Soil-Structure Drive Train Interaction of wind turbine

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Soil-Structure Drive Train Interaction of wind turbine
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Outline

1. Motivation
2. Project scope
3. Generic wind turbine & Tool Chain
4. Investigation of the soil and the aerodynamics
5. Conclusion and Outlook
Motivation

- modern onshore wind turbines are not raising in power but in:
  - tower height (above 110m)
  - Rotor Diameter (above 120m)
Motivation

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  - tower height (above 110m)
  - Rotor diameter (above 120m)

- with a bigger rotor diameter the operating region descends from 10-16 to 5-11rpm because the maximum tip speed is fixed.
Motivation

- modern onshore wind turbines are not raising in power but in:
  - tower height (above 110m)
  - rotor diameter (above 120m)
- With a bigger rotor diameter the operating region descends from 10-16 to 5-11rpm because the maximum tip speed ratio is fixed.
- The natural frequency of the tower decreases with raising heights
- The Campbell diagram shows that the region for a so called soft tower dimension gets smaller.
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Project scope

1. design of a modern 3MW wind turbine in order to understand the design process

2. understanding the loads on the tower
   - from the rotor aerodynamics
   - from the wind on the tower with the blade shadow

3. analysing the influence of different soils and foundation types
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Onshore Wind Turbine Modell – 3MW with 126m rotor diameter

- 3MW wind turbine for low wind speeds according to wind turbine category III with a turbulence intensity of A
- The rotor diameter was set to 126m (comparable to the NREL 5MW/61.5 wind turbine)

### Technical data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>rotor diameter</td>
<td>126 m</td>
</tr>
<tr>
<td>tower height</td>
<td>115 m</td>
</tr>
<tr>
<td>mass of the nacelle with the blades</td>
<td>200 t</td>
</tr>
<tr>
<td>nominal rpm</td>
<td>11 rpm</td>
</tr>
<tr>
<td>nominal power</td>
<td>3 MW</td>
</tr>
<tr>
<td>( i_{\text{gearbox}} )</td>
<td>~91</td>
</tr>
<tr>
<td>( \text{Cut}_{\text{in}} )</td>
<td>3 m/s</td>
</tr>
<tr>
<td>( \text{Cut}_{\text{out}} )</td>
<td>25 m/s</td>
</tr>
<tr>
<td>rated wind speed</td>
<td>11 m/s</td>
</tr>
<tr>
<td>maximum tip speed</td>
<td>72.5 m/s</td>
</tr>
</tbody>
</table>
Calculation tool chain

- complete load calculation process with post processing in order to quantify different influences
- using AERODYN v.13 for the aerodynamic loads
- using SIMPACK as multibody simulation
- controller and electric system are modelled in MATLAB/SIMULINK

Pre Processing

Defining the boundary conditions

<table>
<thead>
<tr>
<th>DLC</th>
<th>Operational Conditions</th>
<th>Wind type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Power Production</td>
<td>NTM</td>
</tr>
<tr>
<td>1.3</td>
<td></td>
<td>ETM</td>
</tr>
</tbody>
</table>

Generating Wind files

- TurbSim
- Matlab

Generating a Calculation-Matrix

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</table>

Calculation with Simpack

Aerodynamic system
Mechanical system
Electrical system

WT Controller

Post Processing

With Matlab
- Rainflow
- LDD
- DEL

- Calculation done according to IEC 61400-1 (~2000 load cases)
- with a simple model one load case takes 10 min with turbulent wind speed

Variability in Model def.
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Aerodynamics on the tower

- The aerodynamic load calculation calculates load on the blade and the effect of the tower on the blade aerodynamics but not the load on the tower.

- For the design of the tower this is in a first case not relevant but for a dynamic simulation it is if one is interested in the tower oscillation.

- In order to implement and calculate the force on the tower the first calculations are done with CFD in order to see the effect.

First results show that the aerodynamic thrust on the tower is up to 12,5% of the thrust of the rotor.
Influence of the Soil

- Definition of the soil with two different layers
- Characterizing the soil with the shear module from a soft soil from 50MN/m² up to a stiff one with 500MN/m²
- The soil stiffness is calculated with an analytic model
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Conclusion & Outlook

- The soil has a significant influence on the tower frequency, it can change the first bending frequency up to 17%.

- The aerodynamic load on the tower is up to 15% of the thrust force with a 3p periodicity.

- The stiffness of the soil will be calculated with a FEM boundary layer method in order to get better results for higher shear modules.

- The aerodynamic load on the tower will further be analysed in the CFD and compared with wind tunnel test in order to implement an analytic approach into the multibody simulation.
Thank you for your attention.