Wind Turbine Aerodynamics - Current Challenges & Future Opportunities

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Friday, September 18, 2015 12:00 P.M.

2005 Mechanical Engineering Lab (Deere)

Abstract
Wind Energy continues its growing impact on the global electricity market as a viable source of renewable energy. In recent years, fundamental research in the aerodynamics of wind turbine blades has gained renewed interest due to a number of challenges associated with the limited capability of state-of-the-art computational modeling techniques in predicting time-varying loads on wind turbine blades. This seminar addresses current challenges in computational modeling of wind turbine aerodynamics at various fidelity levels and across disparate scales, ranging from the blade chord to the mesoscale. Sectional blade aerodynamic effects such as inboard stall delay and blade tip modeling are addressed in the context of Blade-Element Momentum Theory (BEMT) and the Actuator Line Method (ALM) within the OpenFOAM framework. The blade aerodynamics are altered due to atmospheric effects such as icing events and wake interactions in wind farms. The results of selected scaled ice accretion experiments and subsequent wind-tunnel analyses are presented with some suggestions for turbine controls during atmospheric icing conditions. Furthermore, the ALM is used as a turbine model in a Large Eddy Simulation (LES) of the atmospheric boundary layer (ABL) to investigate the effect of the ABL stability state on the recovery process of the wake momentum deficit downstream of wind turbines. Differences between ALM modeling approaches are highlighted. Additional quantitative analyses include distributions of Reynolds stresses and turbulent kinetic energy (TKE) along vertical and horizontal lines. Complete flux integrals along wake planes reveal some new insight into the recovery process as a result of different behavior above/below turbine hub height. In addition, state-of-the-art flow visualization of high-resolution LES data shows sudden vortex breakdown as a result of coincident ABL low-speed streaks and updrafts in an unstable atmosphere. The seminar concludes with a summary of future research needs and opportunities.

About the Speaker
Dr. Sven Schmitz joined the faculty of Aerospace Engineering at Penn State University in 2010. He received a diploma degree in Aerospace Engineering from RWTH Aachen (Germany) in 2002 and a Ph.D. in Mechanical and Aeronautical Engineering from the University of California, Davis in 2006. Dr. Schmitz spent four years as a post-doctoral researcher and project scientist at Davis before coming to Penn State. He is an expert in rotary wing aerodynamics with an emphasis on vortical flows. His growing research program embraces the areas of wind turbine aerodynamics and rotorcraft aeromechanics. Current activities include wind farm wake modeling, icing on wind turbines, helicopter rotor hub flows, and rotor active control.

Host: Professor Leo Chamorro