Wind Turbine Loading
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Måltidets Hus,
Ullandhaug,
Stavanger
Basic loading mechanisms

- Wind
- Aerodynamics
- Gravity/Inertia
- Waves
- Wakes
- Fault situations
- (Earth quakes)

Loads without turbulence, 10m/s 5MW

Mflap

Medge

Mtorsion
Structural modes of 3-bladed turbines during operation

1st fore-aft twr 1st side-side twr 1st BW flap 1 sym. flap

1st FW flap 1st BW edge 1st FW edge 1st drivetrain

DTU Wind Energy, Technical University of Denmark

Courtesy M. H. Hansen, DTU Wind Energy, 2015
How low frequent turbulence causes high frequent excitation

Effect of rotational sampling for a 3B turbine

The turbulence level affects all frequencies and is the single most important environmental parameter regarding wind turbine loads!
Natural variation of atmospheric conditions

- Eg. variations in the wind shear
Shear effects on loads at 12m/s
5MW ref. Turbine, class A turbulence

Shears can have a significant impact on blade loads, whereas other load components are less affected

Importance of Veer

Høvsøre
Veer effects on loads at 12m/s
5MW ref. Turbine, class A turbulence

Veer seem to have limited impact on the load level.

What about wake effects?

- Wind farms loads and production
- Wake modelling
- Optimization of layout, turbine design and control (WT + WF)
- Load maps for Operation & Maintenance
Principle of Dynamic Wake Meandering

The wake is superpositioned on the ambient turbulence
Wake modelling – important for loads and power

Lidar measurement of the wake and the DWM predicted wake center position

LES CFD

DWM
Results from Egmond aan Zee

This difference could to some extent be explained by the stable weather conditions above 10m/s, not accounted for

Results from Lillgrund
3-7D spacing, single and multiple wake situations

Wake effects may cause significantly increased loads at high wind speeds, even though a single wind turbine here is “aerodynamic transparent”

Horns Rev 1 Offshore Wind Farm

Wind direction Probability

Wind Farm Layout

Assuming 100% availability for all WTs

1) Which WTs suffer the highest fatigue damage?
2) Which WT produces the most energy during a year?
Blade Root Lifetime Fatigue Damage

Wind direction
Probability

- WTs at column 10 experience the highest blade fatigue damage

Mapping Wind Farm Load and Power Production – A Case Study on Horns Rev 1
Christos Galinos, Nikolay Dimitrov, Torben J Larsen1, Anand Natarajan and Kurt S Hansen
Preliminary results – To be finally presented at Torque from Wind, 2016
WT 60+68 suffers the largest tower damage

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Annual Energy Production

WT number 8 produces the most energy, 97% compared to a stand alone (no wake effects) WT

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Different concepts