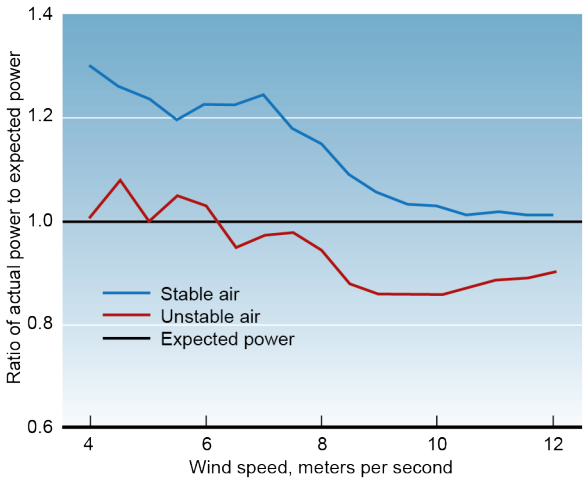
Extracting More Power from the Wind

Forecasting the Availability of a Renewable Resource

Wind power use in the U.S.—and worldwide—is expanding rapidly. In 2010 and 2011, nearly 15,000 megawatts of wind turbines were installed in the United States. Over the course of a year, wind power in the United States generates enough electricity to power over 20 million homes. The Department of Energy calculates that wind power could be 10 times larger in the future, potentially providing 20 percent of total U.S. electricity needs by 2030, up from about just over 2 percent in 2010.



Results from the Livermore wind study show that more power is produced than expected during stable atmospheric conditions (low turbulence) and less power is produced than expected during unstable atmospheric conditions (high turbulence) over a wind speed range of 4 to 12 meters per second.

However, significant expansion of wind power production cannot be met simply by installing a massive number of turbines. Delivering wind power at a competitive price requires that turbines are located where atmospheric flows will produce the most power over time, not necessarily where the wind is fastest. This balancing act demands an understanding of the atmosphere across a broad range of spatial and temporal scales. Only supercomputers are capable of combining this range of scales, which are required to solve coupled, nonlinear problems.

Livermore researchers used meteorological observations and wind farm data in conjunction with high-performance computing to help industry partners understand the connections between the atmosphere, wind power, and the electrical grid. This technical approach—joining meteorologists, engineers, and computer scientists—makes it possible to address a problem of this complexity, where relatively small-scale turbulence features can significantly shift power generation.

The Livermore team has collected data at wind farms from both North America and Europe, and have employed state-of-the-art meteorological instrumentation to measure atmospheric parameters not typically observed at wind farms. Analysis of these data have resulted in new insights into wind farm performance. For instance, it was found that for certain locations, in unstable atmospheric conditions (high turbulence) turbines generated less power than expected, while in stable conditions (low turbulence) they generated more. The Livermore team also observed that the actual power generated by a turbine can vary by 20% or more from the manufacturer's predicted performance. These findings help wind farm operators better predict the amount of power they will actually supply to the grid over the range of meteorological conditions experienced at particular site locations.

LLNL's technical expertise in data analysis and application of high-performance computing led Siemens Energy, Inc., to sign a Cooperative Research and Development Agreement with the Laboratory to develop high-resolution atmospheric forecasting and simulation tools to improve their wind farm operations.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory is operated by Lawrence Livermore National Security, LLC, for the U.S. Department of Energy, National Nuclear Security Administration under Contract DE-AC52-07NA27344.