Use of Higher Frequency SCADA Data for Turbine Performance Optimisation

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Outline

- Higher frequency SCADA data – the opportunities and the challenges
- Example 1: analysis of performance in high turbulence
- Example 2: analysis and optimisation of yaw strategy
- Example 3: tower/foundation condition monitoring
- Conclusions
Higher frequency SCADA data

**Opportunities**
- Much deeper understanding of the behaviour of a wind turbine in the field
- Easier to identify operational state even when counters are not available
- Analysis (and possibly optimisation) of
  - Speed control (f $\geq$ 1Hz)
  - Yaw strategy (f $\geq$ 0.2Hz)
  - Start/stop policies (f $\geq$ 0.2Hz)
  - Tower/foundation dynamics (f $\geq$ 1Hz)
  - Effects of turbulence intensity on power

**Challenges**
- Data storage and handling
- Visualisation
- Need to develop new tools and procedures

1 month of data at 1s = 50 years of traditional 10 minute data!
### Example 1: Analysis of performance in high turbulence

- Site specific turbulence intensity can cause significant deviations from nominal power curve
- Difficult to analyse effects of turbulence with 10 minute data
- In this example an analysis of 2 months of 2s data clearly shows the effects of turbulence
- Similar results with 10 minute data would require years of data and therefore be affected by seasonality
Example 2: Analysis of yaw strategy

Analysis of one day of 2s data (selected to include a sufficient number of yaw manoeuvres) allowed the identification (with no prior knowledge of the yaw algorithm) of:

1. Variable (wind-speed dependent) yaw thresholds
2. The averaging time filter applied to the misalignment signal
3. The effect of operation in high yaw misalignment on the power curve
Example 2: Optimisation of yaw strategy

- Yaw strategy normally receives relatively little attention in terms of overall energy capture optimisation.
- Detailed knowledge of the strategy based on high-frequency data enables its optimisation.
- DNV GL has developed a simulation tool that combines low-frequency site-specific wind characteristics, turbulence statistics and detailed knowledge of the control algorithm to run long-term (i.e. years) of simulations at sub-second rate\(^1\).
- The tool allows optimisation of the yaw strategy to maximise the trade between energy capture, yaw activity and turbine loading.
- Equally allows optimisation of start/stop, cable unwind, speed exclusion zone policies.

\(1\) E Bossanyi, T Delouvrié and S Lindahl, Long-term simulations for optimising yaw control and start-stop strategies.
Example 3: Foundation/tower condition monitoring

- Typical soil-structure interaction failure modes:
  - Shear modulus degradation – observed in onshore hybrid monopile foundations and occurring over several months
  - Rock anchor bond strength degradation – more sudden change observed with all types of rock anchor foundations
- These have been observed to result in up to 80% loss in soil-structure interaction stiffness
- Stiffness loss results in a reduction of the 1st tower frequency
- In typical turbine designs the 1st tower frequency is below 0.5Hz, so...
- ...the analysis of 1Hz data (i.e. 1s SCADA) allows the identification of the 1st tower frequency

Diagnostic one-off analysis of foundation integrity

On-going prognostic foundation condition monitoring
Example 3: Results & real life story

- Analysis of synthetic 1s data generated in DNV GL Bladed by simulating different levels of stiffness reduction give very good results using nacelle acceleration or generator speed signals.

- In 2015 DNV GL supported with analysis and control design work an owner at whose wind farm major non-compliances had been identified in the foundation construction.

- After inspections revealed the issues, the owner had to keep most of their turbines offline during high wind season, causing them to “burn an engineer’s yearly salary every 12 hours”.

- Early identification of the foundation issues would have allowed remedial work to be carried out in the low wind season.
Conclusions

- Collection of high frequency SCADA data provides significant opportunities to improve the analysis of operational wind farms.
- High-frequency data combined with expert knowledge of turbine design enables the identification of many aspects of the wind turbine behaviour:
  - Start/stop policies
  - Yaw strategy
  - Cable unwind manoeuvres
  - Speed exclusion zone
- Detailed knowledge of these policies, together with appropriate long-term simulation tools, allows the optimisation of trades between energy capture, manoeuvre frequency and turbine loading.
- High-frequency data also enables identification of tower structural dynamics and related diagnostic/prognostic analysis.
- New tools, procedures and infrastructure are needed to face the data storage and handling challenges.
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