Wave and Wind Load on Offshore Wind Turbines

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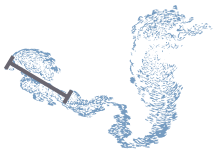
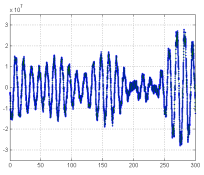


Motivation

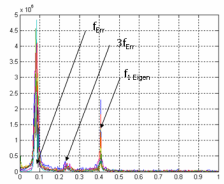
Offshore wind turbines represent very slender and flexible structures. The dynamic structural behaviour has significant influence on the design. Mainly offshore wind turbines are dynamically loaded by sea state and wind, as there is high short-duration loading due to extreme waves and strong-wind gusts as well as long-term loading due to sea state and wind.
In order to describe the different exposures acting on an offshore wind turbine appropriate numerical models are developed.

Sea state loading

- stochastic sea state from sea state spectra
- application of wave theories
- transfer function sea state - force : Morison's equation



bottom moment (time)



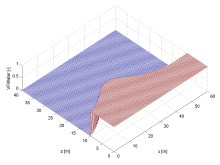
bottom moment (frequency)

Wave shape for extreme wave

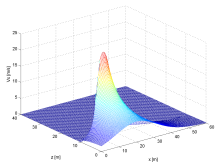
- modeling the wave as potential flow with free surface evolution
- numerical solution of the pde-system (boundary element method, BEM)

$$\alpha(\mathbf{x}_c)\Phi(\mathbf{x}_c) = \int_\Gamma \left[\frac{\partial \Phi(\mathbf{x})}{\partial n} G(\mathbf{x}, \mathbf{x}_c) - \Phi(\mathbf{x}) \frac{\partial G(\mathbf{x}, \mathbf{x}_c)}{\partial n} \right] d\Gamma$$

- explicit time integration scheme



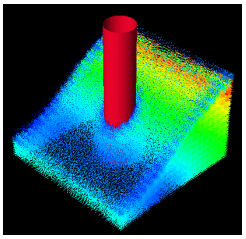
wave shape



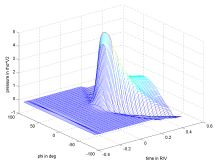
horizontal velocity field

Pressure impact

- high, short-duration load
- two-phase-flow (air-water mixture)
- Navier-Stokes flow with free surface (phase interface)
- discretization: Finite-Volume - Volume-of-Fluid model



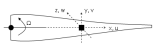
wave around tower



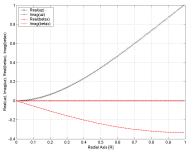
temporal pressure evolution

Structural dynamics

- translatory substructure (tower)
- rotating substructure (rotor system)
- due to rotation stiffening of the system and gyroscopic damping
- coupled eigenforms for rotor system (transverse deflection, torsion)



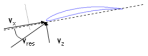
rotating rotor blade



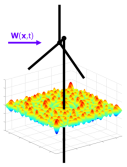
coupled eigenforms

Aerodynamics

- transient wind field
- blade element theory (rotor blades)
- hysteresis effects (circulation, dynamic stall)



incident flow on rotor blade



global structure