Methods and Tools to Enable Preacting Maintenance Measures

Dirk Reinhold, Head of Offshore Maintenance
Offshore Wind R&D Conference 2015
13 - 15 October 2015
Agenda

- Introduction and Problem Description
- Preactive Maintenance
- Selected Components
- Example for Implementation
- Conclusion and Outlook
Introduction and Problem Description
# Senvion Offshore Wind

<table>
<thead>
<tr>
<th>Projects</th>
<th>Contracts Signed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beatrice</td>
<td></td>
</tr>
<tr>
<td>Thornton Bank I</td>
<td>2x 5M (10 MW)</td>
</tr>
<tr>
<td>Alpha Ventus</td>
<td>6x 5M (30 MW)</td>
</tr>
<tr>
<td>Ormonde</td>
<td>6x 5M (30 MW)</td>
</tr>
<tr>
<td>Thornton Bank II/III</td>
<td>30x 5M (150 MW)</td>
</tr>
<tr>
<td>Nordsee Ost</td>
<td>48x 6.2M (295 MW)</td>
</tr>
<tr>
<td>Nordergründe</td>
<td>48x 6.2M (295 MW)</td>
</tr>
<tr>
<td>Nordsee One</td>
<td>18x 6.2M (111MW)</td>
</tr>
<tr>
<td>Various</td>
<td>54x 6.2M (332 MW)</td>
</tr>
<tr>
<td></td>
<td>6.XM152</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth Capacity</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45m</td>
</tr>
<tr>
<td></td>
<td>23km</td>
</tr>
<tr>
<td></td>
<td>12-19m</td>
</tr>
<tr>
<td></td>
<td>30km</td>
</tr>
<tr>
<td></td>
<td>33m-45m</td>
</tr>
<tr>
<td></td>
<td>56km</td>
</tr>
<tr>
<td></td>
<td>33m-45m</td>
</tr>
<tr>
<td></td>
<td>9km</td>
</tr>
<tr>
<td></td>
<td>12m-28m</td>
</tr>
<tr>
<td></td>
<td>26km</td>
</tr>
<tr>
<td></td>
<td>22-25m</td>
</tr>
<tr>
<td></td>
<td>57km</td>
</tr>
<tr>
<td></td>
<td>3-11m</td>
</tr>
<tr>
<td></td>
<td>18km</td>
</tr>
<tr>
<td></td>
<td>26m-34m</td>
</tr>
<tr>
<td></td>
<td>47km</td>
</tr>
<tr>
<td></td>
<td>TBA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Methods and Tools to Enable Preacting Maintenance Measures· Dirk Reinhold· Senvion GmbH · 13.-15. Oktober 2015</th>
<th>Order Book Additions (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>'06-07</td>
</tr>
</tbody>
</table>

|                         | Winner of the Renewable UK prize for Best Large Project '12 | Before schedule delivery | Contract effective | Contract effective | In Negotiation |
The operation and maintenance of offshore wind turbines is complex and challenging

- **Difficult to access**
  - Waves are high during high wind periods (when the load on the turbines is high)
  - Complex planning for Jackup Barge operations (Main component replacements)
  - Limited capacity of helicopter access

- **Time restrictions**
  - Long arrival and transfer times to or between the turbines
  - Only summer suitable for bigger blade repair or major component replacement

- **Challenging conditions**
  - Significantly higher loads then Onshore
  - Salt, Water, Lightning
  - Dynamic loads

Source: Senvion GmbH
Preactive Maintenance
Overview Offshore Maintenance strategies

Corrective maintenance
- Replace after it breaks
- Replace the component after failure
- Leads to unplanned stops
- High maintenance costs and downtime

Preventive maintenance
- Replace before it breaks
- Replace the component after a defined period of time
- Planned stops (downtime)
- Wear margin not fully used

Preactive maintenance
- Replace just before it breaks
- Failure prediction and replacement of the component just before the breakdown
- Fewer / shorter planned stops
- High availability and lower costs
Aim of proactive Maintenance

Aim:
Only preventive visit per year and as less as possible unplanned stops

Corrective Maintenance „Troubleshooting“
Preventive Maintenance
Preactive Maintenance

Number of unplanned stops
Working hours
today
Preventive Maintenance

- Usage and combination of different types of data for the estimation of the system condition
- Linking of different diagnostic and prognostic models for predicting the remaining useful lifetime
- Dynamic adjustment of maintenance intervals and reduction of reactive measures
- Prioritization of maintenance measures and automatic initiation of logistic processes
PdM with PreInO: Concept of processing engine PE-
Basic conception at the beginning

1. Framework methods and tools

3. Data’s for input, processing and output
output = classification and/or forecast

2. context sensitive time series from the past

Parameters:
- Statistic structure
- Funktional context
- Geographical Data
- etc.

Event (effecting measurements)
Selected Components
1. Structure-borne noise and vibration measurement
2. Thermography
3. Oil analysis
4. Ultrasonic
5. Visual Inspections
6. Inspection due to DIN 31051
7. SCADA monitoring
I setup matrix / one per PdM method (7 matrices)

<table>
<thead>
<tr>
<th>Component</th>
<th>Effort</th>
<th>Effect</th>
<th>Scoring</th>
<th>Quadrant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor bearing</td>
<td>Scoring 1-16</td>
<td>Scoring 1-16</td>
<td>Addition effort/addition effect</td>
<td>Placement in diagram</td>
</tr>
<tr>
<td>Gearbox</td>
<td>Scoring 1-16</td>
<td>Scoring 1-16</td>
<td>Addition effort/addition effect</td>
<td>Placement in diagram</td>
</tr>
<tr>
<td>Component 3</td>
<td>Scoring 1-16</td>
<td>Scoring 1-16</td>
<td>Addition effort/addition effect</td>
<td>Placement in diagram</td>
</tr>
<tr>
<td>Component n</td>
<td>Scoring 1-16</td>
<td>Scoring 1-16</td>
<td>Addition effort/addition effect</td>
<td>Placement in diagram</td>
</tr>
</tbody>
</table>

II setup diagramm / one per method (7 diagrams)

Quadrant II
Small effort
Big effect

Quadrant I
Big effort
Big effect

Quadrant III
Small effort
Small effect

Quadrant IV
Big effort
Small effect
Diagram: Structure-borne noise and vibration measurement
Example for Implementation
Example for preactive maintenance

- Aggregate information of the general condition of a wind turbine
  - possible deduction of maintenance priority automatically

- Question: Which is the most suitable sequence for maintaining the wind turbines?
  - Scheduling based on the knowledge about the condition of each wind turbine

- Annual maintenance scale
  - Dynamical adjustment based on information about the behavior of the wind turbine
Neural network

- Is able to learn complex relationships between input and output data and to calculate the future behavior of an output variable
- Difference between the calculated and actual temperature is used as error indicator
Conclusion and Outlook

- **Preactive Maintenance**
  - Linking of corrective and preventive maintenance
  - Usage and combination of different type of data and methods / models for diagnosis and prognosis
  - Condition based ruling and prioritization of necessary maintenance measures

- **Enabler for:**
  - Optimal planning
  - Risk reduction
  - Cost reduction
  - Availability improvements
Thank you

Senvion GmbH
Dirk Reinhold
Head of Maintenance