Capability

Intelligent Wind Turbine Program

Applications:

- Wind turbine and blade design optimization
- Energy production enhancement

Benefits:

- Understand how dynamic forces affect turbine structures
- Predict, detect and manage growth of blade and turbine defects
- Minimize turbine damage in the field while maintaining energy production

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Summary:

As the wind energy industry works to provide the infrastructure necessary for wind turbine reliability, expectations for performance and design criteria continue to escalate as the world community develops a means to augment power production with wind-derived energy. Turbines have become massive and are likely to grow as technology advances, further straining the limits of current design standards. As a result, modern wind turbines, having a design lifespan of 20 years, they typically fail 2.6 times per year during the first 10 years and average 3.9 unplanned maintenance incidents per year. The industry struggles to understand the causes of these premature failures and is currently unable to predict, detect the onset, or manage growth of defects.

Wind-turbine reliability issues, e.g., defect prediction/containment, design optimization, and performance enhancement in the field are believed to result from poorly understood turbulent and unsteady wind factors. Specifically, LANL researchers are concerned about complex and dynamic blade loading resulting from the interaction of the blade with unbalanced wind forces under conditions of strong shear. These potentially damaging loads are in turn transmitted to the turbine hub and gearbox, eventually leading to compromised rotor integrity and failure. Such dynamic, turbulent wind interactions need to be measured, modeled, anticipated, and managed in order to bring down the costs of wind-turbine power-producing operations. Therefore, it is paramount that a capability be developed that monitors and understands how blades interact with atmospheric wind conditions as the blades are the physical mechanisms by which loads are transmitted to the turbine hub, gearbox, and generator.

Currently, there are no methods for modeling the interaction between landscape wind events and spinning wind turbines. There are no tools for modeling two-way interactions between realistic wind fields, deforming blades, and the resulting stresses imparted on the blades and hub. In addition, there has been minimal research in developing techniques for real-time monitoring and control of turbines under realistic wind-loading conditions.

LANL researchers are using extensive Laboratory resources by integrating experiments, simulations and modeling capabilities with the ultimate goal of providing solutions to these pressing issues. In particular, LANL's expertise in the areas of predictive modeling and simulation (see HIGRAD/WindBlade), advanced sensing technologies (see Wind Turbine Structural Health Monitoring), and prognostic decision making linked to active performance enhancement and damage control (see Wind Turbine System State Awareness) will be leveraged to create intelligent models for predictive control of wind-farm operations.

Status: A unique LANL research team composed of world experts in structural health monitoring, modeling and simulation, and prognostic decision making is well underway in this research effort. The intelligent wind-turbine project has resulted in a number of U.S. Patent Applications and copyrighted software.

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