Wind Turbines – Components and Design Basics

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ENERCON
ENERGY FOR THE WORLD
Overview
Part I

• Product range

• Components of a wind turbine

Overview
Part II

• Load assumptions for wind turbines

• Loads and load cases

• Rocking spring stiffness
Wind Turbines – Components and Design Basics

<table>
<thead>
<tr>
<th>Model</th>
<th>Rated Power</th>
<th>Hub Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>E33</td>
<td>330 kW</td>
<td>44 – 50 m</td>
</tr>
<tr>
<td>E44</td>
<td>900 kW</td>
<td>45 m / 55 m</td>
</tr>
<tr>
<td>E48</td>
<td>800 kW</td>
<td>50 – 76 m</td>
</tr>
</tbody>
</table>
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- **E53**
  - Rated power: 800 kW
  - Hub height: 73 m

- **E70**
  - Rated power: 2,300 kW
  - Hub height: 64 – 113 m

- **E82**
  - Rated power: 2,000 kW
  - Hub height: 78 – 138 m
E126

Highest power producing WEC worldwide:

- Rated power: 6.000 kW
- Rotor diameter: 127 m
- Hub height: 135 m
- Power production: 20 Mio. kWh p.a.

- Produces electricity for more than 5000 households
- 35% more yield compared to predecessor - E-112
- Two-segment rotor blade facilitates transport
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- blades

- nacelle with generator and hub

- tower (steel / concrete)

- electrical installation and grid connection

- foundation

- with piles or soil improvement (if necessary)
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-> blades
Wind Turbines – Components and Design Basics
Wind Turbines – Components and Design Basics

-> nacelle

1. Maschinenträger | Main carrier
2. Azimutmotor | Yaw motor
3. Ringgenerator | Annular generator
4. Blattadapter | Blade adapter
5. Rotornabe | Rotor hub
6. Rotorblatt | Rotor blade
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- steel tower
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- concrete tower
-> foundation
with basket
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- foundation
  with section
-> foundation for concrete tower
Overview Part I

- Product range
- Components of a wind turbine

Overview Part II

- Design situations for wind turbines
- Loads and load cases
- Rocking spring stiffness
Wind Turbines – Components and Design Basics

Design situations

Environmental conditions

• Wind, Temperature, Ice, Earthquake

Operational conditions

• Normal operation and power production
• Start up, shut down, idling, standstill

Temporary conditions

• Transportation of components
• Installation and assembling
• Maintenance and repair
Design load cases

- Normal operation and normal external conditions
- Normal operation and extreme external conditions
  - extreme wind speed
  - extreme direction change
  - extreme dynamic wind shear
- Fault situations and appropriate external conditions
  - Control system fault
  - Electrical fault
  - Yaw system fault
- Transportation, installation and maintenance situations
Load cases for operational and environmental conditions defined in EN 61400-1

<table>
<thead>
<tr>
<th>Design situation</th>
<th>DLC</th>
<th>Wind condition*</th>
<th>Other conditions</th>
<th>Type of analysis</th>
<th>Partial safety factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Power production</td>
<td>1.1</td>
<td>NTM $V_{hub} = V_i$ or $V_{out}$</td>
<td></td>
<td>U</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td>NTM $V_{in} &lt; V_{hub} &lt; V_{out}$</td>
<td></td>
<td>F</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>1.3</td>
<td>ECD $V_{hub} = V_i$</td>
<td></td>
<td>U</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>1.4</td>
<td>NWP $V_{hub} = V_i$ or $V_{out}$</td>
<td>External electrical fault</td>
<td>U</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>EOG 1 $V_{hub} = V_i$ or $V_{out}$</td>
<td>Loss of electrical connection</td>
<td>U</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>1.6</td>
<td>EOG 50 $V_{hub} = V_i$ or $V_{out}$</td>
<td></td>
<td>U</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>1.7</td>
<td>EWS $V_{hub} = V_i$ or $V_{out}$</td>
<td></td>
<td>U</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>1.8</td>
<td>EDC 50 $V_{hub} = V_i$ or $V_{out}$</td>
<td></td>
<td>U</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>1.9</td>
<td>ECG $V_{hub} = V_i$</td>
<td></td>
<td>U</td>
<td>N</td>
</tr>
<tr>
<td>2) Power production plus occurrence of fault</td>
<td>2.1</td>
<td>NWP $V_{hub} = V_i$ or $V_{out}$</td>
<td>Control system fault</td>
<td>U</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>2.2</td>
<td>NWP $V_{hub} = V_i$ or $V_{out}$</td>
<td>Protection system or preceding internal electrical fault</td>
<td>U</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>2.3</td>
<td>NTM $V_{in} &lt; V_{hub} &lt; V_{out}$</td>
<td>Control or protection</td>
<td>F</td>
<td>*</td>
</tr>
</tbody>
</table>
Due to the nature of wind the loads are high variable!

- mean wind, gravity loads (steady)
- turbulence, earthquake (stochastic)
- unbalanced mass, rotor frequency (periodic)
- start up / shut down, gusts (transient)

- Loads are calculated with special computation program in time domain.

- Load calculations have to determined for each type separately.
Different aspects for structural design

1. Extreme Loads (Ultimate Limit State)

2. Fatigue Loads (Ultimate Limit State)

3. Stiffness of components (ULS and SLS)
   - Vibrations (resonance effects)
   - Deflections (distance between blade and tower)
Vibrations - Rocking spring stiffness $k_{\phi,\text{dyn}}$

To avoid resonance we have to consider the stiffness of the components but also the soil-structure interaction. The eigenfrequency of the system *machine - tower – foundation - soil* shall not be in the range of the variable frequencies. To ensure this requirement a minimum stiffness of foundation and soil is necessary.
Important design parameter for WEC:

- Rotational frequency of rotor (1P)
- Rotational frequency of one blade (3P)
- Eigenfrequencies of the whole system (1. EF / 2. EF)

Eigenmodes of the tower structure
Merci pour votre attention