DETECTING AND PREDICTING MW WIND TURBINE DRIVE TRAIN FAILURES

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Adopted for
Wind Power Management class
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Causes of vibration

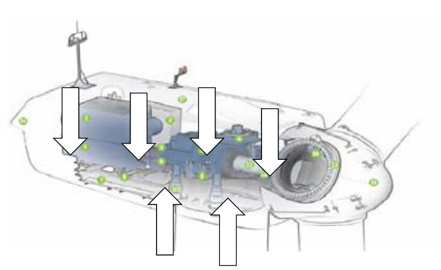
- MISALIGNMENT
- IMBALANCE
- MECHANICAL LOOSENESS
- RESONANCE
- BEARINGS

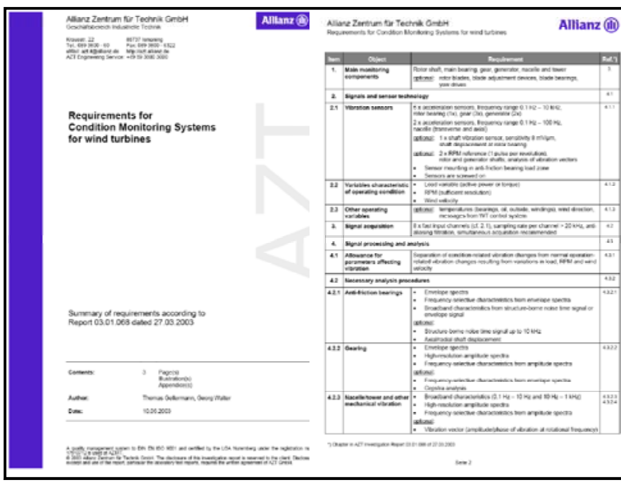
90% of machine vibration is attributed to these 5 issues

THE ABOVE PROBLEMS MANIFEST THEMSELVES IN THE CONDITION OF THE ASSET

TYPICAL SENSOR LOCATIONS

Basically monitor what fails or what is expensive when it fails





Allianz Zentrum für Technik GmbH
Geschäftsbereich Industrielle Technik

Requirements for Condition Monitoring Systems for wind turbines

Summary of requirements according to Report 03.01.068 dated 27.03.2003

Contents: 3 Page(s) Illustration(s) Appendix(ces)

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Requirements for Condition Monitoring Systems for wind turbines

Item	Object	Requirement	Ref.*)
1.	Main monitoring components	Rotor shaft, main bearing, gear, generator, nacelle and tower; optional: rotor blades, blade adjustment devices, blade bearings, yaw drives	3
2.	Signals and sensor technology		4.1
2.1	Vibration sensors	6 x acceleration sensors, frequency range 0.1 Hz – 10 kHz, rotor bearing (1x), gear (3x), generator (2x); 2 x acceleration sensors, frequency range 0.1 Hz – 100 Hz, nacelle (transverse and axial); optional: 1 x shaft vibration sensor, sensitivity 8 mV/µm, shaft displacement at rotor bearing; optional: 2 x RPM reference (1 pulse per revolution), rotor and generator shafts, analysis of vibration vectors; Sensor mounting in anti-friction bearing load zone; Sensors are screwed on	4.1.1
2.2	Variables characteristic of operating condition	Load variable (active power or torque); RPM (sufficient resolution); Wind velocity	4.1.2
2.3	Other operating variables	optional: temperatures (bearings, oil, outside, windings), wind direction, messages from WT control system	4.1.3
3.	Signal acquisition	8 x fast input channels (cf. 2.1), sampling rate per channel > 20 kHz, anti-aliasing filtration, simultaneous acquisition recommended	4.2
4.	Signal processing and analysis		4.3
4.1	Allowance for parameters affecting vibration	Separation of condition-related vibration changes from normal operation-related vibration changes resulting from variations in load, RPM and wind velocity	4.3.1
4.2	Necessary analysis procedures		4.3.2
4.2.1	Anti-friction bearings	Envelope spectra; Frequency selective characteristics from envelope spectra; Broadband characteristics from structure-borne noise time signal or envelope signal; optional: Structure-borne noise time signal up to 10 kHz; Axial/radial shaft displacement	4.3.2.1
4.2.2	Gearing	Envelope spectra; High-resolution amplitude spectra; Frequency selective characteristics from amplitude spectra; optional: Frequency selective characteristics from envelope spectra; Cepstra analysis	4.3.2.2
4.2.3	Nacelle/tower and other mechanical vibration	Broadband characteristics (0.1 Hz – 10 Hz and 10 Hz – 1 kHz); High-resolution amplitude spectra; Frequency selective characteristics from amplitude spectra; optional: Vibration vector (amplitude/phase of vibration at rotational frequency)	4.3.2.3 4.3.2.4

*) Chapter in AZT Investigation Report [illegible]

Seite 2

3 COMMON EXAMPLES OF MW WTG ISSUES

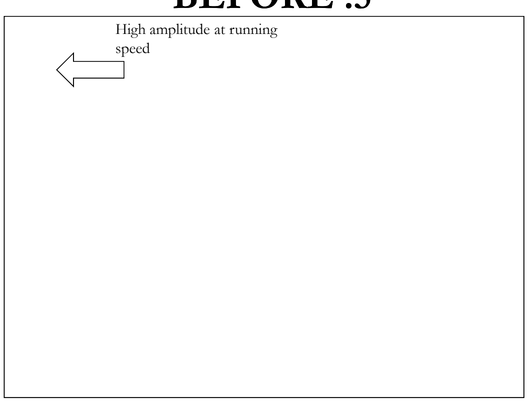
1. MISALIGNMENT
2. BEARINGS
3. PLANETARY GEARBOX

EXAMPLE # 1

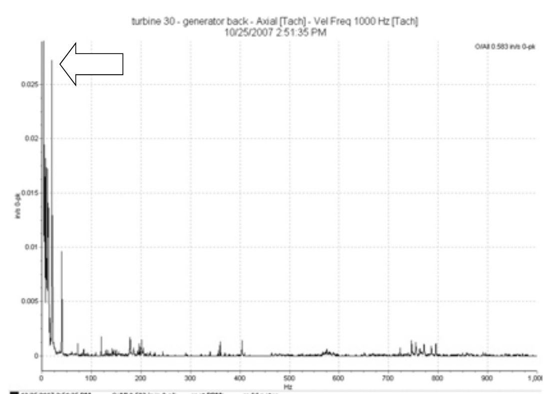
- **Misalignment of a Megawatt class wind turbine**

- Gearbox to generator
- Shows as a high peak at the running speed
- First vibration signature shows .5 amplitude in a velocity measurement (before)
- Second shows .025 amplitude after alignment (after)

BEFORE .5



AFTER .025

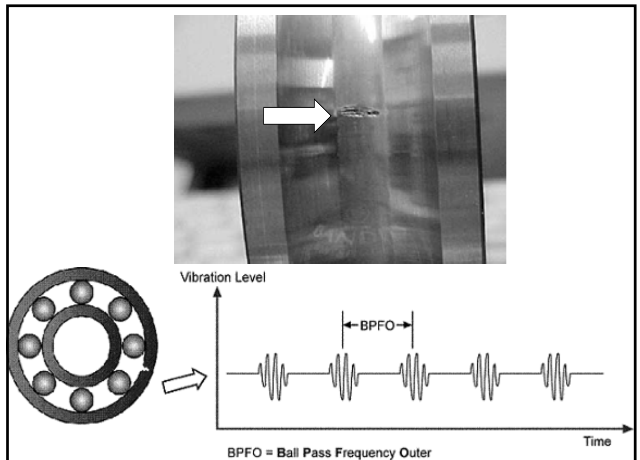


EXAMPLE # 2

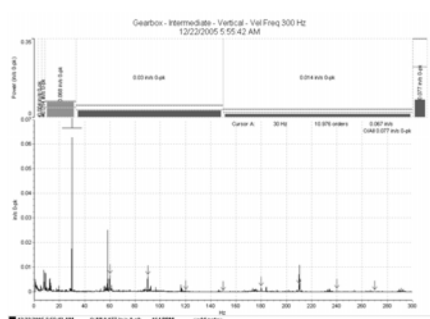
- **BEARING FAULT IN A MEGAWATT CLASS WIND TURBINE**
- COMMON BEARING ABREVIATIONS

- **BPFO** (outer race defect)
- **BPFI** (inner race defect)
- **FTF** (cage defect)
- **BSF** (rolling element defect)

- There are 2 ISO standards for alarms and 1 widely accepted 30 year study also used for alarming



AMPLITUDE = SEVERITY



PROGRESSION OF THE FAILURE

- TYPES OF VIBRATION MEASUREMENTS INDICATE THE FAILURE PROGRESSION OF THE COMPONENT. *"VELOCITY"* AND *"DEMODULATED"* MEASUREMENTS GIVE AN APPROXIMATE TIMELINE

How do I interpret the results? Look for peaks at known bearing fault frequencies in both the normal vibration velocity spectra and the demodulated spectra.

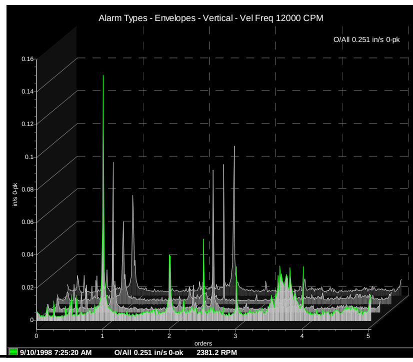
No peaks in either spectrum: Condition is good, use as a baseline for future comparisons.

Peaks appear in Demod only: Early warning indication that defects exist (or the bearing needs lubrication).

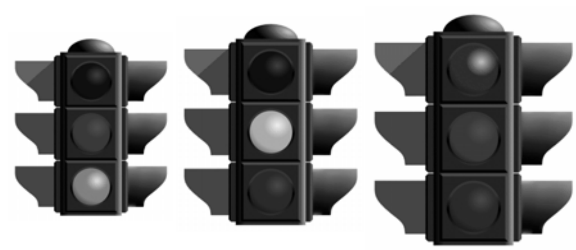
Peaks appear in Velocity and Demod spectra: Plan replacement at next maintenance period.

Peaks appear in Velocity spectra only, combined with a rise in the Demod noise floor: Replace the bearing now!

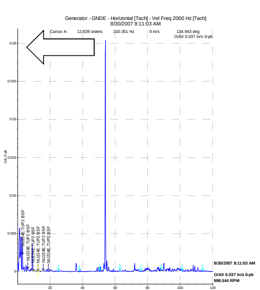
WIND TURBINES ARE VERY EASY TO COMPARE TO EACH OTHER TO DETERMINE A FAULT

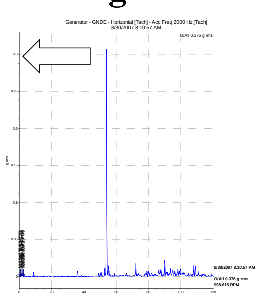


VIBRATION ANALYSIS INTERPRETATION IS REDUCED TO *TRAFFIC SIGNALS* WITH ALL MAJOR CONDITION MONITORING SUPPLIERS



GOOD(.03) vs. BAD(.3) Generator Bearing



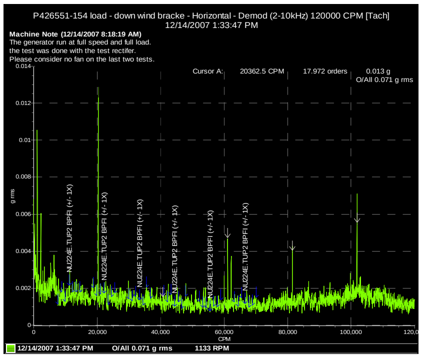


- There are 2 ISO standards for alarms and 1 widely accepted 30 year study also used for alarming

MEGAWATT GENERATOR BEARING

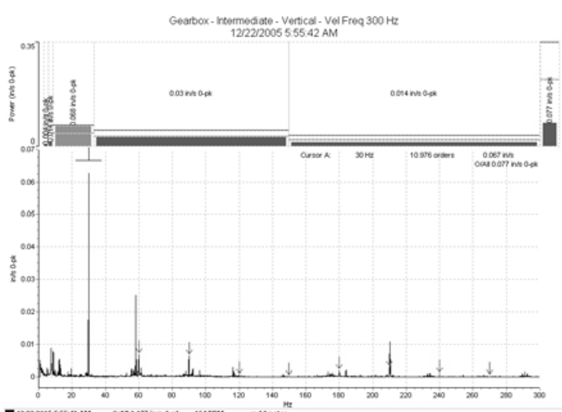
looks like this:

VIBRATION SIGNATURE IS LABELED WITH BPFI (INNER RACE DEFECT)



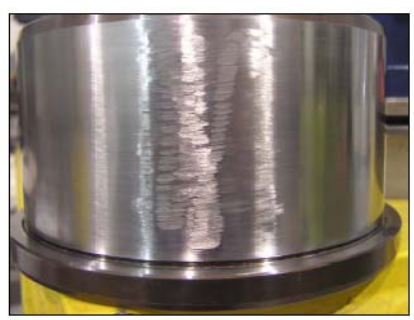
MEGAWATT CLASS GENERATOR BEARING

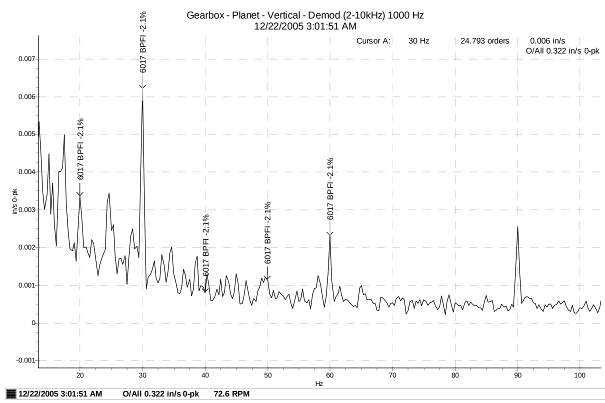
looks like this:



GEARBOX PLANET BEARING

looks like this:

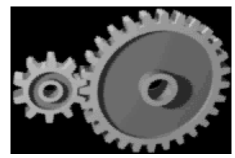




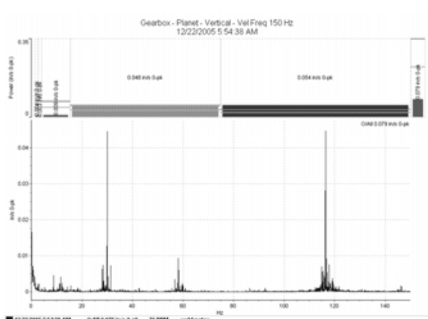
EXAMPLE # 3

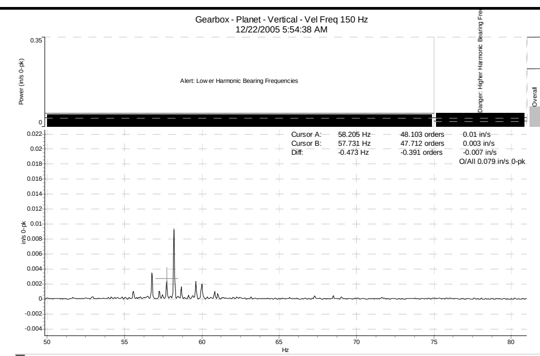
- **MW WIND TURBINE GEARBOX GEAR ISSUE**
- There are 2 ISO standards for alarms and 1 widely accepted 30 year study also used for alarming
- GEAR MESH FAULT FREQUENCY =

GEAR TOOTH COUNT x GEAR TOOTH COUNT x RPM



PLANETARY GEARBOX SIGNATURES





- Data captured on stage 2 mesh on the planet at 2:54 p.m.
- **Again, the problem appears to be with very early stages of gear wear on the carrier. No other faults were noted.**
- ***As levels of vibration in all these tests seem quite low, and there is no substantial alarming; it is safe to conclude that we are seeing only early stages of wear in the gearboxes that require no immediate action, but warrant more frequent monitoring.***

WIND TURBINE MODELS USED IN THE EXAMPLES (in no particular order)

- VESTAS V-80
- GE 1.5
- Clipper 2.5

PREDICTING USING VIBRATION

- Know before wind season starts
- Know before the warranty expires
- Know what needs to be fixed
- Know when it needs to be fixed
- Know what parts need to be ordered
- Know if it's an up tower repair or crane call
- Know if it was rebuilt or installed properly