Sandia National Laboratories

Energy, Climate, & Infrastructure Security

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High-Performance Computing to Support Wind Energy Development

Vision

To enhance the nation's security and prosperity through sustainable, transformative approaches to our most challenging energy, climate, and infrastructure problems.

Sandia National Laboratories hosts many DOE EERE research efforts to improve the efficiency, energy density, reliability, and durability of wind energy systems. Researchers leverage DOE-funded Sandia high-performance computing (HPC) assets, built to support national defense research activities, to accelerate wind energy innovation and provide greater insight into design and manufacturing processes. This research seeks to improve design efficiency and help industry develop cost-effective, reliable products.

HPC has broad applications for wind research and development from turbine design, to single-turbine and wind plant performance modeling, to wind forecasting and meso-scale weather modeling. By using DOE-funded HPC capacity, national laboratory researchers can provide the wind industry the data they need to make informed decisions to solve critical wind-energy design issues, while remaining cost effective. Sandia also maintains strong partnerships with several academic institutions, which affords them access to large-scale HPC assets, which they might not otherwise have.

Simulating the Load History of Wind Turbines On and Offshore

Challenge

Wind turbines must be designed to operate reliably over a twenty year life. However, until recently, no one had directly simulated a wind turbine's lifetime load history. Turbine manufacturers were forced to maintain relatively large safety factors due to uncertainty concerning the actual loads a turbine experiences—due to the limited data available. Sandia had the wind technology and HPC expertise to develop the methods to attack the problem—to the benefit of the entire wind industry.

In the offshore environment, the

Wind-farm operators and investors must be able to accurately estimate a turbine's lifetime load history. Our HPC simulations provide this data in the context of the turbine's interactions with other turbines and the appropriate environmental conditions in a wind-farm setting.

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total space of possible wind/wave conditions at a given site is enormous. Because of this, wind turbine design standards define a relatively small simulation set to be performed in an attempt to envelope the possible loads that will be encountered in a wind turbine's lifetime—the resulting extreme load estimates are uncertain.

Approach

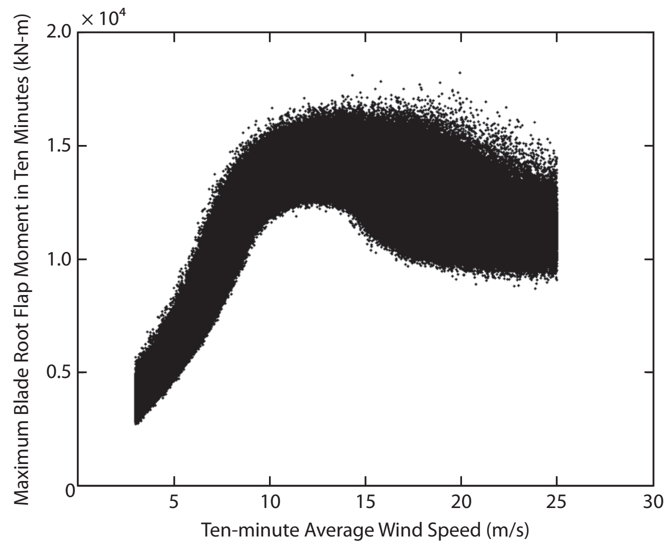
In order to learn more about the behavior of wind turbines under a variety of conditions, Sandia performed 5,020,189 simulations of an onshore turbine: 10-minute operation blocks of a turbine under different wind conditions while operating in a turbulent wind field (i.e., the conditions found in a wind farm) in six batches using DAKOTA (a computational framework that enables large-scale simulation studies, developed at Sandia) and FAST (a National Renewable Energy Laboratory code used to model the structural dynamics of a wind turbine). The simulation used 1,028 Red Sky cores and lasted over 4.5 days of real time. The effort simulated a turbine's load history over a period of approximately 96 years. This long simulation period allows analysts to directly quantify infrequent wind-turbine load events currently specified in the design standards, such as the one-in-fifty-year load.

Going forward, the design of offshore wind turbines is a key R&D element of the DOE's national wind energy strategy. As a part of this effort, Sandia also investigated an offshore turbine's load history. Researchers performed 552,809 one-hour aero-hydro-elastic load simulations (approximately 63 years of simulated time) for a 5 MW wind turbine deployed in shallow water using NREL's inflow turbulence code TurbSim and FAST on 1,024 Red Sky cores in a little under five days of real time.

Impact

As a result of these HPC efforts, researchers will soon have large databases of on- and off-shore turbine load histories—giving the wind community the ability to validate turbine load-prediction techniques. These results will enable improved turbine and turbine control-system designs to mitigate issues the simulations revealed. The wind community also will soon have a large database of extreme loads that can be applied to offshore turbine designs and can also be used to evaluate load-extrapolation methods. Sandia is already participating in the International Electrotechnical Commission's (IEC's) efforts to improve turbine design standards. This international governing body establishes wind turbine design codes and standards and is in the process of developing new codes based on the latest knowledge provided by science, engineering, and simulation.

The data provided by these unique HPC studies will improve these standards by reducing design load uncertainties, leading to more cost-effective and reliable industry turbine designs in the future.



This scatter plot shows the maximum bending load on a wind turbine blade for each of more than five million simulations, plotted against the average wind speed over the duration of each simulation. This information allows designers to understand the most important wind conditions driving the design of different wind-turbine components.

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