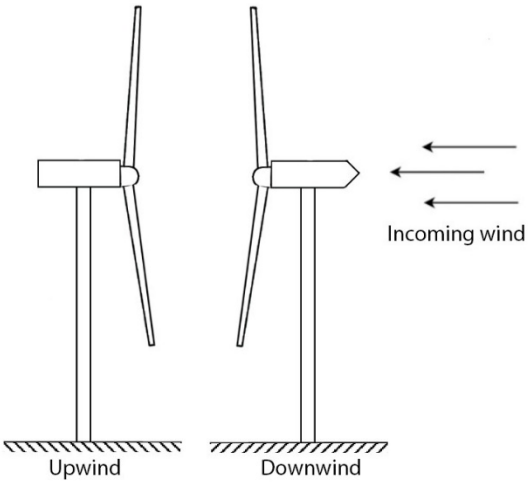
TU Delft

Offshore & Dredging Engineering

Technische Universiteit Delft

The dynamic response of a wind turbine blade to downwind tower shadow

The quest for affordable renewable energy causes the need for bigger and more efficient wind turbines. To counter the problem of possible collisions between the growing turbine blades and the tower support structure, downwind turbines might be a solution. For this configuration blade flexibility no longer forms a problem and besides that passive yaw systems can be applied. However, the fatigue lifetime of the turbine components might significantly decrease due to tower shadow effects.



This thesis aims to decrease the uncertainty in the difference between downwind turbines and the conventional upwind turbines. An aeroelastic blade model is constructed using a finite element model of the NREL 5MW turbine blade. This model is subsequently converted to a downwind model including a wake behind the tower structure that temporarily slows down the inflowing wind on the blade when the blade is in the tower shadow area. This wake description follows from a literature review and should be valid for the flow conditions around the turbine. History dependency of the aerodynamic forces on the blades is included in the model using the Küssner function.

A comparison in tower wake effects is done using simulations of upwind and downwind turbine blades which result in the blade motions caused by the tower shadow disturbance. From these motions also the root moments are deduced over time as well as the angle of attack variations for the different blade elements. A comparison with other software confirms the order of magnitude of the blade position in equilibrium and a check for dynamic stall issues is done to show the possible influence on the blade lift after the tower shadow disturbance. The root moment variations are used as a fatigue indicator using rainflow analysis.

Concluding from this, wind velocities near cut-out speed for downwind turbines cause the biggest wake effects. The static blade deflections and root moments are highest for rated wind speed at upwind turbines. Compared to upwind turbines, the downwind turbines are prone to higher wake effects and therefore increased fatigue damage. The overturning root moment and flapwise deflection variations for downwind turbine blade have shown to be up to 88 % and 100 % higher compared to those for upwind turbines respectively.

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