ECN

Energy research Centre of the Netherlands

Condition Monitoring: Theory and practice

Theo Verbruggen

Wind Turbine Condition Monitoring Workshop, *October 8-9, 2009*

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- Why and how use CM for O&M optimisation?
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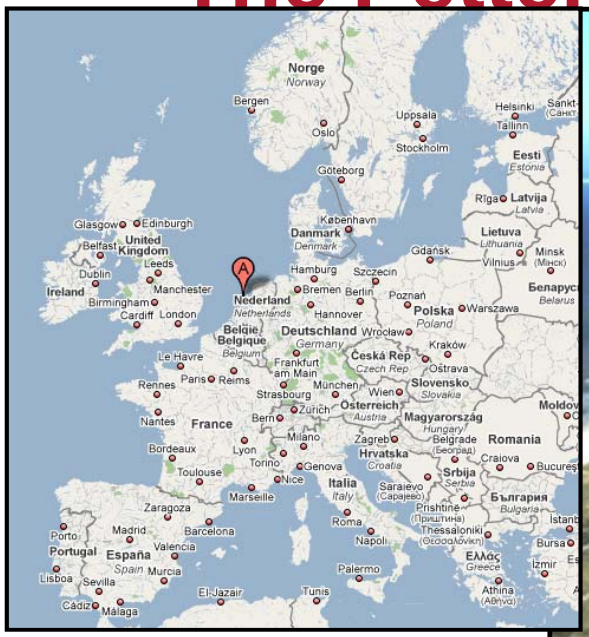


ECN Wind Energy (45 fte's)

1. Rotor and wind farm aerodynamics
2. Integrated wind turbine design
3. **Operations and Maintenance**
4. Measurements & Experiments

EWIS — ECN Wind energy Industrial Support

EWTW — ECN Wind turbine Test Site Wieringermeer

Knowledge Centre WMC — Wind Turbine Materials and Constructions

Research Turbines at EWTW

- Five Nordex N80 research turbines (2,5 MW)

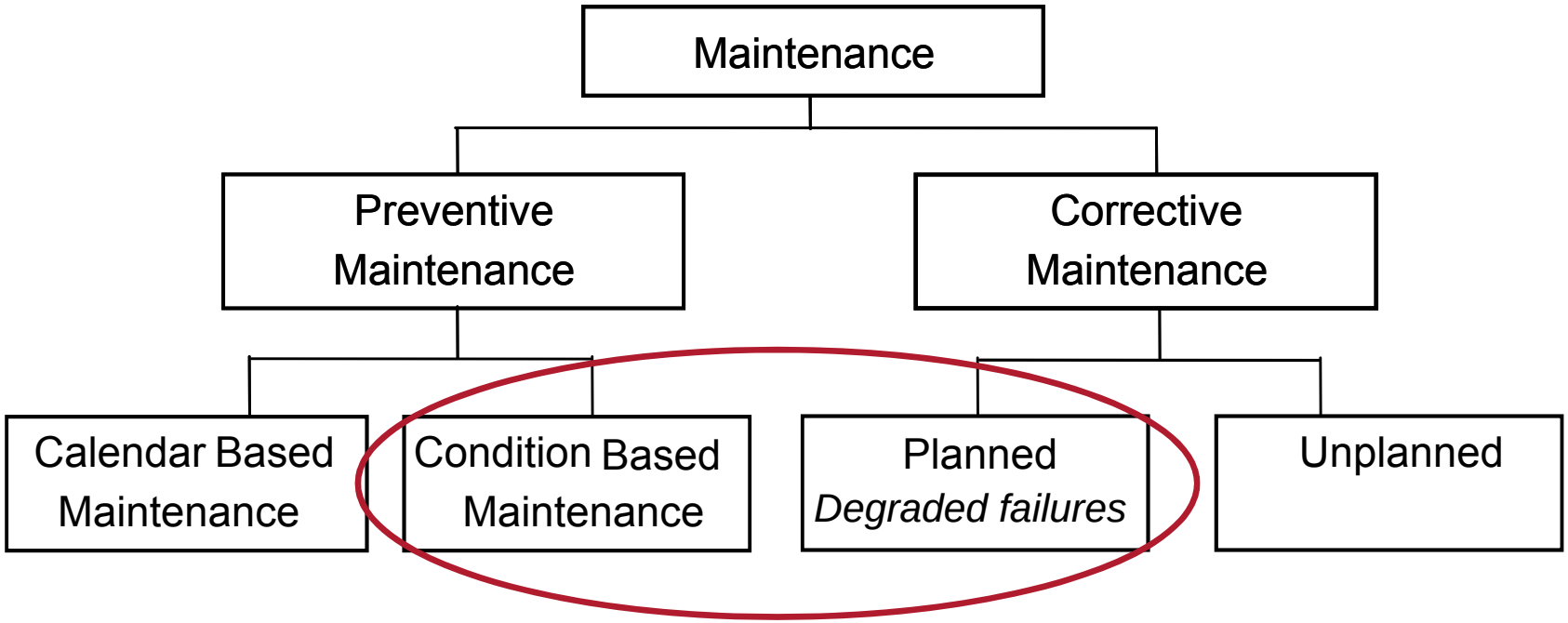
- SCADA data
- PLC: time series
- Service reports: O&M data
- Condition monitoring
- Mechanical load measurements

Four Prototype locations

- Prepared building permits up to 6 MW
- Fast installation and good wind conditions
- Measurement infrastructure available

	Power [MW]	rotor [m]	hub [m]
GE 2.5	2,5	88	85
GE 2.3	2,3	94	100
Siemens 3.6	3.6	107	80
Darwind (2010)	5.0	115	100

CM for O&M optimisation



CM for O&M optimisation

Condition monitoring *is the process of monitoring a parameter of condition in machinery, such that a significant change is indicative for a developing failure*

So three conditions to be fulfilled

1. Detection of failure mechanism (indicator)
2. Detection on time to make prognosis (early indicator)
3. Criteria (**green**, **yellow**, **red** light)

CM for O&M optimisation

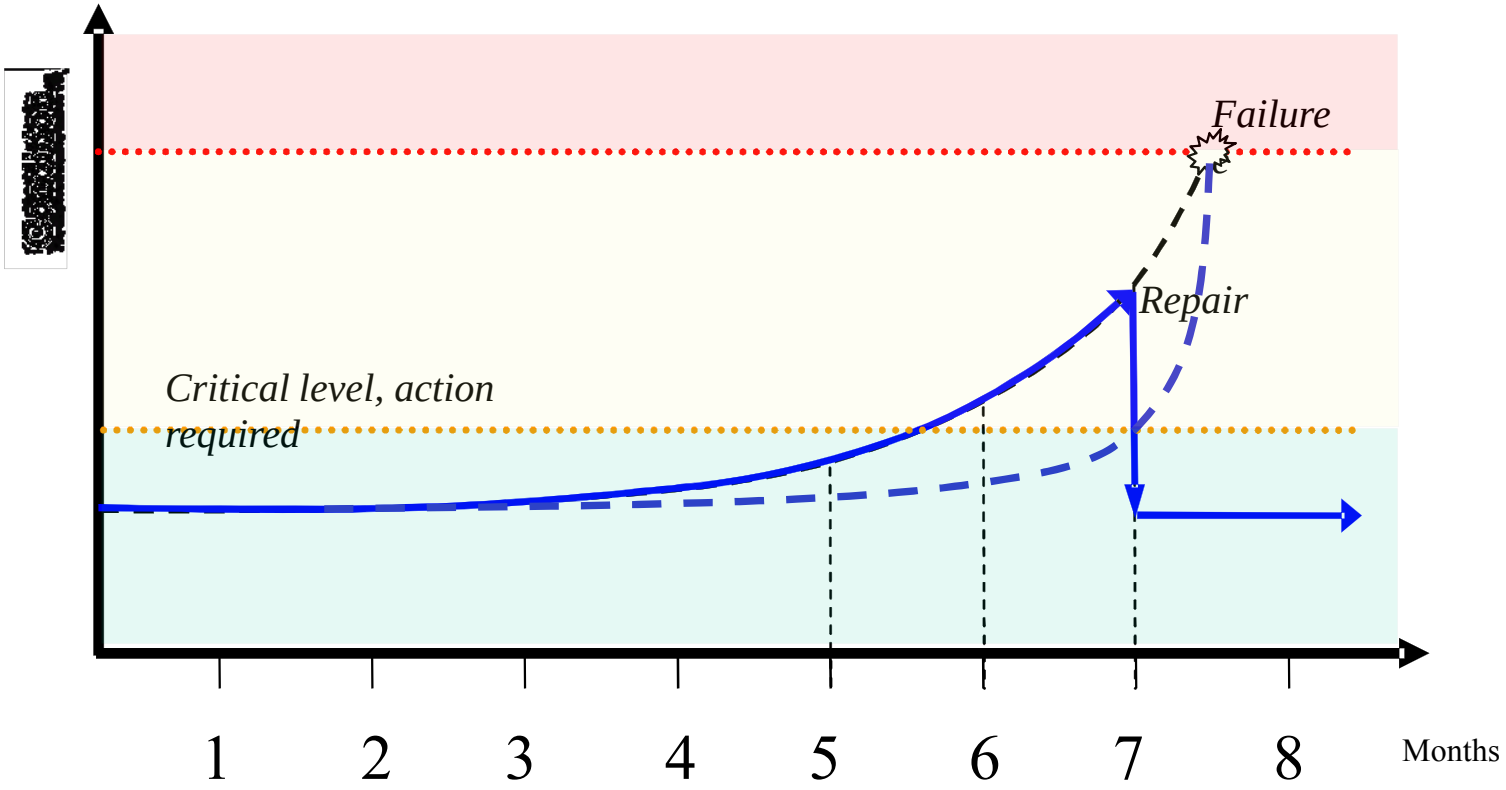
First condition: Detection of failure mechanism

- Component degradation
  - measurements with data analyses
    (vibrations, play, oil samples, thermal, SCADA data, …..)
  - observations during scheduled maintenance

- Usage monitoring and consumed lifetime
  - energy production
  - operating hours
  - “loading” of components *(mechanical, electrical, or thermal)*

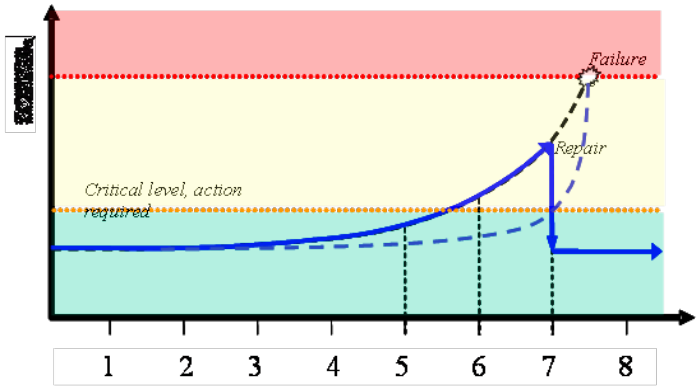
CM for O&M optimisation

Second condition: Detection on time to make prognosis



CM for O&M optimisation

Third condition: Criteria (green, yellow, red light)



Long term experience needed to determine “abnormal behaviour”

- large population with similar systems,
- similar loading and similar failures
- interpretation and assessment of large amounts of data

CM for O&M optimisation

Condition monitoring: **if** maintenance is foreseen but unclear **when**

Example: gearbox oil

(e.g. postpone replacement from year 4 to year 7)

Gearbox, bearings, …???

- Replacement is not foreseen every ?? year
- Early failures and serial damages
- If too many identical failures: retrofit instead of CM

CM Techniques for wind energy

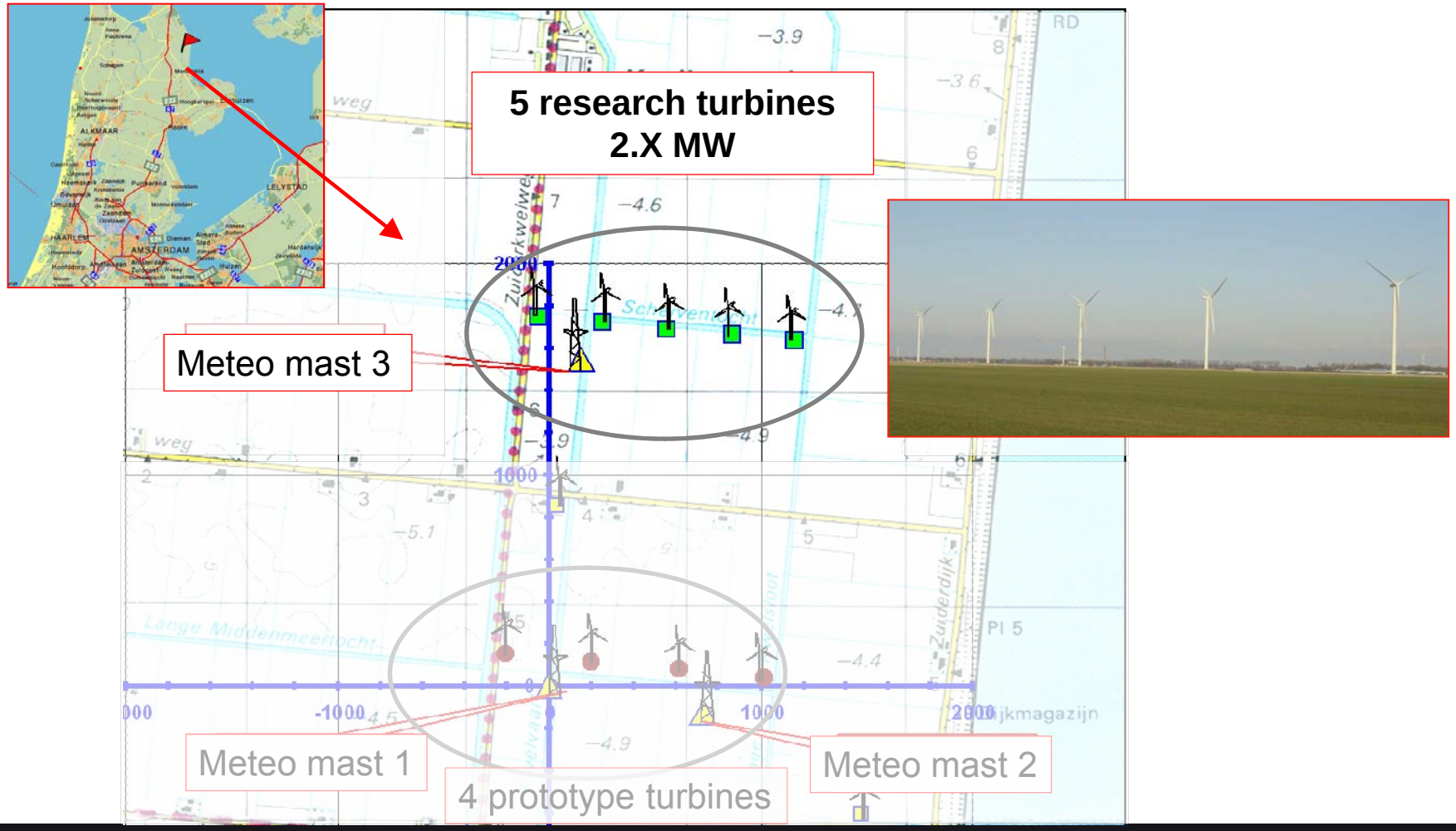
ECN's experiences with:

- Analysis of PLC data
- Analyis of SCADA data

→ *Present in turbine*

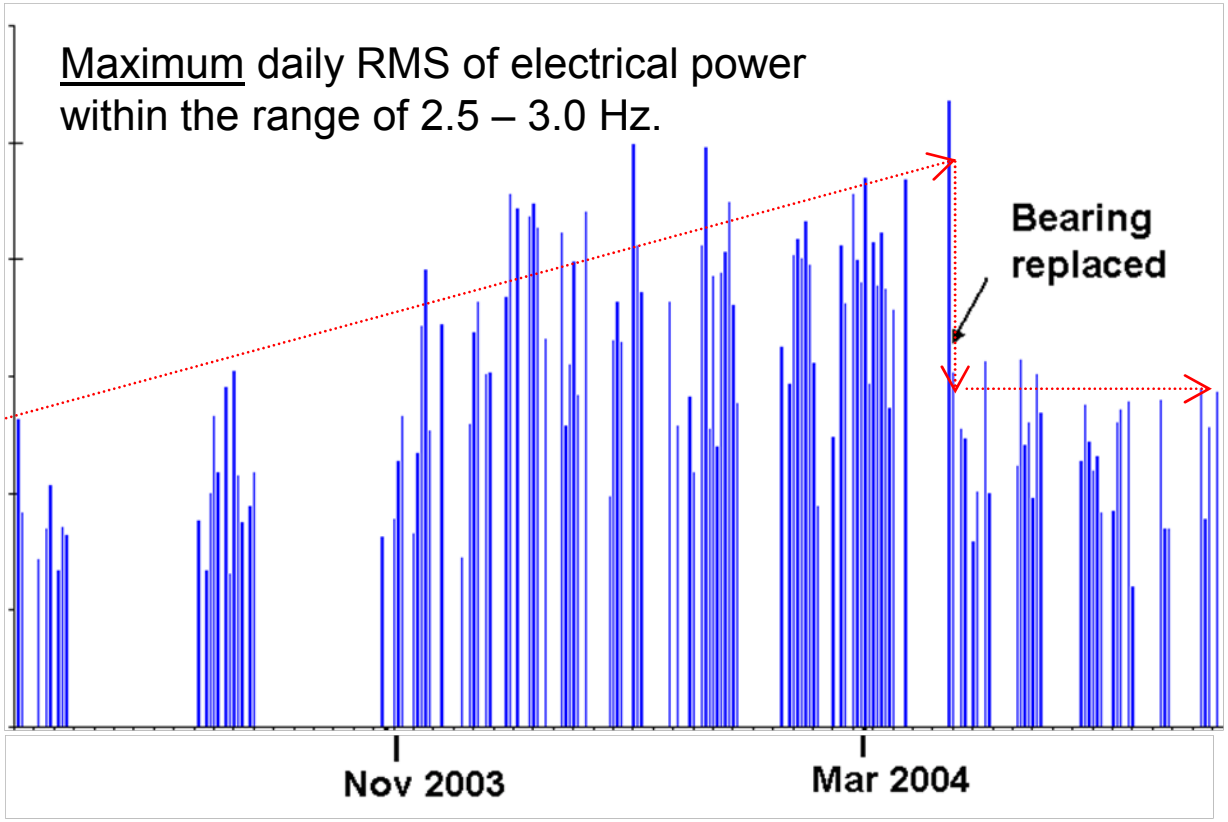
- Vibration monitoring → *Add on, firmware*
- Usage monitoring (loads) → *R&D phase*

CM Techniques for wind energy



CM Techniques for wind energy

1) PLC data (time series): High RMS value from electrical power



CM Techniques for wind energy

1) PLC data: Assessment

1. Detection of failure mechanism (early indicator)

   Unclear from PLC data only

2. Detection on time to make prognosis

   No, unclear how fault would progress

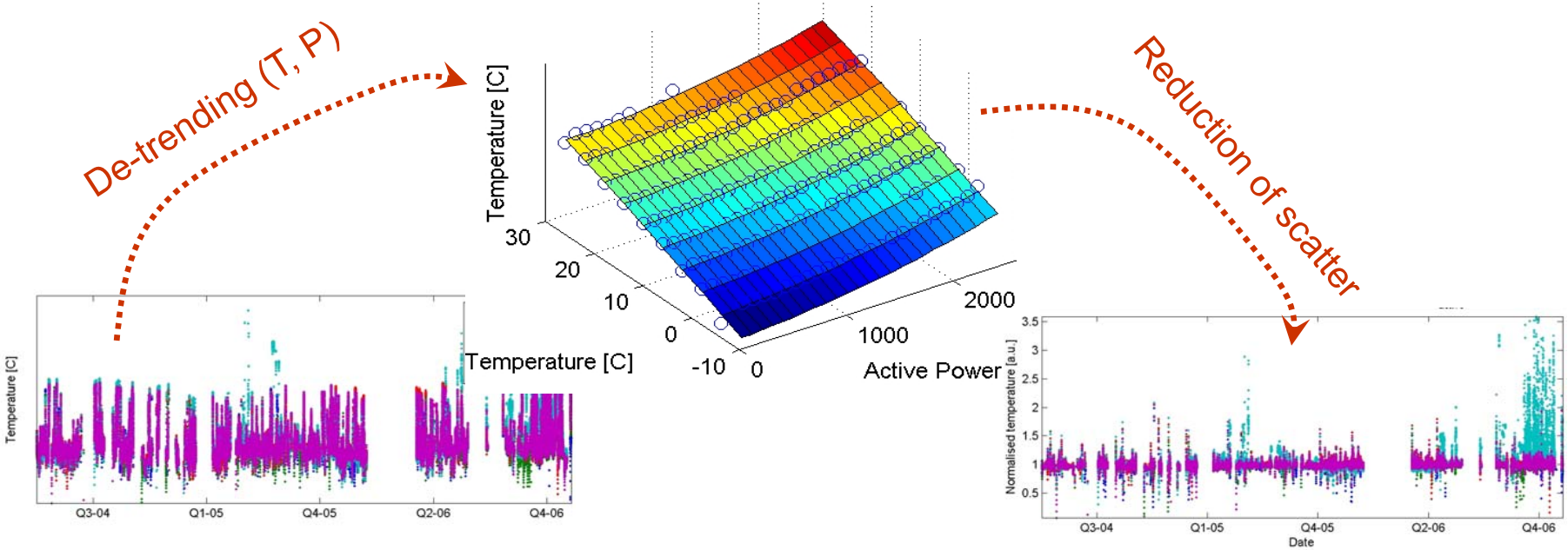
3. Criteria (**green**, **yellow**, **red** light)

   No, inspections lead to replacements

Applicable for early warnings, not yet for CBM

CM Techniques for wind energy

2) SCADA data: Component temperatures



- De-trending with temp. and power effectively reduces signal variability
- However, no deviations from fingerprint found during measurement period

CM Techniques for wind energy

2) SCADA data: Assessment

1. Detection of failure mechanism (early indicator)

   Unclear from experiments

2. Detection on time to make prognosis

   Unclear from experiments

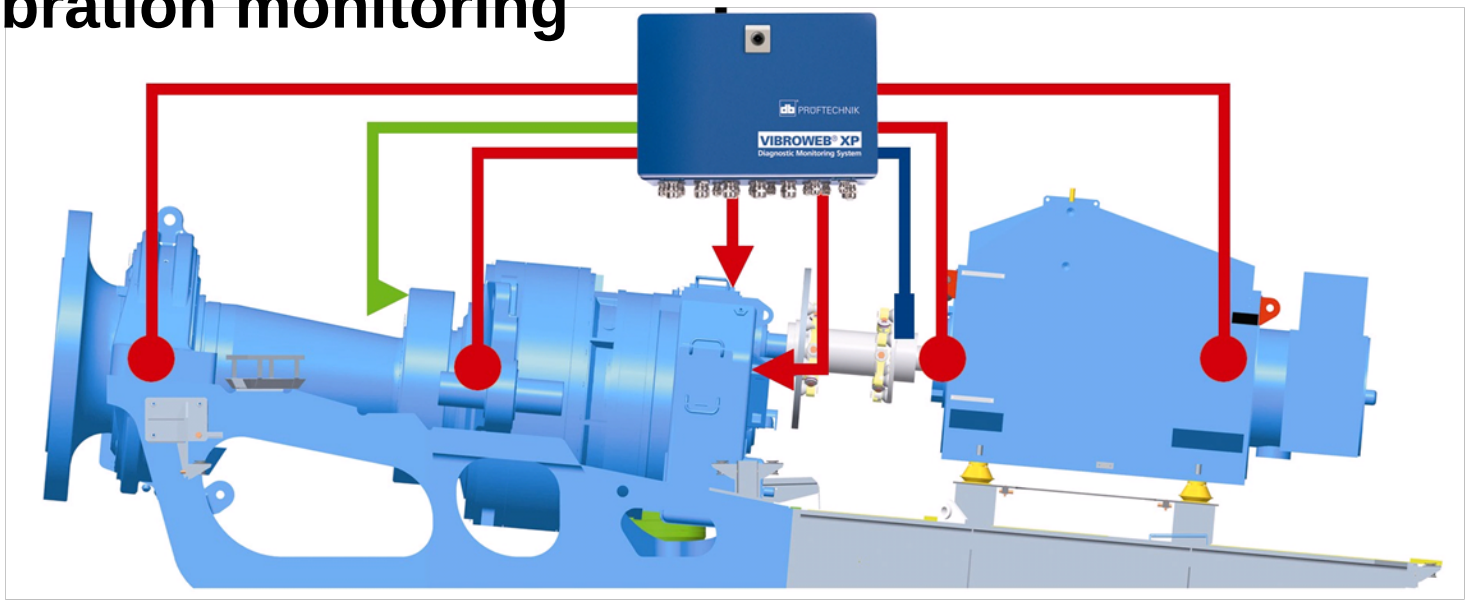
3. Criteria (**green**, **yellow**, **red** light)

   No

Labour intensive, too many signal combinations possible, unclear what to look for

CM Techniques for wind energy

3) Vibration monitoring



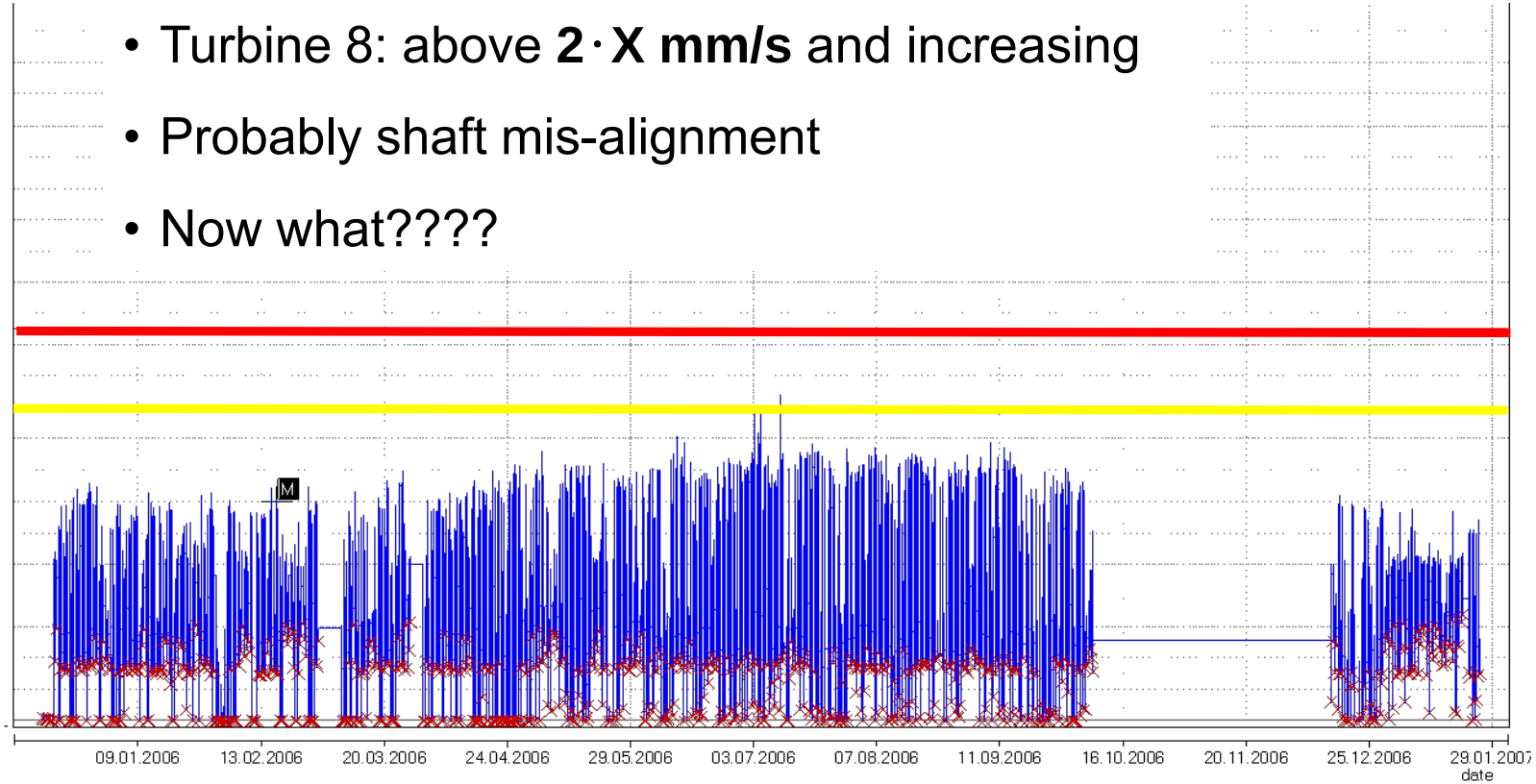
<u>Typical configuration</u>

- Main bearing 2D-displacement
- Gearbox meshes and bearings
- Generator bearings

CM Techniques for wind energy

High vibration level generator

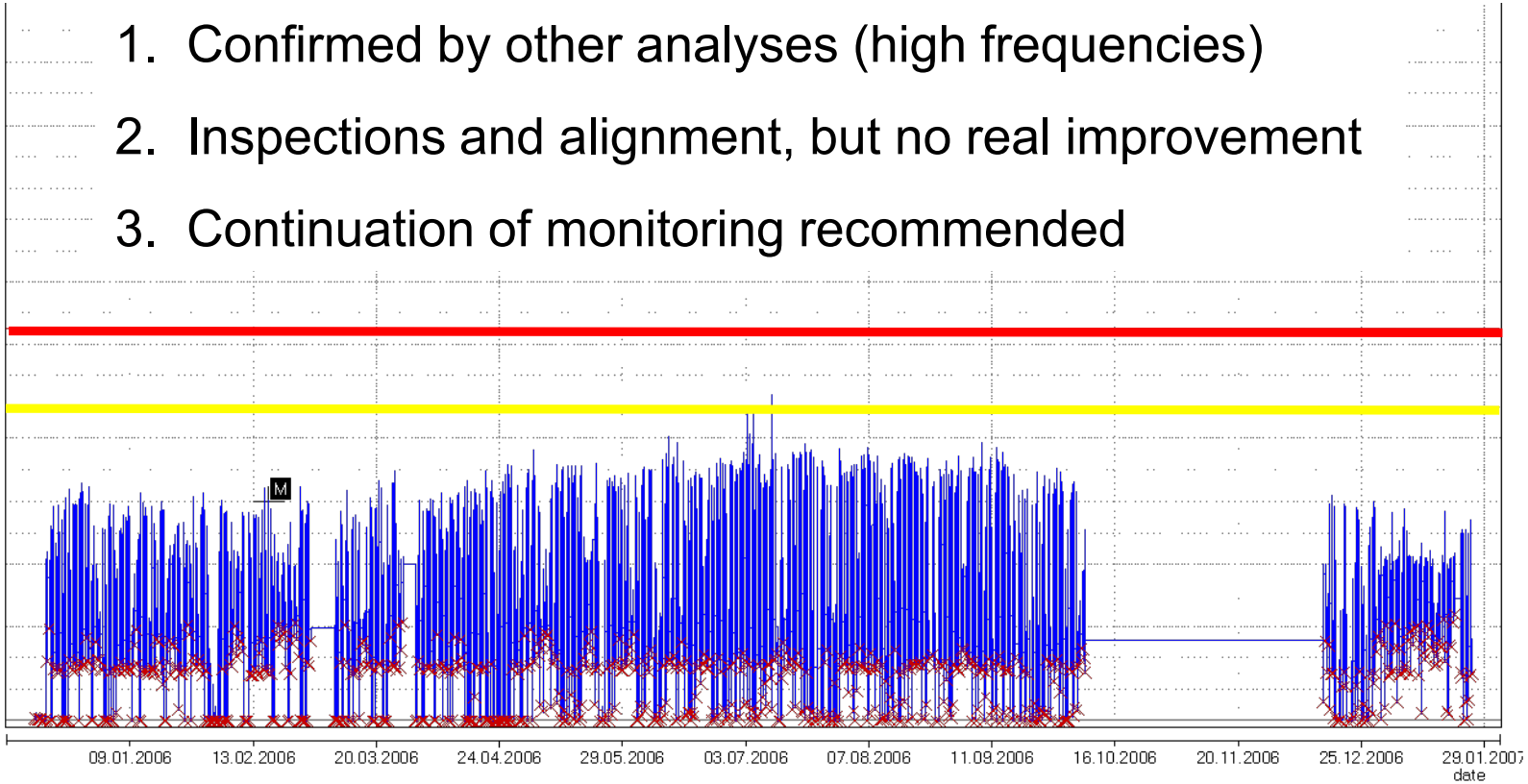
- Turbine 8: above **2·X mm/s** and increasing
- Probably shaft mis-alignment
- Now what????



CM Techniques for wind energy

High vibration level generator

1. Confirmed by other analyses (high frequencies)
2. Inspections and alignment, but no real improvement
3. Continuation of monitoring recommended



CM Techniques for wind energy

3) Vibration monitoring: Assessment

1. Detection of failure mechanism (early indicator)

   Yes, detailed about the exact spot

2. Detection on time to make prognosis

   No, unclear how fast fault will develop

3. Criteria (**green**, **yellow**, **red** light)

   Yes, but arbitrary, danger of false alarms, on-site visits still necessary

Applicable for fault detection and avoiding consequence damage, not yet for CBM

CM Techniques for wind energy

- PLC data:

  Deviations from fingerprints difficult to correlate with failure cause

- SCADA data:

  Potential, but not yet demonstrated

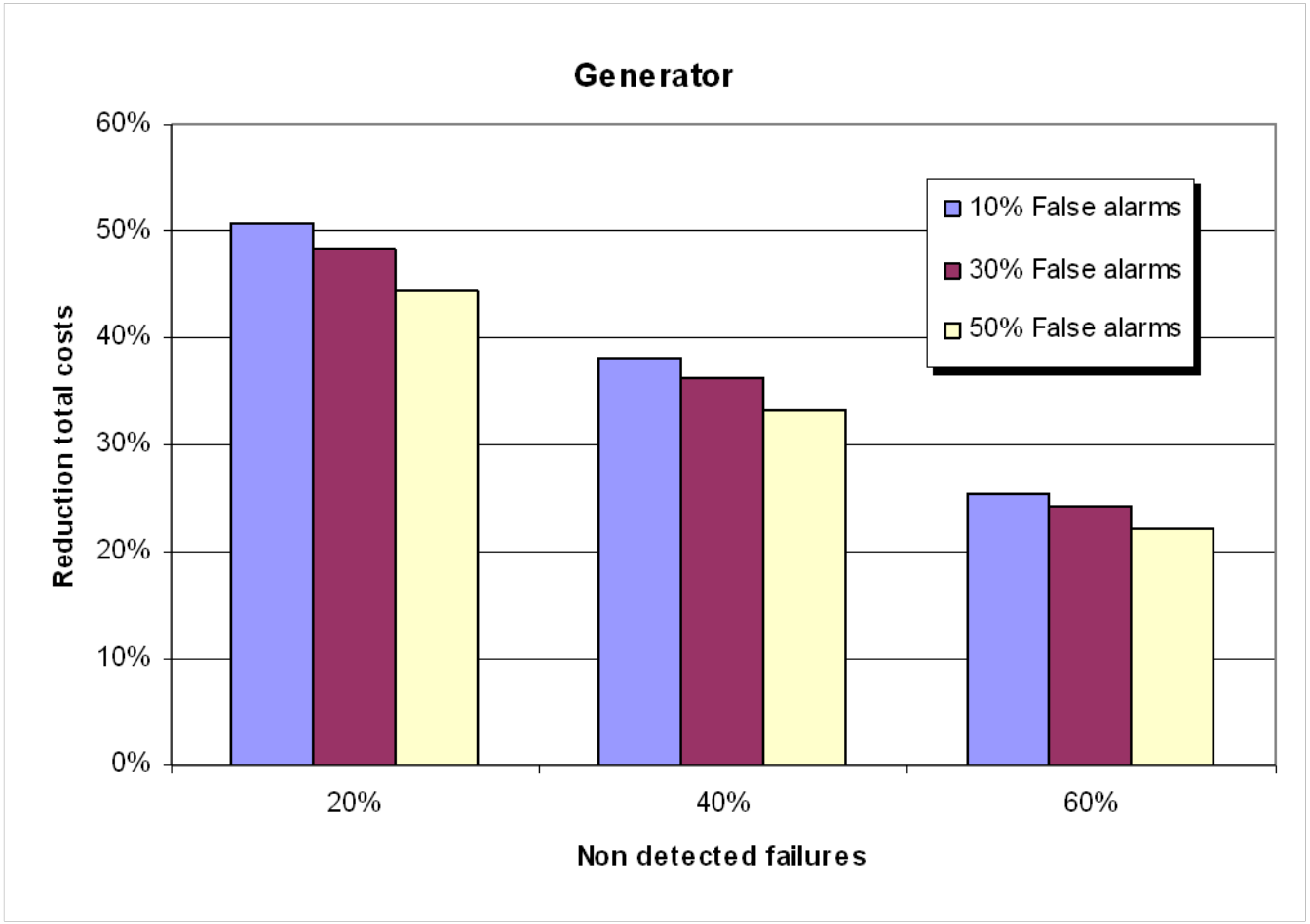
- Condition Monitoring (online drive train vibration):

  - Failure cause detection OK

  - Uncertainties about: 1) criteria (**green**, **yellow**, **red**)

    2) prognoses of degradation

Impact and financial aspects of CM



Conclusions

- CM can be used for CBM if conclusions from diagnostics are reliable
- Only few wind turbine components suitable for CBM
  ⇒ *online CM too often used for serial damages*
- CM hardware functioned reliable over long period
- CM systems generate large amounts of data
  ⇒ *specialists needed for interpretation*
- Cost modelling effective means to assess costs/benefits

Thank you for your attention!