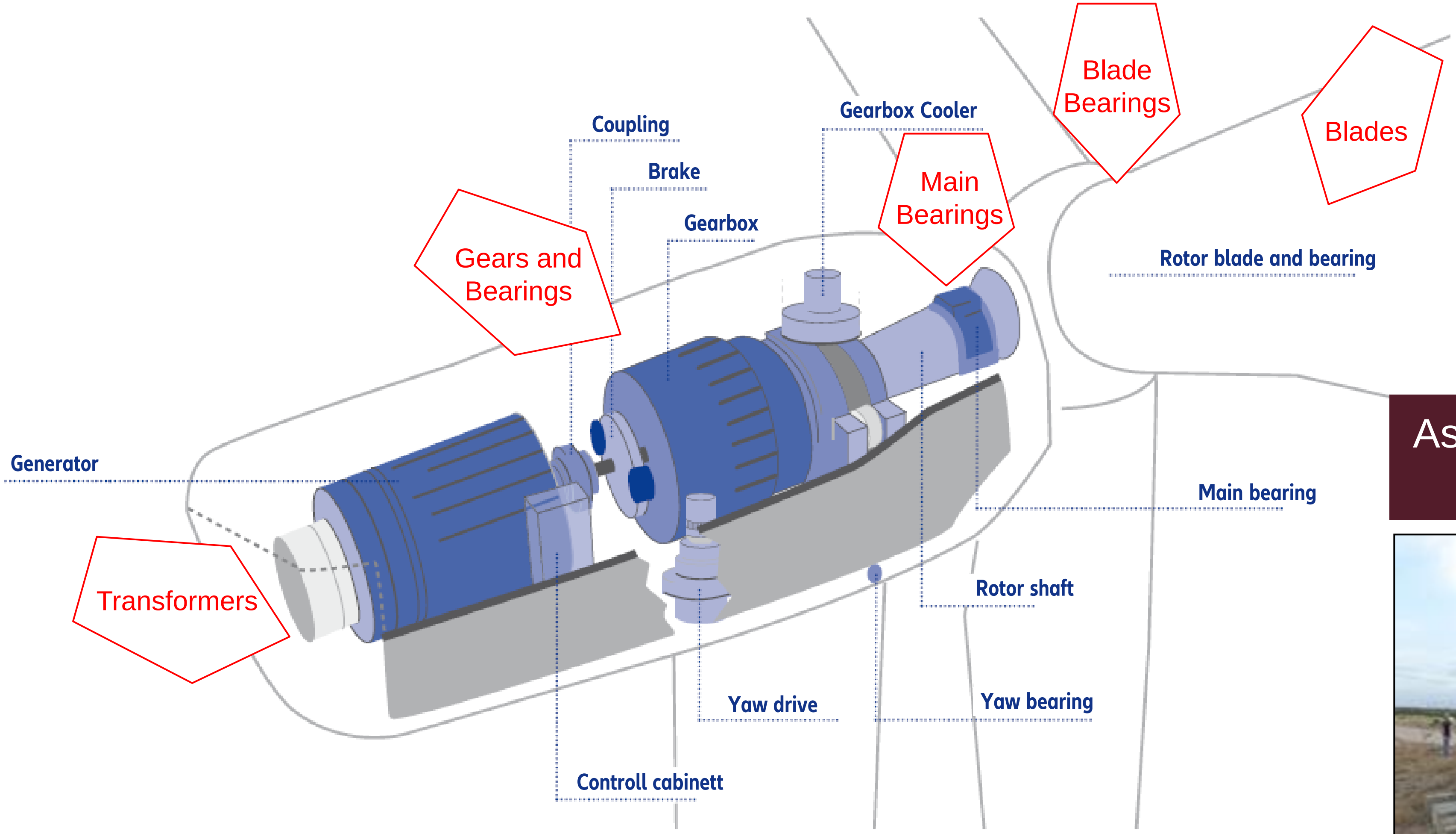
CURRENT MAIN DAMAGE AREAS

- Overview
- Example 1 - Blade Bearings
- Example 2 - Rotor Blades

04

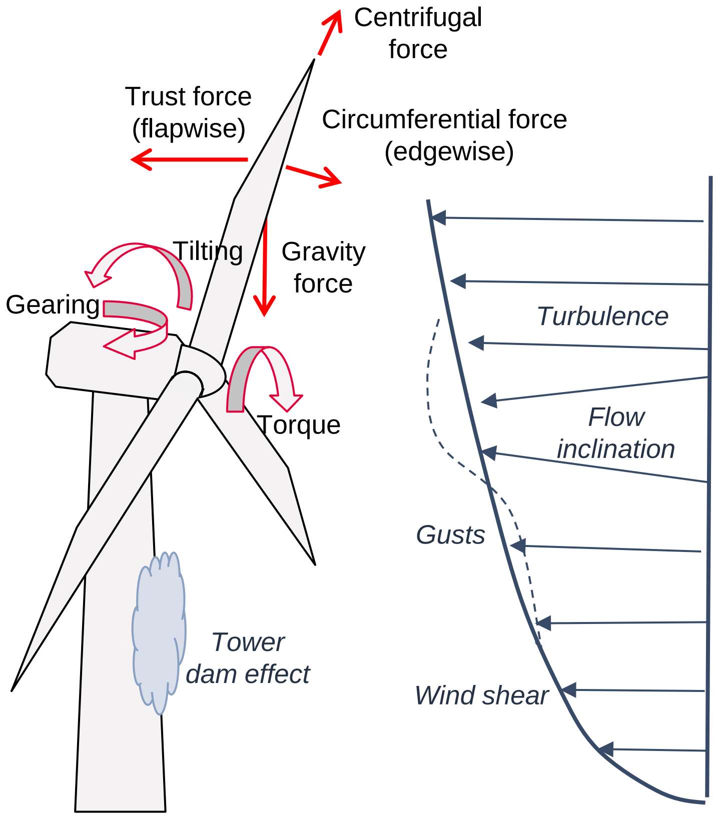
CURRENT MAIN DAMAGE AREAS

ACCORDING TO AGCS & AZT EXPERIENCE



As well as total losses of entire WTs due to fire or collapse

HIGH DYNAMIC LOADING OF WT



Characteristics of loads acting on the rotor blades

- **Edgewise bending:**
  Cyclic bending due to rotation through gravity and torque
  → The blades cumulate a huge number of rotations during the life time (> 10^7 rotations)

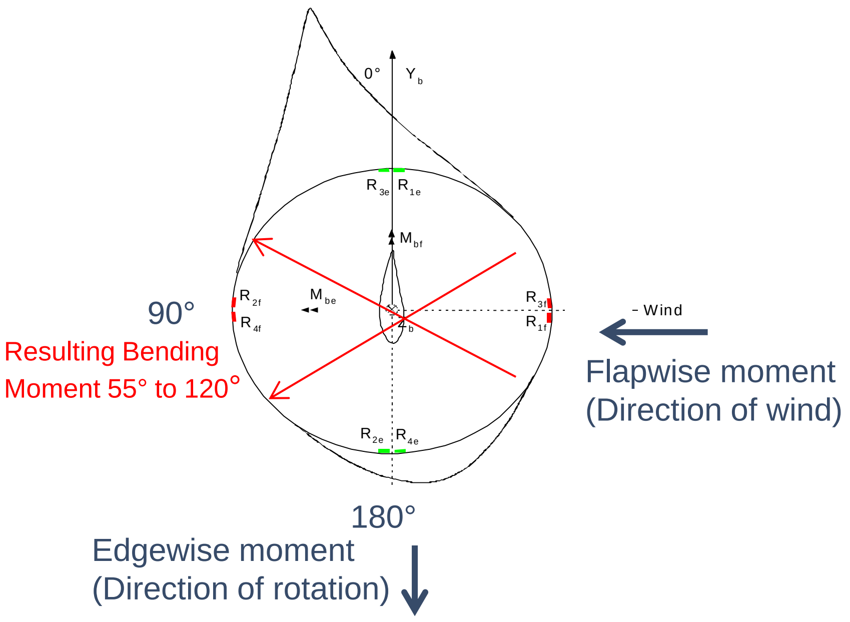
- **Flapwise bending:**
  Fluctuating bending in wind direction due to large trust loads
  → Wind shear, gusts, turbulence, tower dam effect, wake from turbines in front. It strongly depends on local conditions.

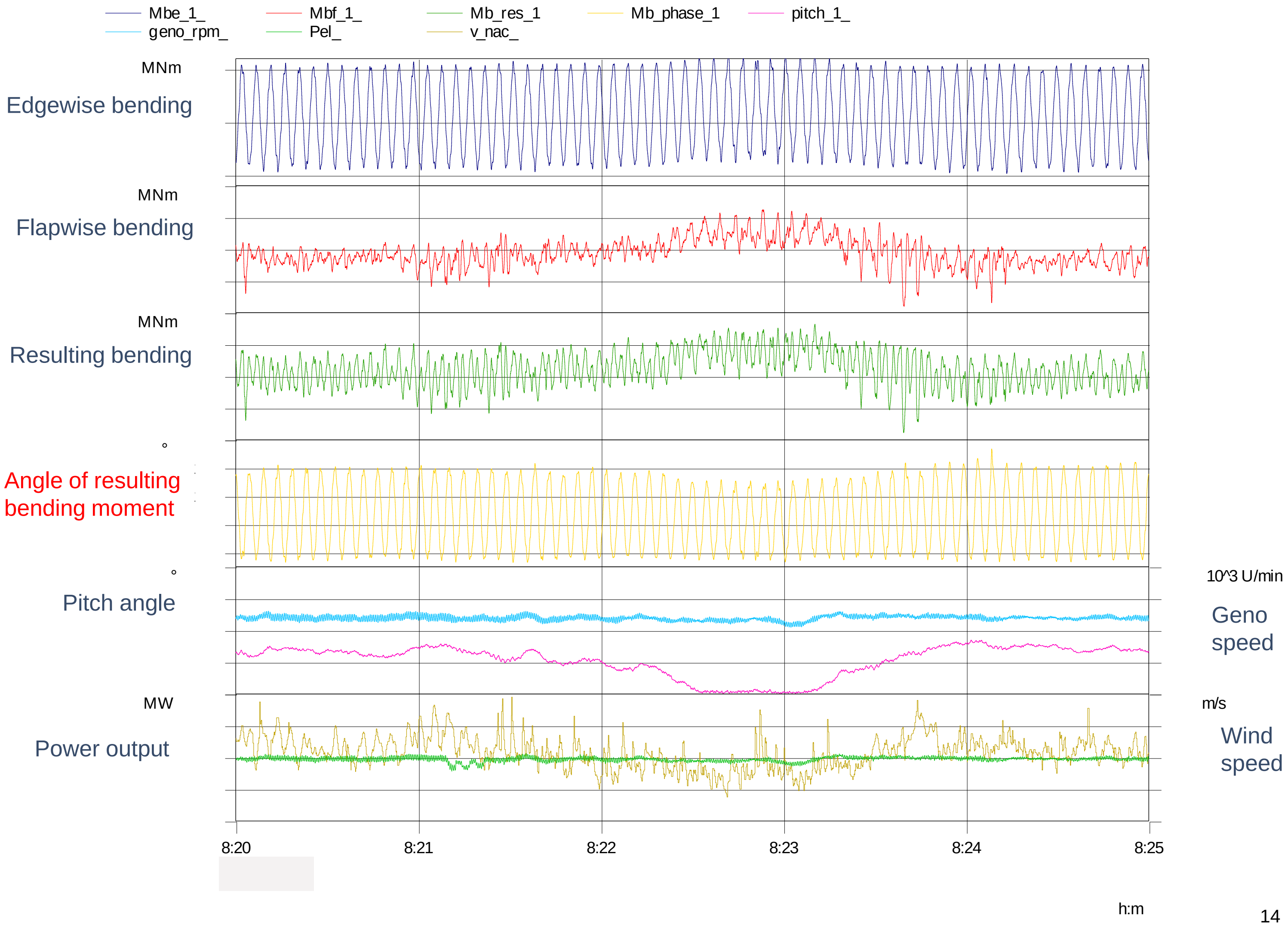
These loads have to be carried by the blade bearings and are transferred to the drive train and structure (tower and foundation).

Continuous trend of enlarging rotor diameters increases dynamic loads of rotor blades and components

EXAMPLE OF BLADE ROOT BENDING OF 5 MW TURBINE

RESULTING BLADE ROOT MOMENTS AND ANGLE OF ATTACK DURING NOMINAL LOAD OPERATION





BLADE BEARINGS – CHALLENGES & THREAT

Small angular movements (challenging lubrication)

High dynamic loads

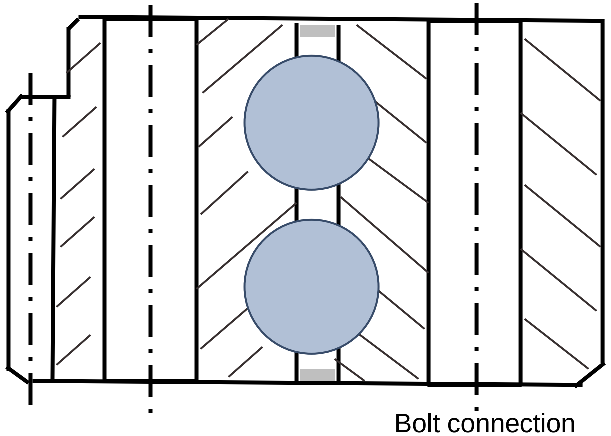
Corrosive atmosphere

Uneven stiffness of supporting structure (hub and blade flange)

Manufacturing challenges (large size, material quality, surface hardening)

Special features (increased rotor diameters, cyclic pitch or individual pitch control)

Double row four point ball bearing

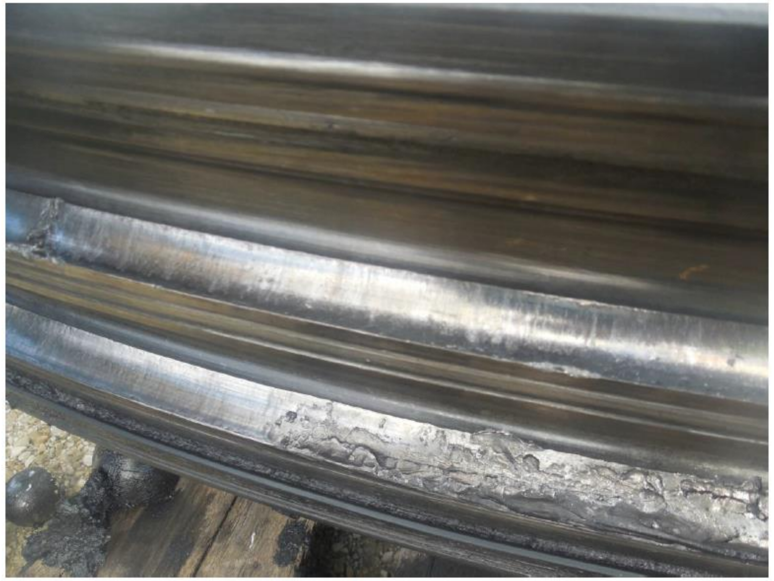


In this respects common standard methods (such as ISO 281) for determining bearing life are lacking

- GL Certification Guideline 2012 did not require a rating life calculation for blade and yaw bearings
- DNVGL Standard ST-0361 (2016) requires a modified rating life calculation according to NREL Guideline DG03 (2009)

→ Improved methods for fatigue life time calculation are still under development
(e.g.: DNV GL JIP on slewing bearings and IWES project HAPT)

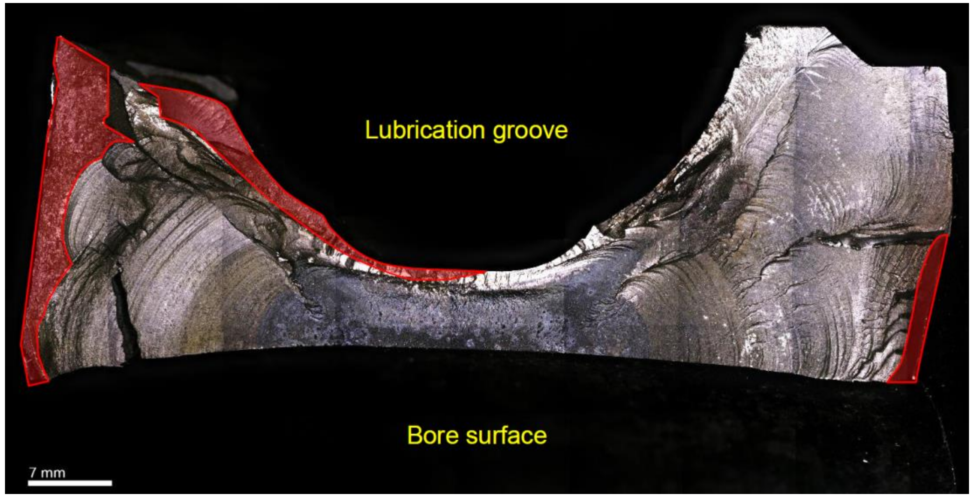
TWO EXAMPLES OF BLADE BEARING DAMAGES



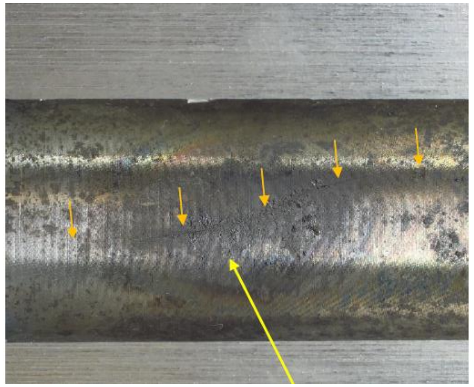
Local spalling of raceway due to RCF

Contributors

- High operational loads
- Lubrication
- Uneven stiffness of supporting structure



Residual forced fracture (laboratory) marked in red



Stress corrosion cracking developed from bore surface

Contributors

- Corrosion
- High operational loads
- Uneven stiffness of supporting structure

The number of blade bearings, which will be affected by a limited service life, will probably further increase

ROTOR BLADES – CHALLENGES & THREAT

Increasing blade size & requirements for light weight

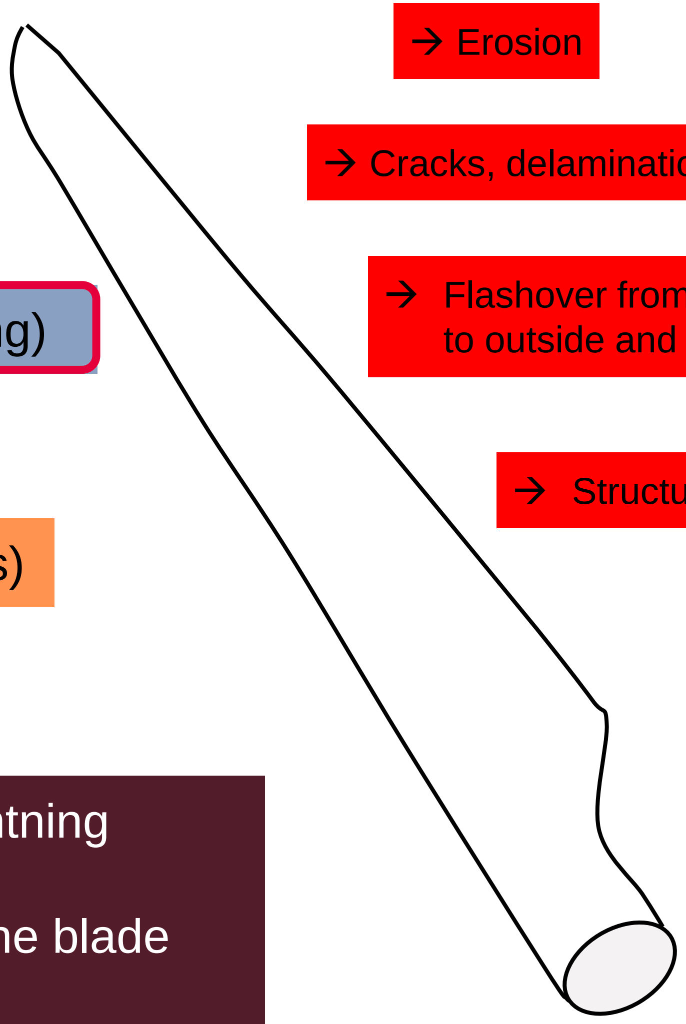
High dynamic loads

Lightning protection (Receptors, lightning current transfer, earthing)

Erosion protection

Manufacturing challenges (Manual fabrication, quality and tolerances)

Special features (CF composites, load tuning measures)



→ Erosion

→ Cracks, delamination

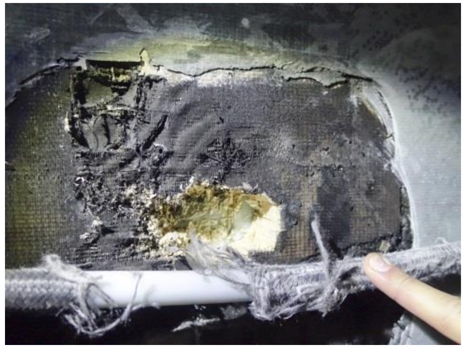
→ Flashover from inside to outside and vice versa

→ Structural damages

The standard IEC 61400-24:2010 “Wind turbines – Part 24: Lightning protection” provides comprehensive design requirements.
→ For long blades it describes the risk of flashovers through the blade surface, which can result into severe damage.

EXAMPLE OF BLADE DAMAGE DUE TO LIGHTNING

Minor lightning damage



Major internal flashover (lightning arcs) can lead to delamination and blade fracture

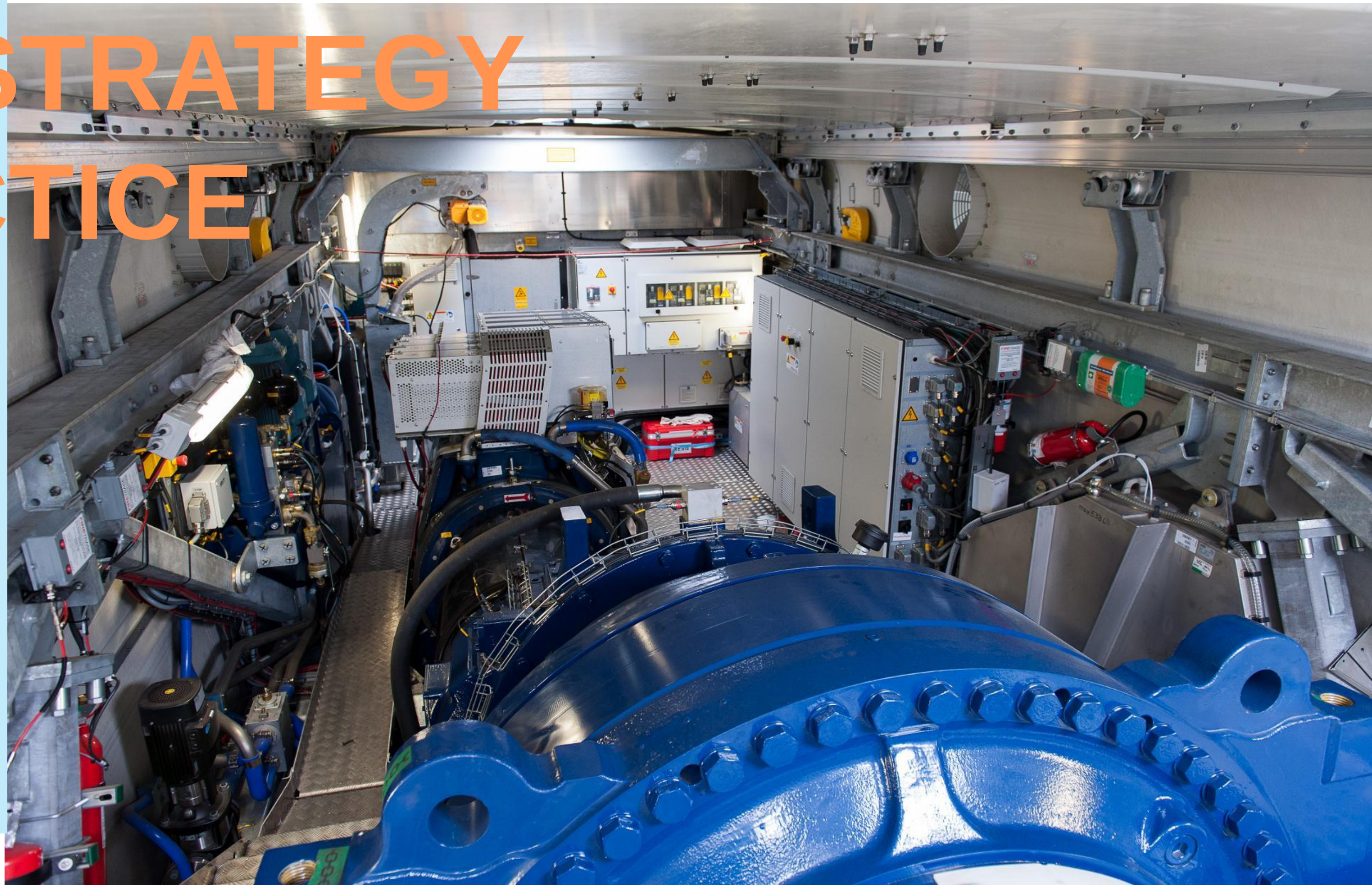
Lessons Learned

- The specific design of a lightning protection system needs to be investigated by high voltage flashover tests at real blade structures (type testing); also the influence of alterable conditions during operation should be included (wetness, fouling, corrosion of electrical contacts, aging).
- To protect electrical components of wind turbines a proper overvoltage (surge) protection and effective earthing system is essential. Inspection and maintenance of these systems is important to prevent critical damage from repeating overvoltage events.
- It is recommended to equip WT with monitoring systems to detect lightning strikes and measure the currents. This provides the basis to conduct inspections according to lightning activity.
- Repair of small damages can prevent severe additional damage.

Note: the above recommendations are also part of IEC 61400-24

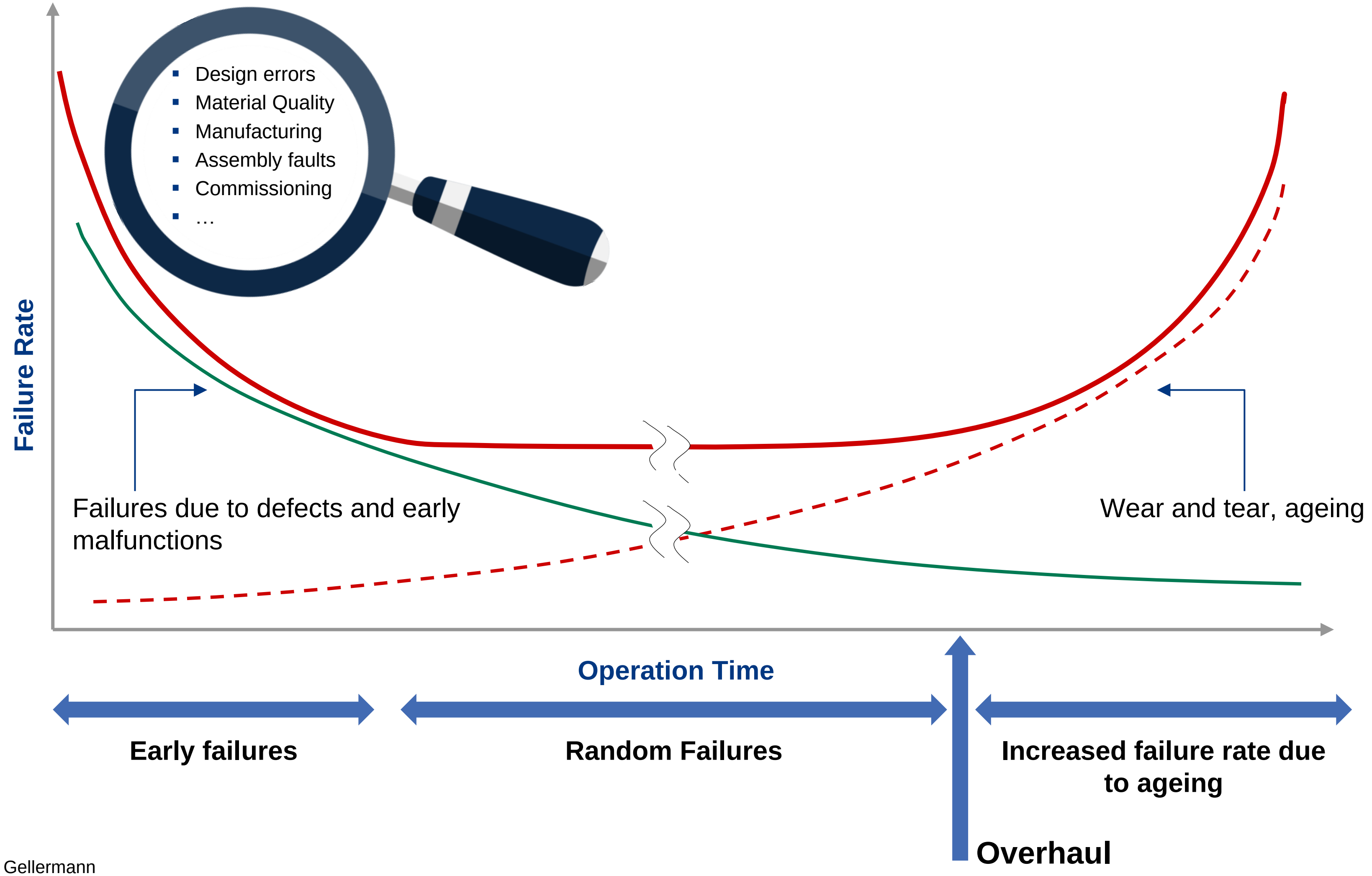
05

MAINTENANCE STRATEGY AND BEST PRACTICE



Source of picture Allianz Deutschland AG

TECHNICAL RELIABILITY „BATHTUBE CURVE“



DESIGN LIFE TIME AND OVERHAUL INTERVALS

Steam turbines

- Design life time 30 years (~240,000 Oh)
- Manufacturer recommendation Major Overhaul every 50,000 .. 75,000 Oh
- VGB-R 115M Intermediate Overhaul after 50,000 Oh, Major Overhaul 100,000 Oh

Wind Onshore

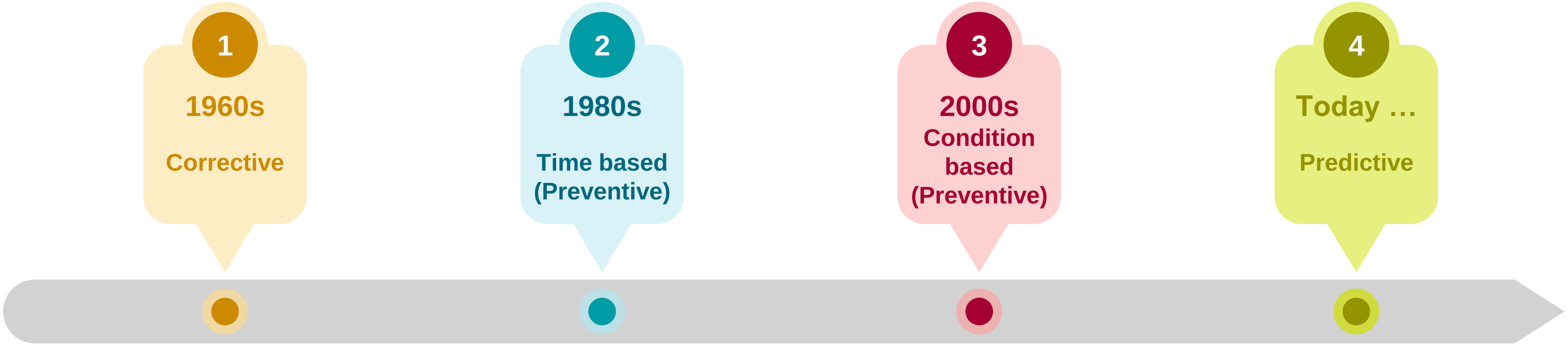
- Design life time 20 years (~ 130,000 to 160,000 Oh)
- **No scheduled Overhauls!**
- Trigger of overhauls by damage event or condition based

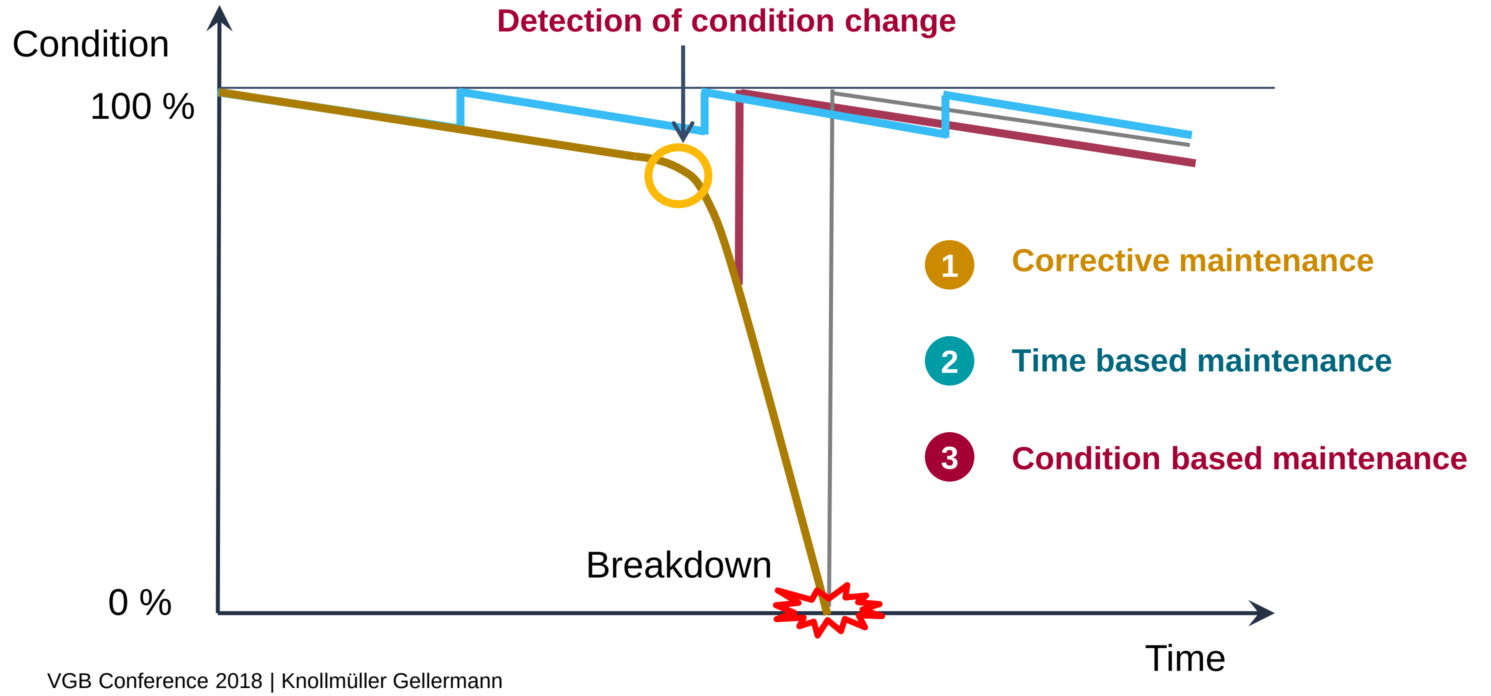
Wind Offshore

- Design life time 25 years (~ 200,000 Oh)
- **No scheduled Overhauls!**
- Trigger of overhauls by damage event or condition based

1) It cannot be expected that each component of wind turbines (onshore and offshore) has a service life time in the range of 20 years
2) Unscheduled maintenance is costly and affects the reliability by increased down times

DEVELOPMENT OF MAINTENANCE STRATEGIES

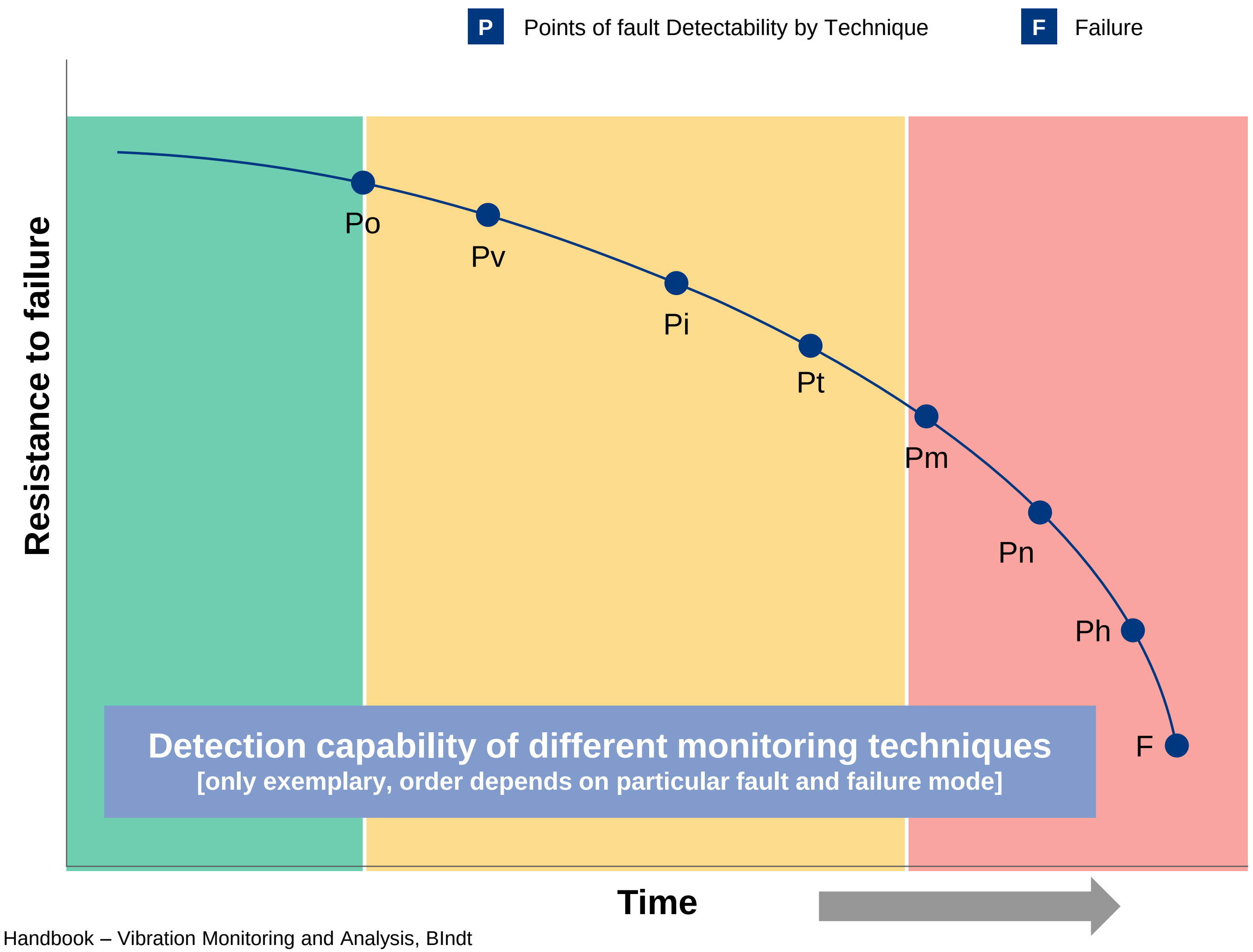




Predictive Maintenance

- AI and prognostics
- Analytical modelling (empirical/physical based/ experience)
- Multiple data types and sources
- Smart sensors and cloud connection

SUITABLE MONITORING TECHNIQUES NEED TO BE ADAPTED



Po	**Point where fault occurs**
Pv	**Changes in Vibration** P-F interval 1–9 months
Pi	**Wear Debris in Oil** P-F interval 1–6 months
Pt	**IR Thermography** P-F interval 3–12 weeks
Pm	**Performance Monitoring** P-F interval 5–8 weeks
Pn	**Audible Noise** P-F interval 1–4 weeks
Ph	**Heat by Touch** P-F interval 1–5 days
F	**Failure**

Source: Handbook – Vibration Monitoring and Analysis, BIndt

STANDARDS AND PAPERS PROVIDE SUPPORT

Standards

ISO 17359	„Condition monitoring and diagnostics of machines - General guidelines”
ISO 13373	„Condition monitoring and diagnostics of machines - Vibration condition monitoring”
ISO 13381	„Condition monitoring and diagnostics of machines - Prognostics: General guidelines”
ISO 10816-21/ VDI 3834	„Mechanical vibration - Evaluation of machine vibration by measurements on non-rotating parts: Horizontal axis wind turbines with gearbox”
ISO 16079-1	„Condition monitoring and diagnostics of wind turbines - General guidelines”

AZT papers

VGB PowerTech 9 | 2013 CMS in offshore wind power plants

Extension of the scope of Condition Monitoring Systems for multi-MW and offshore wind turbines

Thomas Gellermann

Kurzfassung

Erweiterung des Umfangs von Condition Monitoring Systemen für Multi-MW und Offshore Windturbinen

Schwingungsbasierte Condition-Monitoring-Systeme (CMS) haben sich seit mehreren Jahren für die Zustandsüberwachung des mechanischen Triebstrangs von Windenergieanlagen etabliert. Durch die hohen Investitionssummen

Introduction

During the last years, the number of installations of vibration-based Condition Monitoring Systems (CMS) on wind turbines has increased significantly. According to AZT's survey of CMS manufacturers from Europe and the U.S., almost 24,000 condition monitoring systems have been installed on wind turbines until 2012

and those induced by the rotor blades should be monitored via the low-frequency sensors installed at the drive train.

The high expectation of operational availability and the rising values of wind turbines, as well as their restricted accessibility, particularly of offshore turbines, provide important arguments for extending condition monitoring to other wind turbine components.

Vibration monitoring of large wind turbine fleets VGB PowerTech 7 | 2017

Use of VDI 3834-1 & DIN ISO 10816-21 for vibration monitoring of large wind turbine fleets

Thomas Gellermann, Ulrich Oertel und Holger Fritsch

Kurzfassung

Anwendung der VDI 3834-1 und DIN ISO 10816-21 für die Schwingungsüberwachung von großen Windanlagenflotten

Mit der Richtlinie VDI 3834 „Messung und Beurteilung der mechanischen Schwingungen von Windenergieanlagen und deren Komponenten“ [1] ist seit 2009 ein Regelwerk für die Beurteilung der Schwingungen von Windenergieanlagen mit Getriebe verfügbar. In 2015 wurde das aktualisierte Blatt 1 nach umfangreicher Überarbeitung und Ergänzung veröffentlicht. Ebenfalls in 2015 konnte die Überführung der

Introduction and definition of terms “vibration evaluation vs. condition assessment”

Modern wind turbines (WTs) are structures subject to highly dynamic loads and complex vibrations due to the use of rotor diameters and tower heights partly of over one hundred meters, as well as tower head masses of several hundred tons. They are exposed to a wide range of “external” vibration excitations as severe temporal and spatial fluctuations in wind speed as a result of gusts, turbulence and wind shear, as

tems (CMS), which indicate deviations in condition and provide suitable diagnostic tools (cf. [6, 7]). Condition assessment is normally based on relative observations with regard to an individual installation, such as deviations of vibration characteristics from the reference value. CMS has hardly been used up to now for absolute or comparative observations, such as the vibrations of turbines within a wind farm or a special turbine type at different sites. The characteristic quantities defined in VDI 3834 and DIN ISO 10816-21 can be applied here.

VGB research studies: CMS Best Practice & SCADA DATA (in process)

MAINTENANCE QUALITY – SHARING BEST PRACTICE

Windfarm Level

Maintenance & Service Provider

Service Team

Service Provider

Technical Operation Management

Conclusion on component condition and deviating/ faulty operating conditions

Scheduling of **Condition-based Maintenance** and Improvement Measures

Supervision Level

Independent Quality Control

Internal

Service Provider

Conclusion on O&M Performance

Improving and Assuring Maintenance Quality

MAINTENANCE QUALITY

Windfarm Level

Maintenance & Service Provider

Service Team | Service Provider

- **Scheduled Maintenance**
  Periodic maintenance activities according to required scope and schedule of OEMs and Best Practices:
  - every ½ year
  - every 1 year (yearly maintenance)
  - every 5 year (major maintenance)
  - → Correction of findings & malfunctions
- **Preventive Trend Analysis**
  - Vibration based CMS
  - SCADA data analysis
  - Trending of oil analysis
  - Monitoring of lightning currents
  - …

Orders

Reporting

Tracking & Audits

Technical Operation Management

- **Coordination and Control of Maintenance Activities**
  - Timing of scheduled Maintenance
  - Regular inspection checks
- **Evaluation of Reporting**
  - Analysis of findings
  - Archiving of maintenance information
  - Conclusion on (frequent) findings
- **Tracking**
  - Open maintenance activities and corrective actions
- **Analysis**
  - Frequent errors and alarms
  - SCADA and Performance monitoring

Conclusion on component condition and deviating/ faulty operating conditions

Scheduling of **Condition-based Maintenance** and Improvement Measures

Inspection & Audits

Service Reports

Supervision Level

Independent Quality Control

Internal | Service Provider

- **Checks of Maintenance Activities**
  - Site Audits
  - Quality and Timing of Maintenance
  - Reporting Quality
  - Status of Punch Lists
- **Inspection on Turbine Integrity and Machinery Condition [1)]**
  - Defined Intervals for each Turbine
  - 1 Year Interval for Main Transformer
- **Evaluation of Performance**
  - Sharing Best Practice
  - Improvement & Development Areas
  - Escalation Strategy

Conclusion on O&M Performance

Improving and Assuring Maintenance Quality

1) Compare German Wind Energy Association (BWE) “Principles for condition-based maintenance of wind turbines” and DIBT Guideline for Wind Turbines „Grundsätze zur Wiederkehrenden Prüfung”

CONCLUSIONS

06

CONCLUSIONS

Lessons learned

Learning from losses provides an important basis for improvements.
It is a tradition of Allianz to share that knowledge with clients and the industry.

Claims Wind Onshore

Older turbines generally show higher frequency for unscheduled maintenance. Especially gearboxes and generators being troublesome at old age. Overall most losses at blades.

Wind Offshore

Rule of thumb shows cost-ratio of Wind Onshore to Wind Offshore claims is 1:10 mainly due to logistics, e.g. vessel involvement and unpredictable costs, e.g. waiting on weather or general high cost intensive measures, like divers or debris removal.

Service life

Influences on component durability and life time are complex. A life time of 20 years of all main components cannot be realized so far. Understanding of load conditions, design methods, as well as test methods need to be further developed.

Maintenance

Due to the lack of scheduled overhauls, condition-based maintenance is important to avoid costly break-downs. Quality of maintenance plays an important role to assure profitability, reliability and safety.

Collaboration

Existing M&O processes provide many data sources which establish the basis of condition based maintenance. Further digitalization can improve the exchange of maintenance information. But close collaboration of all players is essential.

ALLIANZ GLOBAL CORPORATE & SPECIALTY

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