SAND2013-8968P

Unlimited Release

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

Project Accomplishment Summary

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Sandia National Laboratories
Operated for the U.S. Department of Energy by
Sandia Corporation
Albuquerque, New Mexico

PROJECT ACCOMPLISHMENTS SUMMARY

Cooperative Research and Development Agreement (#1789.01)

between **Sandia National Labs** and **General Electric**

Note: This Project Accomplishments Summary will serve to meet the requirements for a final abstract and final report as specified in Article XI of the CRADA.

Title: High-Fidelity Models for Wind Turbine Blade Noise

Final Abstract:

Researchers from General Electric Global Research (GEGRC) and Sandia National Laboratories (SNL) collaborated on a project to advance the state-of-the-art in wind turbine blade noise prediction methods. A high-fidelity Large Eddy Simulation (LES) code, which was developed with support from GEGRC at Stanford University, was used to predict the detailed fluid dynamic phenomena and resulting noise for a wind turbine blade airfoil. This code was run on SNL s Red Mesa high-performance computer. The resulting flow-field predictions were used towards a critical assessment of current practice in engineering design models of trailing edge noise on wind turbine blades. Assumptions and parameters in the engineering models that most impact the resulting noise predictions were identified, and the high-fidelity results were used to assess the reliability and accuracy of these model choices. The LES results were also used to identify pathways for further improvement of engineering models for blade noise, which will ultimately lead to opportunities for design of new, low-noise wind turbine blades.

Background:

Aerodynamic blade noise continues to be the dominant noise source on modern, utility-scale wind turbines. This noise source functions as a key design constraint in wind turbine design, such that reduction of the noise leads to significant decreases in cost-of-energy for wind energy. The purpose of this project was to leverage the collective resources at General Electric Global Research (GEGRC) and Sandia National Laboratories (SNL) in the areas of wind turbine aero-acoustic modeling and high-performance computing (HPC) to advance the state-of-the-art in wind turbine blade noise prediction methods. GEGRC had previously developed high-fidelity computational fluid dynamics (CFD) models for wind turbine blade noise in collaboration with researchers in the Aeronautics and Astronautics Department at Stanford University. A fundamental research question with significant potential impact on wind turbine blade design was whether the high-fidelity models could be used to assess and improve engineering design models for wind turbine blade noise. This became the focus of the present collaborative effort between GEGRC and SNL, with the idea that the CFD tools could be fully exercised on SNL's HPC platforms. The resulting simulations, along with application of the research team's collective expertise in wind turbine blade noise modeling, would lay the groundwork for improved noise design models.

Description:

The project centered around two technical objectives: (i) Evaluate existing methods for predicting wind turbine blade noise and identify required improvements; and (ii) Identify and evaluate the use of high-fidelity Large Eddy Simulation tools in predicting blade noise and improving engineering noise models. To meet these objectives in the most cost-effective manner, the project was structured around a PhD student internship. SNL hosted a PhD student that had been previously supported by GEGRC to develop the high-fidelity blade noise models. This student worked closely with SNL staff in the Wind Energy Technologies Department to perform Large Eddy Simulations (LES) on Sandia's Red Mesa supercomputer, to perform a literature survey of current state-of-the-art in wind turbine blade noise modeling, and to use the simulation results to assess the state-of-the-art.

The successful internship took place from late July 2012 until late September 2012. During this time, LES simulations of the turbulent flow past a blade section were continuously performed on the Red Mesa HPC system, providing valuable data for the project. These simulations were performed using heretofore untested "natural boundary layer transition" conditions, whereas previous simulations using the Stanford code had used "fixed boundary layer transition" conditions. Thus, aside from meeting the stated technical objectives, the project also enabled progress within the existing GEGRC/Stanford high-fidelity noise tool project.

The results of this collaborative research have been documented in a technical report titled "Assessment of Modeling Assumptions Involved in Engineering Predictions of Trailing Edge Noise." A large portion of the report is devoted to the results from the critical literature review of trailing edge noise models. A key conclusion from this review is that the correct modeling of the wall pressure spectrum for the turbulent trailing edge boundary layer is the Achilles heel of currently used engineering models for trailing edge noise. The three most important model features that noise predictions are most sensitive to were identified as: the assumed eddy convection speed in the trailing edge boundary layer, the assumptions involved in estimation of the wall-normal turbulence intensity profile, and the value of mixing length used in modeling the wall-normal turbulence. The LES simulation results were used to evaluate some of the assumptions and model parameter choices used in the engineering models. In particular, it was found that assumptions used in estimating eddy convection speed can be incorrect when applied to an airfoil boundary layer with significant adverse pressure gradient. Techniques for evaluating other assumptions using the LES results were suggested for future research efforts.

Benefits to the Department of Energy:

This collaboration has led to enhanced understanding of both high-fidelity and design models of wind turbine blade noise. This enhanced knowledge will lead to improvements in ongoing Sandia research in blade aerodynamics and aero-acoustics sponsored by the DoE Wind Energy Program within EERE.

Economic Impact:

In this CRADA, GE and Sandia explored the use of high-fidelity simulations to assess engineering noise models routinely used in wind turbine design. Aerodynamic noise is a key barrier to enhancing energy yield from wind turbines. Noise presently limits the blade tip velocity and hence the wind energy that the turbine can harness. A 1dBA quieter rotor design enables a 2% increase in annual energy yield from each turbine. With today s US installation of over 45 GW of wind turbine power, this would translate to a significant reduction in greenhouse (CO_2) emissions.

Project Status:

The project has been successfully completed and the results have been documented in the technical report titled "Assessment of Modeling Assumptions Involved in Engineering Predictions of Trailing Edge Noise."

ADDITIONAL INFORMATION

Laboratory/Department of Energy Facility Point of Contact for Information on Project

Matthew Barone
Sandia National Laboratories
505-284-8686
mbarone@sandia.gov

Company Size and Points of Contact

Industrial partner: General Electric Company
Company's annual sales: $147.359 billion
Number of Employees: 323,000

Company personnel responsible for the project:
Giridhar Jothiprasad
Telephone: 518-387-4319
Fax: 518-387-4924

Company personnel willing to provide feedback:
Mark Jonkhof
Wind Technology Platform Leader, GE-Global Research
Telephone: 518-387-5269

CRADA Intellectual Property

None

Technology Commercialization

None

Project Examples

A flow visualization image has been created from the high-fidelity simulations performed at SNL.

PROJECT ACCOMPLISHMENTS SUMMARY
Cooperative Research and Development Agreement (SC12/01789.01)
between **Sandia National Laboratories** and **General Electric Company**

This summary has been approved for public release by Sandia and General Electric Company

Sandia National Laboratories

By ____________________   4·18·13
Matthew Barone   Date
Principal Investigator

Sandia National Laboratories

By ____________________   4·15·13
Manager   Date
WFO/CRADA Agreements

General Electric Company

By ____________________   7/12/2013
Title: Bo Li   Date

In order to expedite the process, if we do not receive your signed reply by 07/27/2013 we will assume your concurrence for the release of this document to the public.