Wind Turbine Life Extension

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DNV GL: Organized to maximise customer value
The risks of extending turbine life

Structural failure:
Risk to life, property & the environment

DNV GL-ST-0262: Lifetime extension of wind turbines (2016)
New DNV GL Renewables Certification standard

- DNVGL-ST-0262 Lifetime extension of wind turbines
- DNVGL-SE-0263 Certification of lifetime extension of wind turbines

### Table A-1 Methods for lifetime extension assessment

<table>
<thead>
<tr>
<th>Method</th>
<th>Service</th>
<th>Main deliverables</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifetime extension inspection (LEI)</td>
<td>Lifetime extension inspection (LEI)</td>
<td>Report “Lifetime extension inspection”</td>
<td>suitability for lifetime extension</td>
</tr>
<tr>
<td>Simplified approach for lifetime extension</td>
<td>Analytical part</td>
<td>Statement of compliance “Analytical part lifetime extension, simplified approach”</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lifetime extension inspection (LEI)</td>
<td>Certificate “Lifetime extension, simplified approach”</td>
<td></td>
</tr>
<tr>
<td>Detailed approach for lifetime extension</td>
<td>Analytical part *)</td>
<td>Statement of compliance “Analytical part lifetime extension, detailed approach”</td>
<td>Proof of strength and stability</td>
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<td></td>
<td>Lifetime extension inspection (LEI)</td>
<td>Certificate “Lifetime extension, detailed approach”</td>
<td></td>
</tr>
<tr>
<td>Probabilistic approach for lifetime extension</td>
<td>Analytical part *)</td>
<td>Statement of compliance “Analytical part lifetime extension, probabilistic approach”</td>
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</tr>
<tr>
<td></td>
<td>Lifetime extension inspection (LEI)</td>
<td>Certificate “Lifetime extension, probabilistic approach”</td>
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</table>

*) Remark:
The analytical part may be performed in two steps:
Step 1: Wind turbine type specific, performed e.g. by the wind turbine manufacturer
Step 2: Wind farm site specific, performed e.g. be the wind farm operator
Wind turbine life assessment – combined knowledge

Engineering assistance to new wind energy and marine renewables technology

Key services:
- Technology evaluation
- Design load analysis
- Control system development
- Mechanical engineering design support
- Bladed software for analysis of wind turbines

Targeted inspections:
- Visual inspections, blade inspection
- Gearbox inspections, videoscope, vibrations
- Review of historical failure rate
- SCADA condition monitoring

Turbine Engineering Support (TES)
Asset & Operations Management (AOM)
Project Engineering & Development (PE & PD)
The risks of extending turbine life

**Lifecycle strategies:**
- Continued operation
- Decommissioning
- Repowering

**Continued operation:**
- Business as usual
- Retrofits
- Aero upgrades

**Operation optimization:**
- Turbine control
- Operational modifications
- Inspections & monitoring

**Costs:**
- O&M
- retrofits or modifications
- additional inspections and monitoring

**Technology:**
- availability of OEM technical support
- supply chain vulnerabilities

**Energy sale & regulatory framework:**
- terms of PPA or interconnection agreements
- permits
What is turbine life?

- **Economic** or **useful life** (considers all factors impacting project costs and revenues)

- **Structural design life** vs. **structural site life** (driven by fatigue loads, probabilistic)
Key factors driving structural site life

Typical target reliability for wind turbines:
Annual probability of failure $P_f < \sim 10^{-4}$
DNV GL’s holistic approach to assessing turbine life

**LIFETIME ASSESSMENT WORKFLOW**

- **Site conditions** (PD)
- **Numerical assessment** (PD/PE if “Level 1"
  (TES if “Level 2"
  See details on following slides
- **Review of historical operation** (PE/AOM)
- **Inspections** (AOM)

**Life management strategies** (PD/TES/AOM/PE)

- **“structural life”** probability of failure of structural components
- **failure rates of main mechanical components**

- **“useful life”** performance & O&M cost projections
In general, Level 1 serves only to form an opinion on expected lifetime. Typically used for technical due diligence high level review where available information and/or budget are limited.

"Level 1" Site Suitability Tool
Performs comparison of
  site condition parameters
  vs.
  turbine design class parameters (IEC)
  to provide a rough estimation of
  load margins
in order to confirm turbine suitability from a structural & mechanical perspective.

Possible outcomes:
1) Suitability can be confirmed with comfort;
   or
2) Confirmation subject to quality of inputs;
   or
3) Suitability cannot be confirmed.

Therefore conclusion on lifetime is limited and can only be:
1) Design lifetime (typically 20 or 25 years) is expected to be achieved or exceeded;
   or
2) Design lifetime cannot be confirmed.
Level 2 serves to provide a solid conclusion on expected lifetime.

Typically used for Technical Due Diligence of large portfolios, or for Asset Lifetime Management to enable implementation of a life extension strategy at a particular wind farm.
WIND Gemini – wind farm digital twin model

A digital twin for your wind farm by the world’s renewable expert.

- 24/7 easy access
- Reliable
- Independent
- Affordable
**WIND Gemini – wind farm digital twin model**

- Uses turbine and wind farm sensor data
- OEM agnostic
- “Near” real time
- Turbine life estimator
- Predictive maintenance
- Detection of sub-optimal performance

<table>
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<tr>
<th>Drivetrain condition monitoring</th>
<th>Use 10-minute SCADA data for measuring component health and predicting failures</th>
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<tr>
<td>Structural integrity analysis</td>
<td>Online analysis of ~1 second SCADA data for tracking tower and rotor frequency</td>
</tr>
<tr>
<td>Turbine life estimator</td>
<td>Uses operational data to model wind field / site conditions data, model loads from matrix of loads from Bladed database and quantifies uncertainty</td>
</tr>
<tr>
<td>Performance watch-dog</td>
<td>10-minute SCADA data for real time identification of under performance</td>
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</tbody>
</table>
DNV GL’s ‘Life Assessment’ track record

Level 1 analysis (high-level)
- More than 17,500 MW analysed worldwide

Level 2 analysis (detailed)
- More than 500 MW analysed worldwide

Several wind turbine models
- Vestas, Gamesa, Nordex, Enercon, among others

Thank you

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