DNV·GL

Using 1Hz data to monitor turbine integrity

Winterwind Conference 2019

Carla Ribeiro, 04 February 2019

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  - Rotor imbalance
  - Changes in structural frequency

Why

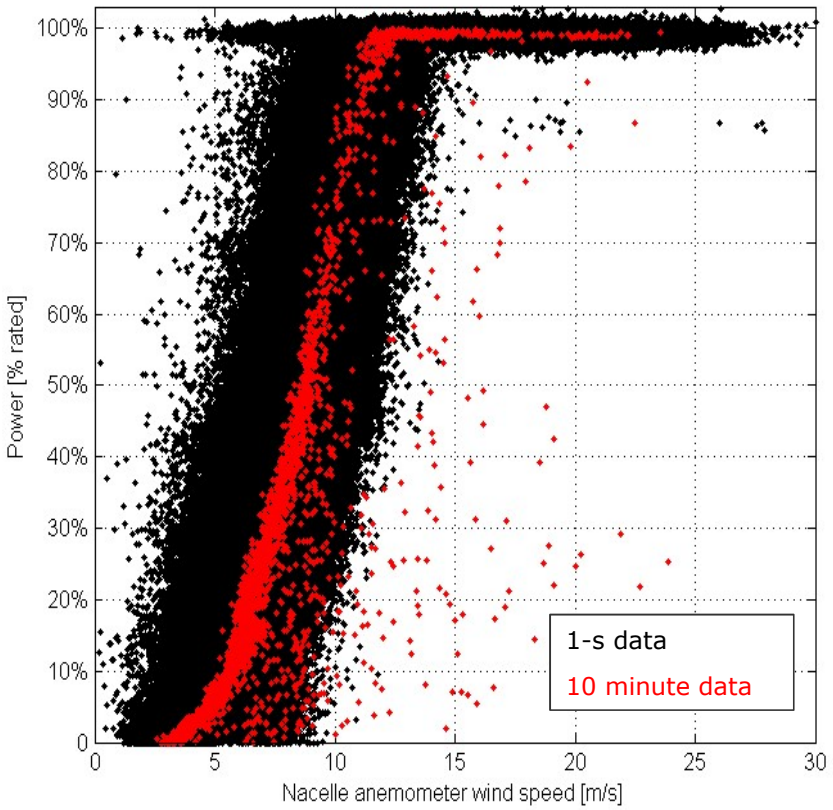
Introduction

- Owners and Operators want to reduce their Levelised Cost of Energy (LCoE) by:
  - Increasing turbine performance
  - Reducing downtime and service and maintenance cost
  - Extending the life of their assets

- Analysis of turbine and wind farm data can provide valuable insights
- 10-minute data is the industry standard - it is cheap and readily available
- Higher frequency data normally requires additional sensors (accelerometers, CMS)…
- …but many modern turbines provide data at 1Hz through their OPC (Object linking and imbedding Process Control) interfaces

Higher-frequency data

- Industry typically using 10min data
  - Sufficient for most "standard" analyses
- Analysis of higher frequency data offers deeper understanding of turbine behaviour:
  - Speed control (f ≥ 1Hz)
  - Yawing strategy (f ≥ 0.2Hz)
  - Start/stop policies (f ≥ 0.2Hz)
  - Tower/foundation dynamics (f ≥ 1Hz)
  - Effects of turbulence intensity on power (f ≥ 1Hz)
- Data quantity challenges
  - 1 month of 1Hz data ~= 50 years of 10min data
  - Digital twin / processing as you go



The digital twin benchmarking “principle”

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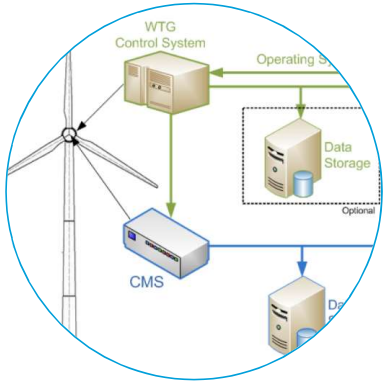


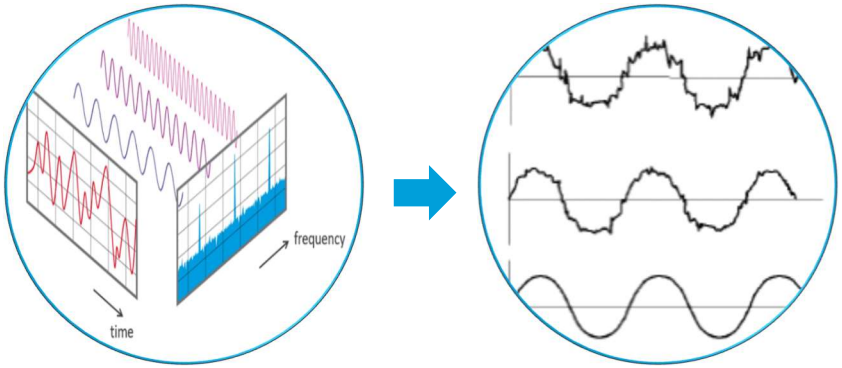
Monitor the data from the wind farm over time

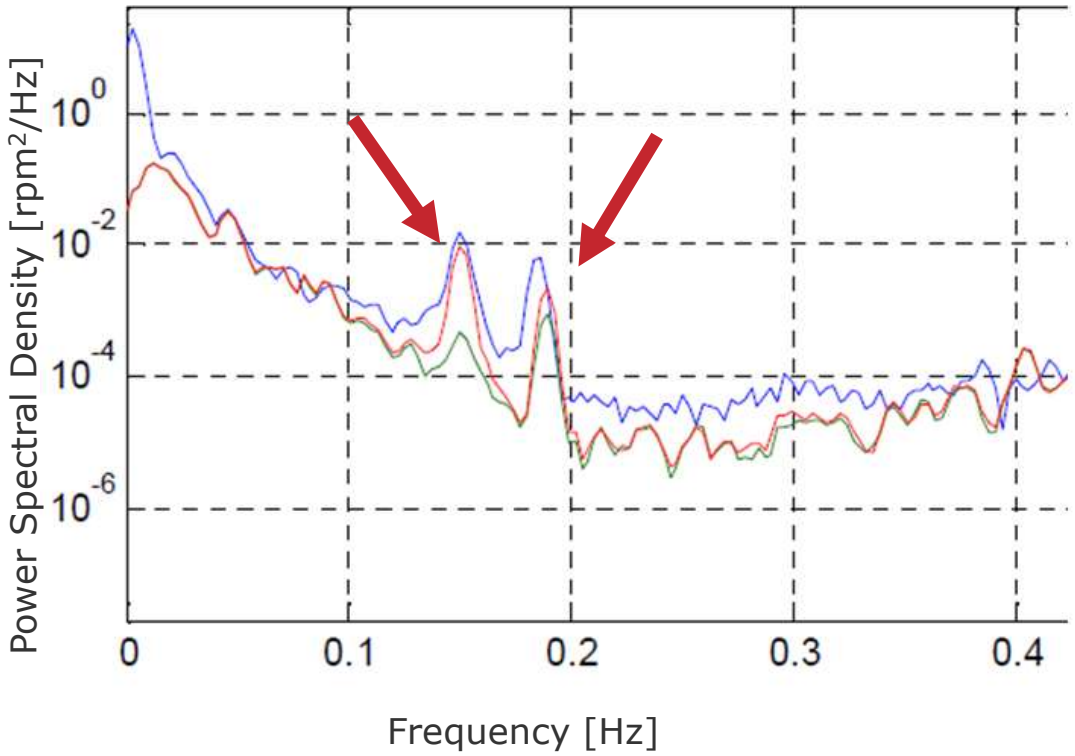
Establish a benchmark of “normal” behaviour average across all turbines

Monitor outliers and deviations from benchmark going forward

How to use the 1Hz data

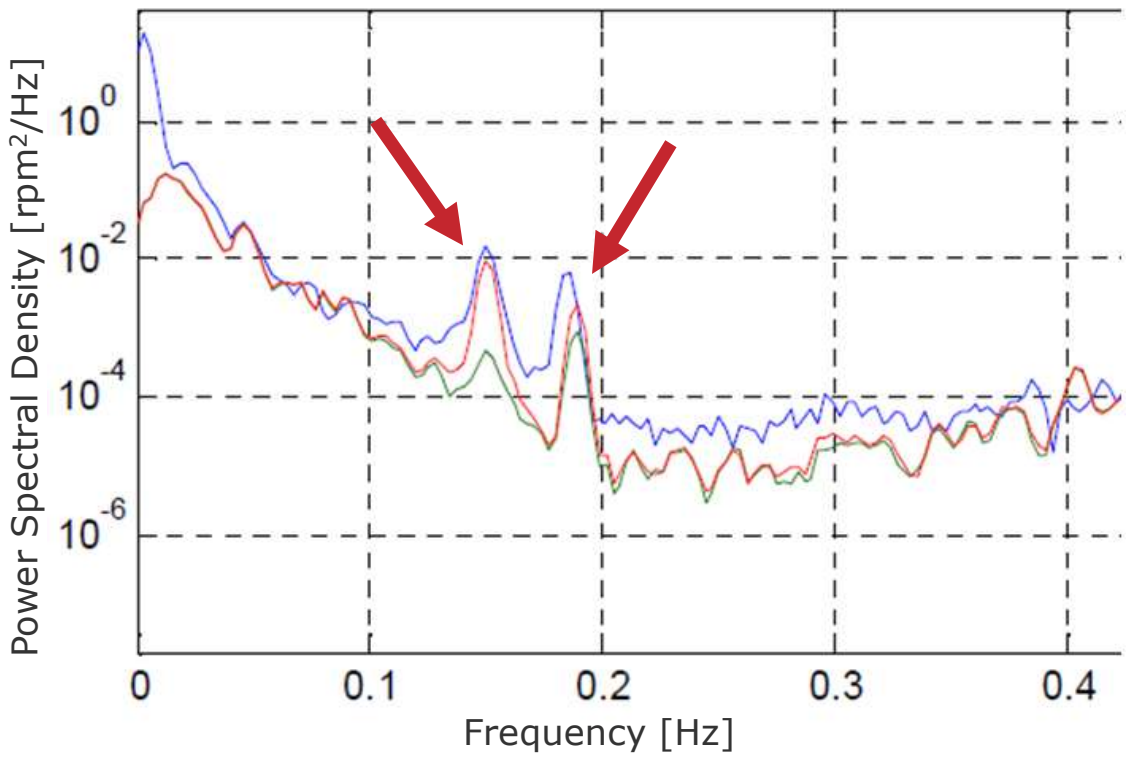
Spectral Analysis – Fast Fourier Transform (FFT)





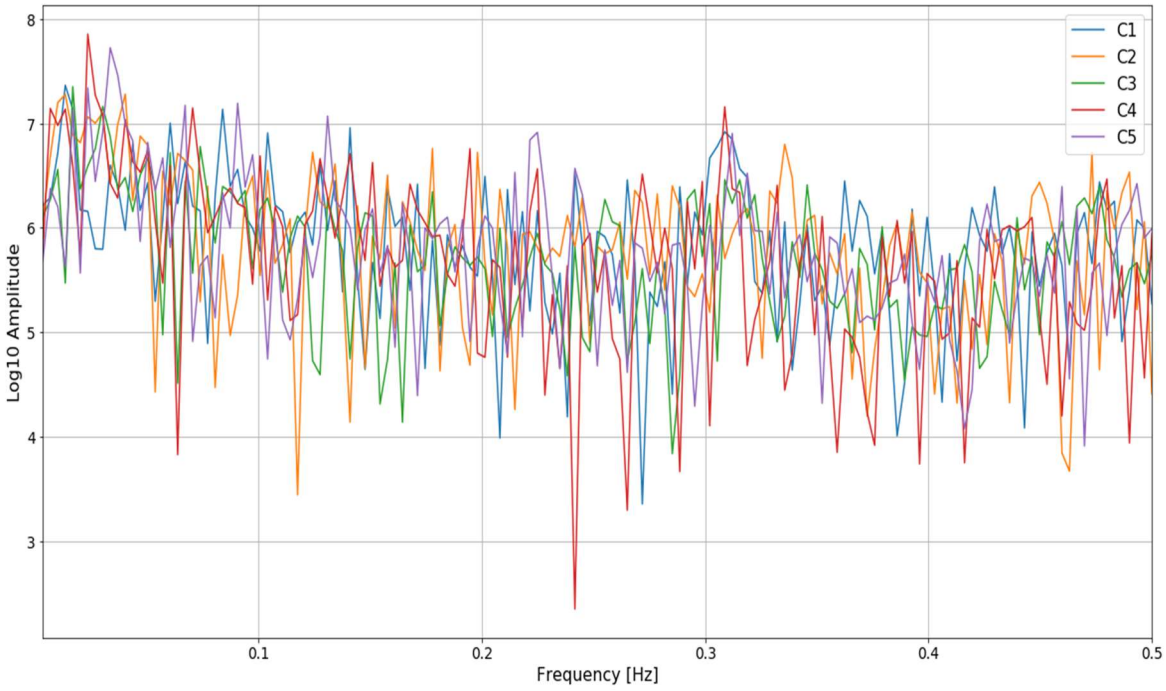
Impact of data quality on analysis (I)

- Not all 1Hz data is created equal!
- This is an example of "good" data
- FFT of generator speed time series
- 10 minute window of 1s data
- Easy to detect
  - Rotor frequency (1P)
  - 1st Tower frequency

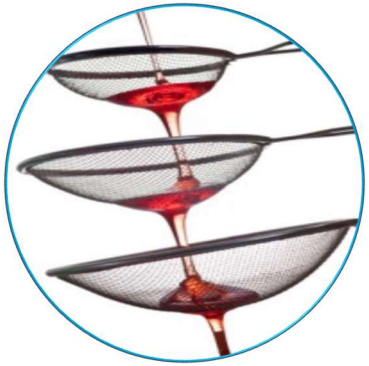


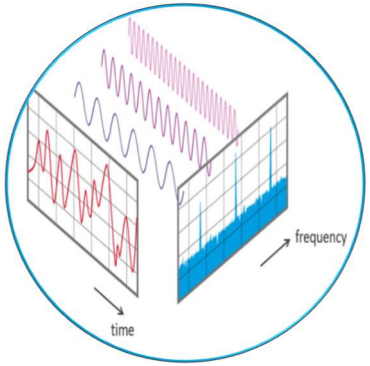
Impact of data quality on analysis (II)

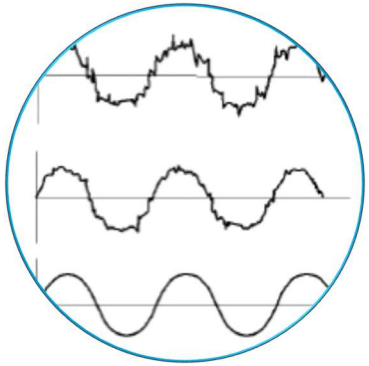
- OPC data is often of poor quality (repeated or missing timestamps, irregular rate)
- This is an example of "bad" data
- 5 minute window of 1s data
- 2 MW turbines
- Hard to detect structural frequencies
- So is there anything we can do?



Novel method of tackling data quality issues - Enhanced spectral analysis







Filtering

Select only rated operation

Remove spurious data

Spectral analysis

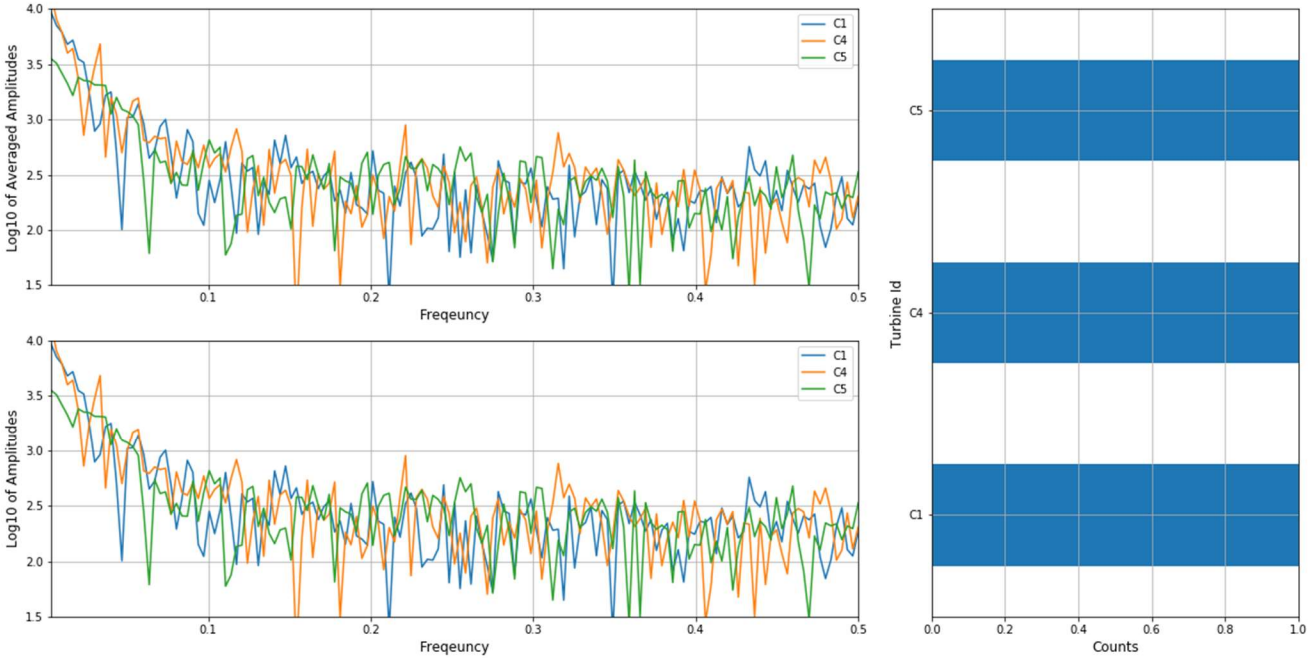
Produce FFT for each 5- or 10-minute window of 1s data

Averaging

Aggregate the spectral analysis output of multiple windows

- The output is a single FFT for the whole averaging period
- A "flavour" of Welch/Bartlett's method
- NOT the same as doing an FFT for a longer window – we trade resolution for smoothness
- Reduces data storage requirements

Frequency Analysis - convergence

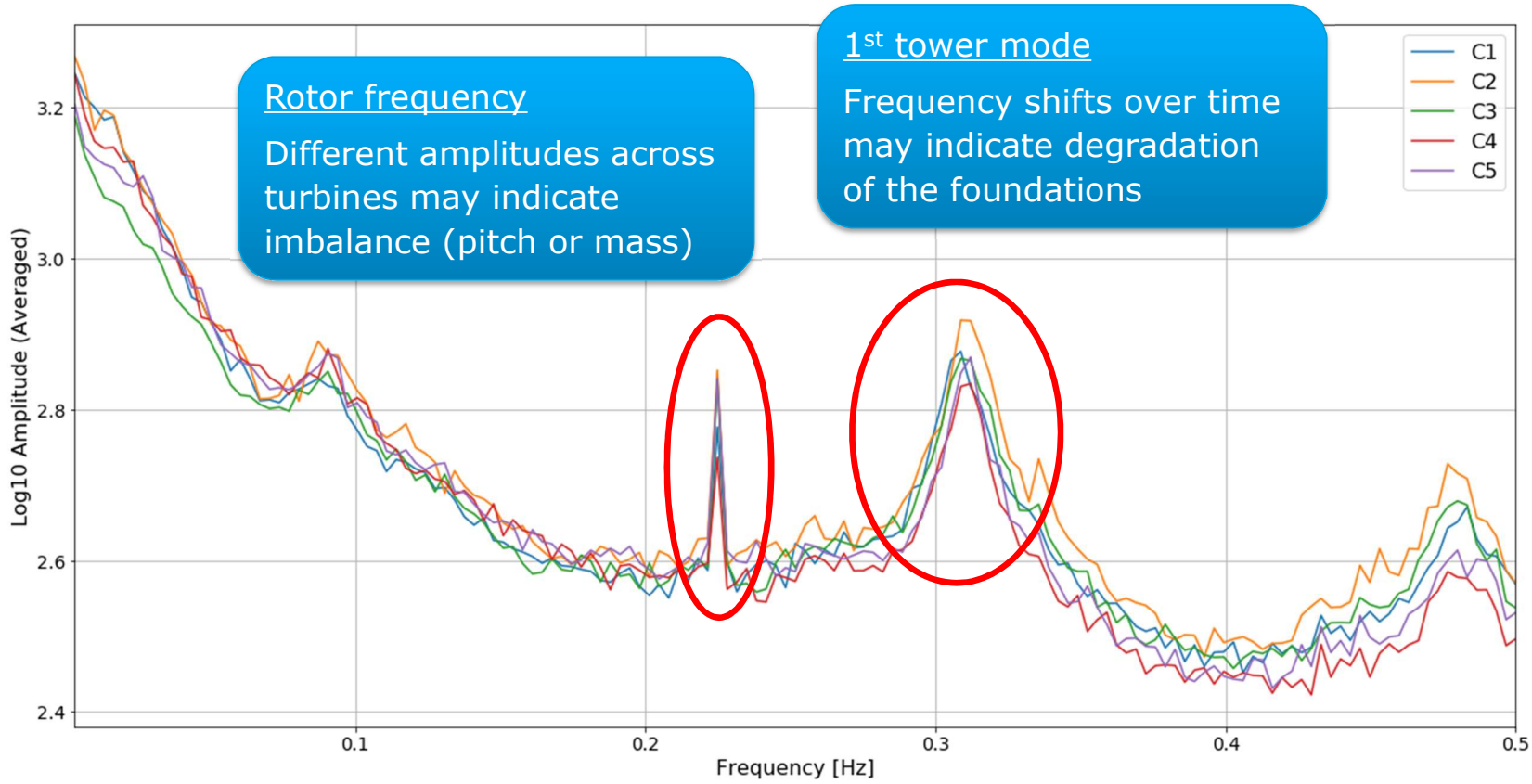


Good results with 50-100 windows of 5-minute data

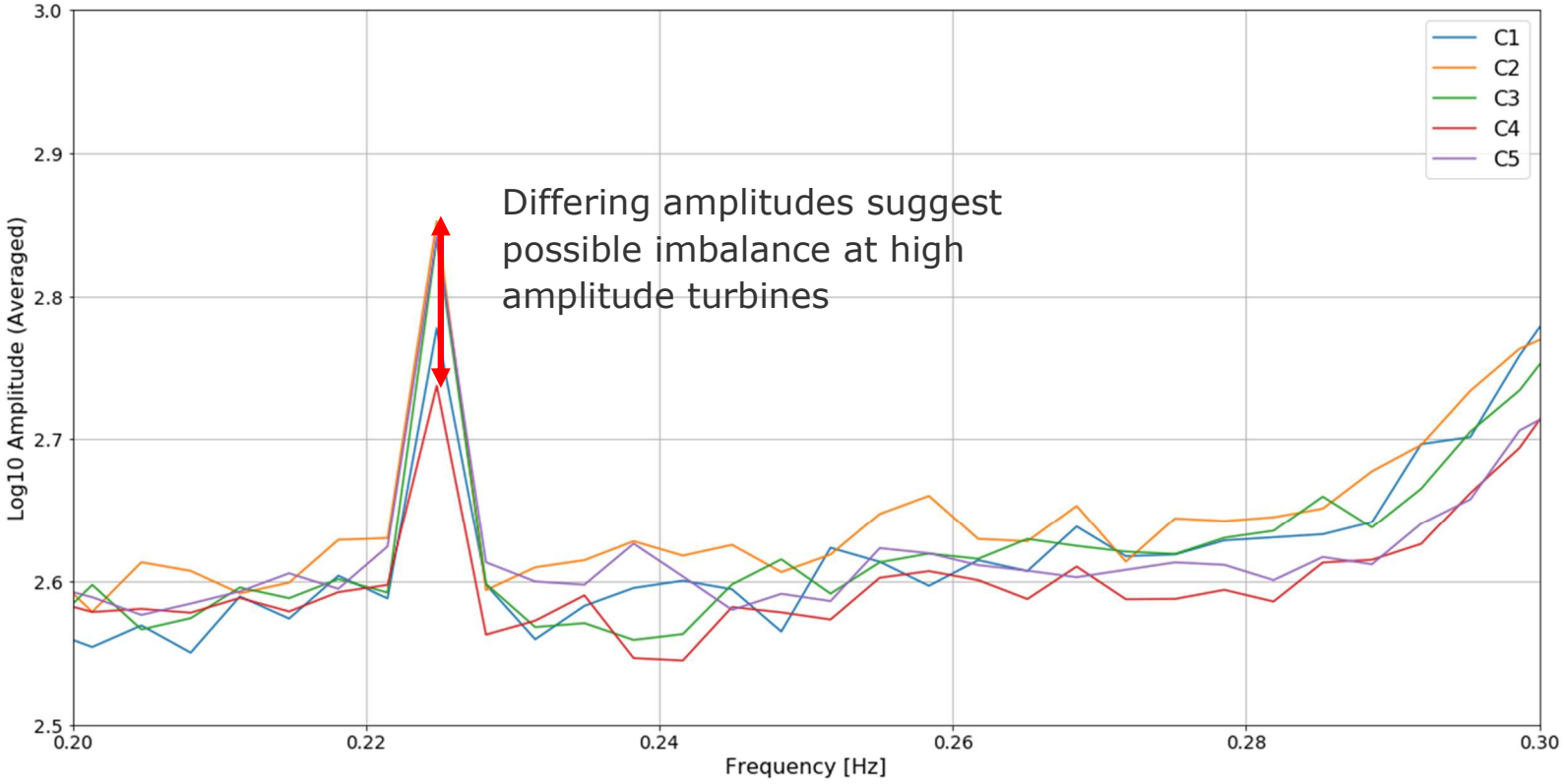
4-8 hours of data at or around rated operation

What we can learn from the data

Frequency Analysis – Time-averaged autospectra (400 windows)



Frequency Analysis – rotor imbalance



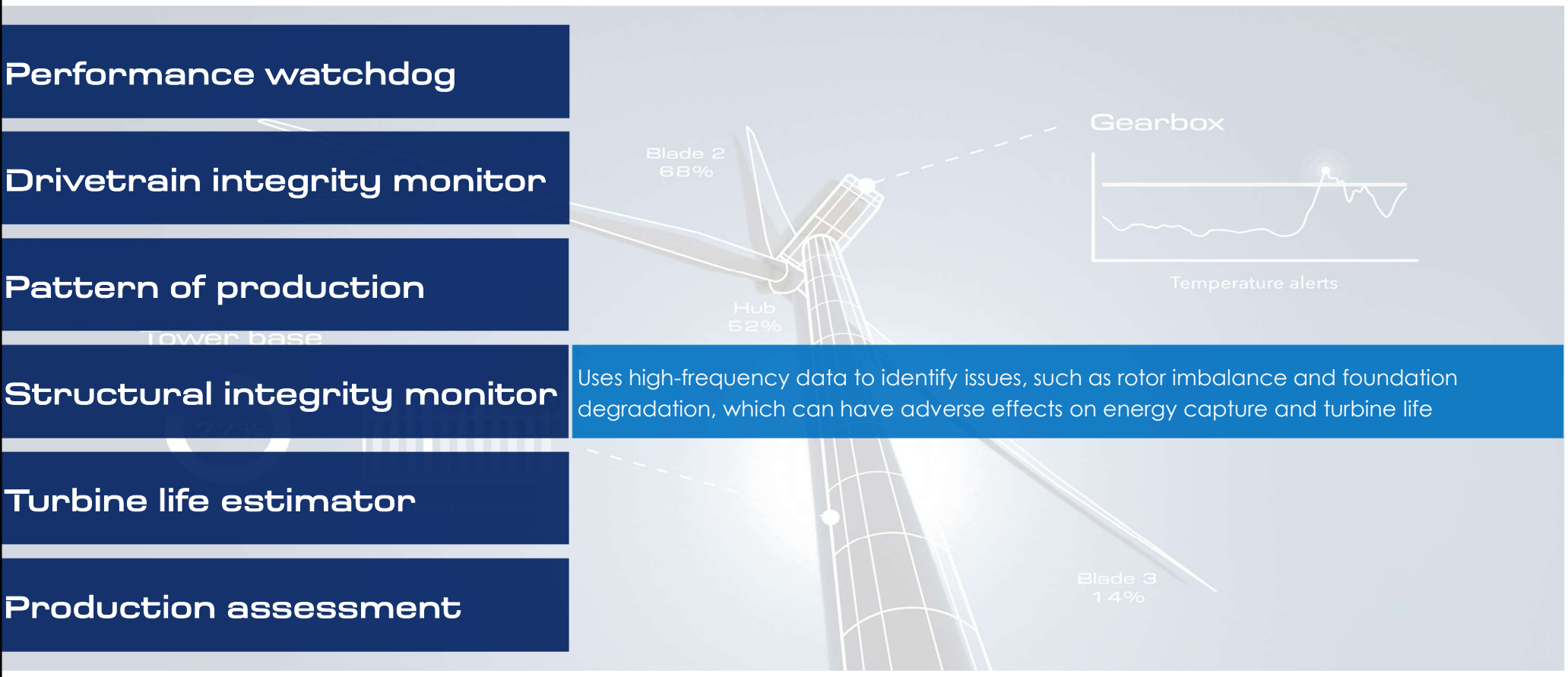
Conclusions

- Spectral analysis of 1Hz data can:
  - Identify rotor imbalance (pitch or mass)
  - Monitor changes in structural frequency
- Cost of adding accelerometers to turbines can be EUR 000s per turbine
- 1Hz data analysis may provide most of the functionality for a whole project for the price of instrumenting one turbine
- More effective for larger turbines / modern designs
- Real 1Hz data extracted by querying the OPC interface
- Digital twin type services can be used to do this very efficiently and smoothly

WindGEMINI – An Online Digital Twin for your Wind Turbines

- Performance watchdog
- Drivetrain integrity monitor
- Pattern of production
- Structural integrity monitor
- Turbine life estimator
- Production assessment

Uses high-frequency data to identify issues, such as rotor imbalance and foundation degradation, which can have adverse effects on energy capture and turbine life



Ask not what your turbines can do for you, ask what you can do for your wind turbines

Thank you, any questions?

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