Monitoring the Operation of Wind Turbines
Alex Robertson, Vestas Northern Europe

Renewable Efficient Energy II Conference, 21.03.2012, Vaasa, Finland
Modern wind power plant produce more data than ever

**Equipment:**
- Vibration
- Temperatures
- Status signals

**Performance:**
- Production
- Reactive power
- Availability
- Service history
- Error logs

**Environmental:**
- Wind speed
- Weather

**Formats:**
- 10 minute averages
- Real-time
- I/O signals
- High frequency event data

Data from multiple power plants
Monitoring the Operation of Wind Turbines - Agenda

1. Vibration condition monitoring

2. Preventative maintenance with low time frequency data

3. Impact of monitoring: from availability to lost production

4. Monitoring for Grid Compliance

5. Looking forward

6. Questions
SCADA System

The starting point of all monitoring is the power plant SCADA system.
Monitoring the Operation of Wind Turbines - Agenda

1. Vibration condition monitoring

2. Preventative maintenance with low time frequency data

3. Impact of monitoring: from availability to lost production

4. Monitoring for Grid Compliance

5. Looking forward

6. Questions
Background to vibration condition monitoring

• Condition monitoring has been used in conventional power plants for many years
• For the last decade it has been an increasingly common option on turbines
• This has been lead by offshore, where some form of condition monitoring has for a long time been standard

• Condition monitoring on wind turbines is made difficult since the input loads, shaft speed and output power are constantly changing
• Lower RPMs in wind turbines making wear harder to detect
• In wind turbine condition monitoring, sophisticated analysis tools are essential
The aim of condition monitoring is predictive maintenance: Avoiding costly mechanical failures

The Aim of Predictive Maintenance

Trending analysis of performance against other turbines in our global fleet allows for EARLY TURBINE PERFORMANCE INVESTIGATION

Planned preventative maintenance MINIMIZES RISK OF UNPLANNED SHUTDOWN MAXIMIZING PRODUCTION
**Condition Monitoring Solution (CMS)**

- CMS gathers high frequency data from vibration sensors on the turbine drive train
- The data is analysed offsite to identify unusual behaviour
- V112 features 13 sensors
Clear advice about severity and estimated remaining life time

Diagnosis of detected potential failures are summarized in an Alarm Report

Report format structured around:

- Observation
- Interpretation
- Assessment of maintenance needs

**Observation**

Progressive rise in Gearbox 2nd Stage Overall Vibration (RMS) to above Alert level. Progressive rise in Gearbox 2nd Stage 1st Gearmesh to above Alert level. Small rise in Gearbox 2nd Stage 2nd and 3rd Gearmesh below Alert level. No significant changes in Gearbox 1st and 3rd Stage Gearmesh levels.

**Interpretation**

The progressive rise in the 2nd Stage Gearbox 1st Gearmesh vibration levels indicates a deterioration in the condition of the 2nd Stage gear. The sidebands indicated in the spectrum below confirms this. This is also reflected in the progressive rise in 2nd Stage Gearbox Overall Vibration. The unchanged 1st and 3rd Stage Gearbox Gearmesh levels indicates that the problem is localized to the 2nd Stage Gearbox. The increase in the 3rd Stage Gearbox Overall Vibration level is believed to be as a result of the 2nd Stage Gearbox deterioration.

**Assessment of Maintenance Needs**

The gearbox should be visually examined when convenient, paying particular attention to the 2nd Stage gear teeth condition. The gearbox mounting bolts and support structure should also be checked. BKV will close monitor the Gearbox to identify any deterioration.
Severity classification – Actionable information

Alarms are classified according to severity
New alarms are issued only when a new severity level is reached
Each severity class specifies a lead time until recommended service action.

<table>
<thead>
<tr>
<th>Alarm Class Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Severity</strong></td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
</tbody>
</table>
Increasingly flexible systems allows for the client and/or Vestas to analyse data.

Continual feedback from the Vestas fleet improves fault catching.
Monitoring the Operation of Wind Turbines - Agenda

1. Vibration condition monitoring

2. Preventative maintenance with low time frequency data

3. Impact of monitoring: from availability to lost production

4. Monitoring for Grid Compliance

5. Looking forward

6. Questions
Conditions from over 23,000 turbines are monitored at the VESTAS PERFORMANCE & DIAGNOSTICS CENTERS

GLOBAL COVERAGE

Vestas Performance and Diagnostics Center has GLOBAL REACH WITH 7 LOCATIONS to aid local preventative maintenance.

VPDC MONITORING

Each VPDC location is equipped with state-of-the-art tools and HIGHLY TRAINED ENGINEERS that analyze incoming conditions and issues.
23,000+ turbines to analyse and optimise

Real time monitoring
130+ SENSORS IN 23,000+ TURBINES

Identify performance deviations in the fleet based and INITIATE PREVENTATIVE MAINTENANCE

Findings are used to improve predictive models to provide RELIABLE PERFORMANCE AND YIELD MANAGEMENT

Maintenance plans based on weather forecast to MINIMIZE LOST PRODUCTION while making repairs
Analysis of low time frequency data – software example

1. Vestas Turbine Monitor: one of the Vestas suite of in-house data analysis tools

2. The tool compares turbines to the fleet for hundreds of different error cases

3. This example compares generator bearing temperature to 5024 similar bearings

4. Turbine will not shut off until the 90 degree alarm

5. But comparison to the fleet shows there is something wrong

6. On next service, technician will inspect bearing, and hopefully solve the problem, before the turbine stops.
Monitoring the Operation of Wind Turbines - Agenda

1. Vibration condition monitoring
2. Preventative maintenance with low time frequency data
3. Impact of monitoring: from availability to lost production
4. Monitoring for Grid Compliance
5. Looking forward
6. Questions
Availability: 98%

98% ≈ 15h?  Bad?

98% ≈ 10MWh?  Bad?

Energy based?

98% ≈ 10MWh?  Good?

Time based?
Lost production

- Time based availability normally offers compensation based on \( \text{avg production} \times \text{downtime [h]} \)
- Production based availability compensates based \( \text{possible production} \times \text{downtime [h]} \)
- Production based availability focus on what is important for the customer and ensures business case certainty.
Lost Production Factor

The result of this is a replacement to ‘Availability [%]’, called ‘Lost Production Factor [%]’:

\[
\text{LPF} = \frac{\text{Actual Production}}{\text{Possible Production}}
\]

**LPF definition:**

*Percentage of MWh loss during downtime out of total Possible Production.*
A Turbine Error might only be active for a few hours before a service team has been dispatched to the turbine and get the turbine running again – but on a high wind day, it’s got a greater impact on production.

A Scheduled Service visit to the turbine can mean 15-20 hours downtime for the turbine. But if it’s executed in low wind periods, it will have a minimal impact on production.
Monitoring the Operation of Wind Turbines - Agenda

1. Vibration condition monitoring
2. Preventative maintenance with low time frequency data
3. Impact of monitoring: from availability to lost production
4. Monitoring for Grid Compliance
5. Looking forward
6. Questions
Monitoring for Grid Compliance
Rapid growth in WTG capacity, plant volume and regulatory grid requirements are challenging the wind industry – emphasising the need for real time power plant control

Major turbine developments

Development in installed capacity

Major technical and regulatory developments

- power limitation
- economic viability
- mechanical loads
- variable operation speed
- power factor requirements
- limitation of inrush currents
- power quality
- flicker
- fast, active power recovery
- reactive fault current injection
- fault ride-through
- voltage control
- frequency control
- Inertia Emulation

The Power Plant Controller

- Grid codes increasingly require turbines to participate in supporting the grid
- Wind power plants are expected to behave more like conventional power plants
- This required fast reactions and accurate real-time changes in turbine performance

Park controller continually monitoring and adjusting the turbine and Q equipment

Full picture from monitoring at the connection, Q equipment and elsewhere in the park
Example of Reactive Power Control
High speed control of a medium sized wind park to comply with the Irish grid code

1. Grid provider changes ‘set point’ to 0.95pu
2. Power Plant Controller instructs turbines to change performance
3. Controller makes tiny adjustments to achieve target Q level
Example of using stored data for post event analysis

- Energisation of feeder of 10 WTGs
- Point of Measurements at PCC

• Grid measurement system continuously logs all parameters, such as RMS, harmonics, waveforms flicker, and frequency
• Provides Transient Fault Recording for performance and post-fault analysis
• The data is logged at intervals of 1024 samples/cycle for voltage measurements and 256 samples/cycle for current measurements.
Q&A