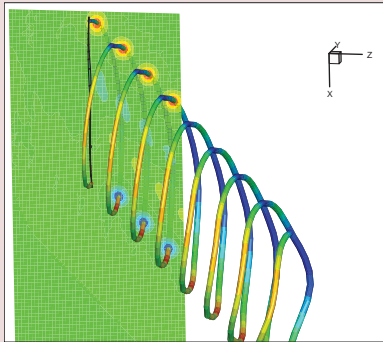


Development of a Prescribed Wake Model for Simulation of Wind Turbines

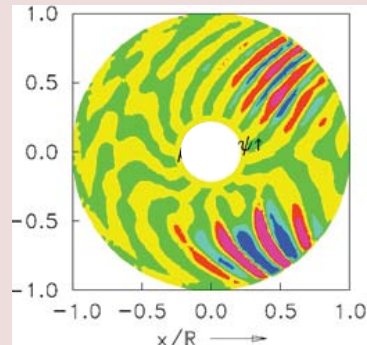
Goal: Develop a Fast and Accurate Simulation Tool

Why: Blade-Element-Momentum Theory (BEMT) not well suited for certain load cases (s. below) and high fidelity approaches e.g CFD or free-wake are very time-consuming

Yawed flow



Blade-Vortex Interaction



Prescribed wake model derived from free-wake model

Vortex Methods are well suited to represent all kind of aerodynamic simulation scenarios. Prescribed wake models offer an appealing trade-off between accurate modelling and acceptable low computing time. The here presented model is derived from data extracted from free wake calculations. The basic procedure is to conduct free-wake simulation with varying rotor thrust, rotational and wind speed in order to reproduce several operational conditions. The resulting rotor wake is analysed and further processed. This procedure results in a set of analytical functions, which describes the rotor wake by means of cylindrical coordinates, dependent on the wake age Ψ_v and the above mentioned parameters: thrust T , yaw angle γ , rotational ω and wind speed v .

$$r_v = a_2 \Psi_v^2 + a_1 \Psi_v + a_0 \quad z_v = b_1 \Psi_v + b_0 \quad a_x, b_x (T, \gamma, \omega, v)$$

Tower influence on the rotor wake

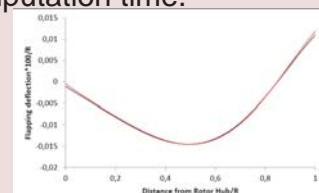
The tower has an influence on the rotor wake for upwind turbines too, since the vortices cannot just pass through the tower and are deflected. This effect is approached in the model through integrating the induced velocities of the tower along the respective vortex trajectory ds between separation point x_0 and the relevant point in space x_v :

$$\Delta x_v = \int_{x_0}^{x_v} v_{i,T} ds \quad (\text{induced velocity derived from standard model based on potential theory})$$

Results

Focus on the accuracy of the new prescribed wake model and its computation time.

Results from free-wake calculations (black) are compared to those of the prescribed-wake model (red). (Here: Flap deflection for constant, yawed inflow). Deviations are negligible in the investigated load case. At the same time, computation time decreases significantly.



	BEMT	Prescribed Wake	Free-Wake
CPU-TIME/BEMT	1	208	24700

Outlook

Validity of the model has to be proven in further investigations, in particular in unsteady conditions. Additionally, the prescribed wake model can be extended to conduct research within the field of wake-turbine interactions in wind farms.