Experimental Investigations of Wind Turbine Wake Towards Offshore Wind Farm Performance Validation

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Motivation
- Laboratory scale representation of atmospheric turbulence and wake generated by Wind Farm
- Near wake investigation exposed to different turbulence contents
- Validation of the offshore wind-farm model performance based on experimental results
- Observation of fluid flow phenomena inside Wind farm due to wake generated turbulence

Approach

Experimental Setup
- Tests are conducted in the closed loop wind-tunnel of LSTM, FAU Erlangen
- The wind turbine is exposed to turbulent flow of different scale
- Turbulence and velocity profile of wind flow are measured by Hot-wire and Pitot-tube, respectively

Grid Generated Turbulence
- The turbulence level increases with the installation of the fine grid at the entrance of the test section
- The same effect, but in a higher level of turbulent intensity, is depicted when using the coarse grid
- The turbulence scale decays in the flow direction

Result & Discussion

Axial Velocity distribution of near wake

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Turbulence Intensity and Energy Spectrum
- Axial Velocity Profile shows tip-vortex, mixing and velocity restoration
- The highest turbulent intensity is observed at x/D=0.3 or 0.7 near wake
- Wake mixing and Tip Vortex Phenomena are shown by analyzing the spectra E(f)
- E(f) distributions show suppression of tip vortex at higher turbulence
- Flow characteristics are different according to blade radial position

Offshore Wind Farm Data and Model

Power & Velocity output order wake inside Middelgrunden Offshore Wind Farm [1]
- Added Turbulence Intensity versus turbine position by different model and wind farm measurements [2]

Conclusion
- TI from 0.07 to 0.114 and E(f) distribution of generated turbulent flow to mimic offshore wind farm atmosphere are generated in laboratory scale
- High turbulence content of oncoming wind increased wake-surrounding interaction with more energy entrainment to the wake regime as higher turbulence can penetrate through turbine rotor plane
- Higher turbulent flow brings different scales and hence more mixing in the near-wake regime with causing faster wake recovery
- Wake recovery part of axial velocity profiles were in same context of TI described by offshore wind farm models
- Experimental results describe TI distribution, tip vortex and flow mixing at near wake (up to x=1.7D)

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