The Department of Mechanical Engineering / College of Engineering and Applied Sciences
Stony Brook University

Mechanical Engineering Seminar
Faculty Candidate

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High-fidelity Simulation of Wind Turbines and Flow Control

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Abstract

Energy prices, supply uncertainties, and environmental concerns are driving many nations to rethink its energy mix and develop diverse solutions to clean alternative energy. In particular, wind power is poised to deliver a significant contribution to the renewable energy portfolio. Current industrial wind plant design and analysis rely on primitive models to calculate the power output and structural loads. These models neglect some of the critical physics such as turbine wake meandering and the effect of atmospheric stability on wake turbulence. As the wind industry shifts from the traditional single turbine analysis to that of a multi-turbine approach where these physics become more important, new tools that fully capture the turbine wake interactions within wind farms and accurately predicting the associated mechanical loads have become necessary. In this work, a set of large-eddy simulations of atmospheric boundary layer flow under various stability and surface roughness conditions were performed to investigate their impact on wind turbines. In particular, the aeroelastic responses of the turbines were studied to characterize the fatigue loads due to the turbulence present in the boundary layer and in the wake of the turbines. The surface roughness was found to increase the fatigue loads while the atmospheric instability had a small influence. In addition, the downstream turbines yielded higher fatigue indicating that the turbulent wakes generated from the upstream turbines had significant impact. These studies were further investigated for a full wind farm consisting of 48 multi-megawatt turbines. Using one million processor-hours, the average power production from the simulation agreed well with field observations. Merging wakes are typical phenomena in wind farm flows in which neighboring turbine wakes consolidate to form complex flow patterns that are as yet not well understood. The wake from the farthest upstream turbine conjoined the downstream wake, which significantly altered the subsequent velocity deficit structures, turbulence intensity, and the global meandering behavior. The complexity increased even more when the combined wakes from the two upstream turbines mixed with the wake generated by the third turbine, thereby forming a “triplet” structure. Although the influence of the wake generated by the first turbine decayed with downstream distance, the mutated wakes from the second turbine continued to influence the downstream wake. In general, turbine wakes persist for extended distances especially for offshore conditions. Novel control strategies to mitigate the deleterious effect caused by the upstream wakes will be presented in this talk.

Biography

Dr. Sang Lee received his B.S. in Mechanical Engineering from Yonsei University in Seoul, Korea. He received his M.S. in Mechanical Engineering from Stanford University and earned his Ph.D. in Aerospace Engineering from University of Illinois at Urbana Champaign. He is currently a research engineer at the National Renewable Energy Laboratory where he received the Laboratory Director’s award. He has published 17 journal papers and 18 conference papers. His main research interests include turbulence, high speed flow control, wind-wave energy and energy storage.

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