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WAKE MEASUREMENT SYSTEM

2014 Wind Peer Review

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U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy | WIND AND WATER POWER PROGRAM

1. INTRODUCTION

Wind turbine wake formation and evolution is not sufficiently well understood, leading to uncertainty in wind plant performance including power production and loads. Novel flow measurement instrumentation is needed to provide field data to enable validation of improved research codes and design tools used to optimize wind plant performance. The primary objective of this project is to develop and demonstrate a measurement system capable of imaging the near-wake velocity profile of a turbine at the Sandia Scaled Wind Farm Test (SWiFT) facility.

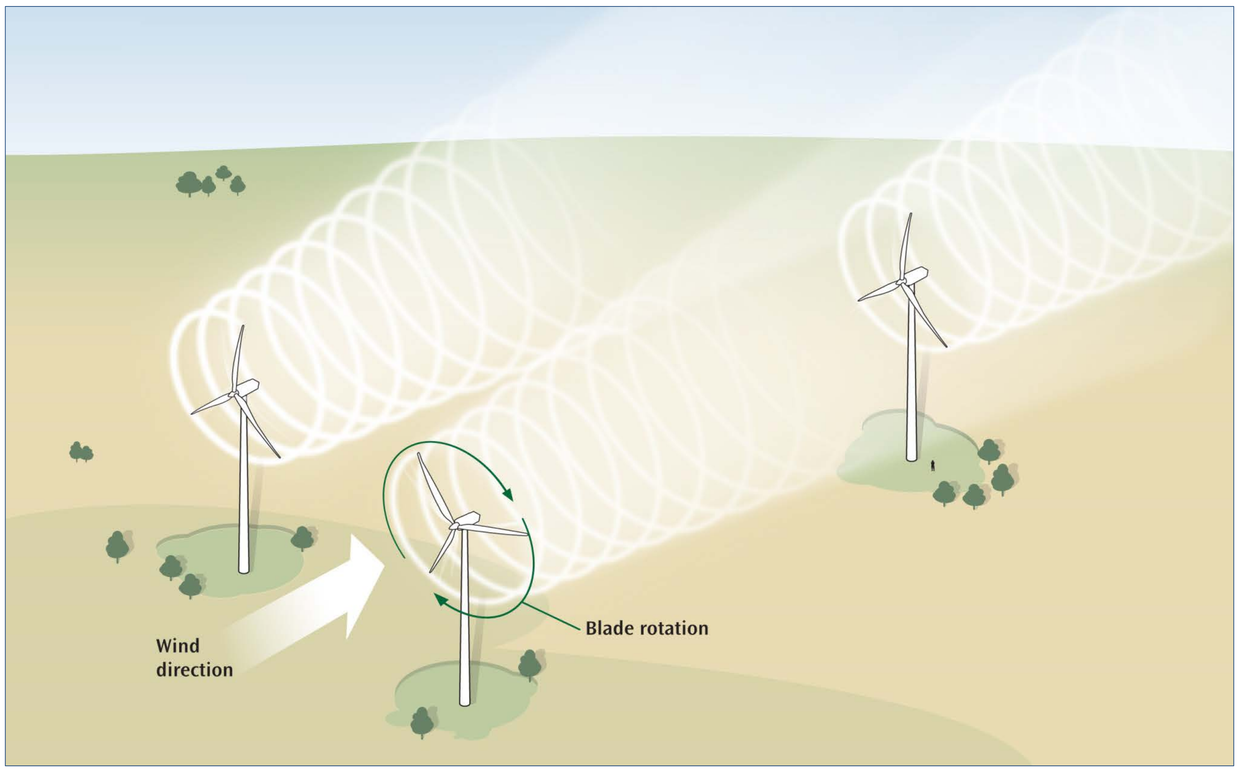
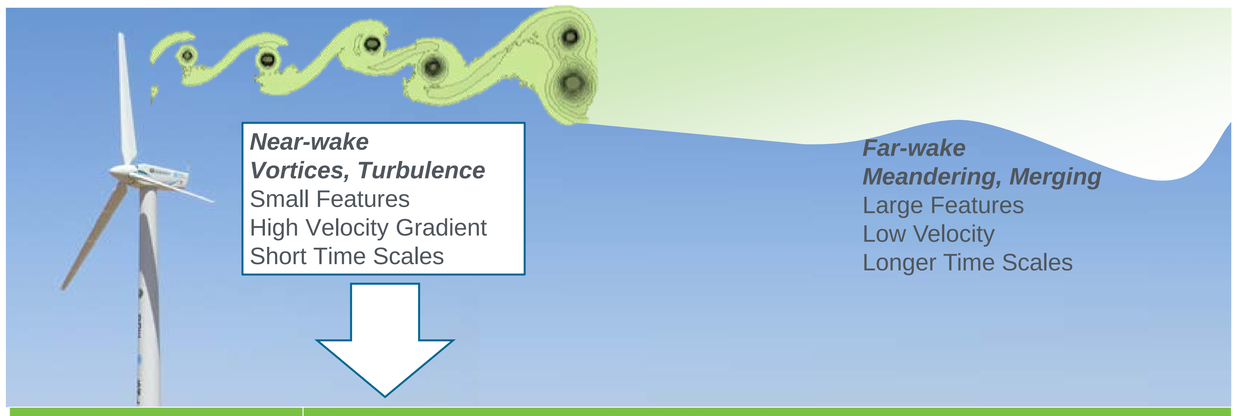


FIGURE 1 – A SCHEMATIC OF THE SANDIA SCALED WIND FARM TEST (SWIFT) FACILITY REPRESENTING THE WAKE STRUCTURES OF INTEREST IMPACTING THE DOWNWIND TURBINE

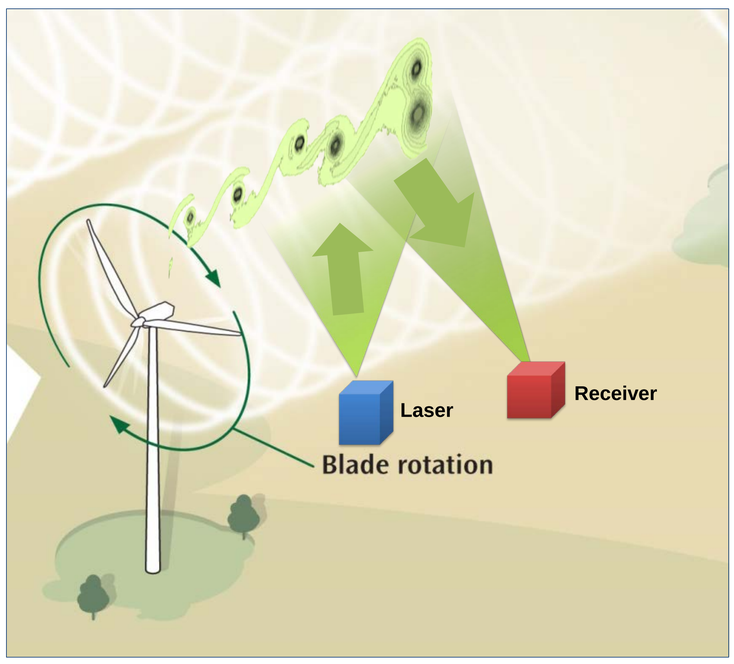
2. METHODS

The project began by assessing the viability of purchasing existing commercial measurement systems, but it was determined that they are not capable of probing the time and length scales needed to capture the near-rotor turbulent structures of interest.



Existing Systems	Challenges in Near-wake field testing
Particle Image Velocimetry (PIV)	**Small field of view** due to particle size and camera resolution relation. Particle release outdoors an **EH&S challenge**.
Scanning LIDAR	**Time resolution** of scanning point measurements is insufficient to capture coherent flow structures

FIGURE 2 – CHALLENGES TO EXISTING MEASUREMENT SYSTEMS IN CAPTURING THE NEAR-WAKE TURBULENT STRUCTURES



A technique called Planar Doppler Velocimetry (PDV) was chosen to measure the time and length scales needed at the SWiFT facility. A laser sheet illuminates the flow field which contains aerosols (natural or seeded) which scatter the laser light, shifting the frequency up or down based upon their velocity and direction, known as the Doppler effect. A two-camera system with a filter that converts frequency changes to intensity differences is used to create a velocity image with the help of software algorithms and calibration data. Unlike PIV, the individual particles do no need to be tracked, however the optical system is much more complex. Instantaneous velocity images are possible.

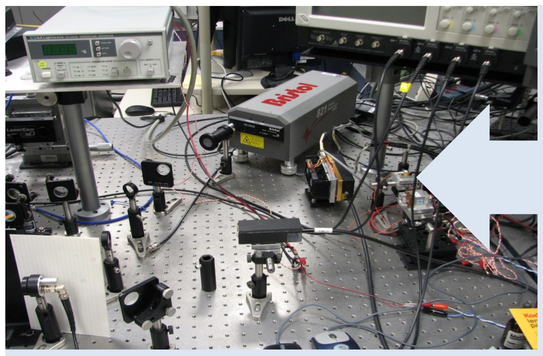
FIGURE 3 – A CONCEPTUAL CONFIGURATION OF A PLANAR DOPPLER VELOCIMETRY SYSTEM DEPLOYED AT SWIFT CONSISTING OF A LASER AND RECEIVER SYSTEM MEASURING THE TIP VORTICES OF THE TURBINE WAKE WITH A LASER LIGHT SHEET

RISK REDUCTION RESEARCH APPROACH

The project has taken a risk reduction approach to keep the project on time and within budget:

- Demonstrate simplest possible system
- Address make-or-break components
- Build up from lab to field experiments
- Identify and resolve EH&S issues early
- Leverage deep expertise, equipment, and facilities at Sandia to save time and money

3. RESULTS



Initial lab experiments:

- characterized hardware
- developed software
- established proof of concept

Initial outdoor testing:

- Demonstrate scaling
- Identify field-deployment issues

FIGURE 4 – PICTURES OF THE LAB TEST SETUP AND THE FIRST FIELD TEST BOTH CONDUCTED AT SANDIA NATIONAL LABORATORIES. SCALED TESTING IS USED TO REDUCE RISK AND FIX PROBLEMS COST-EFFECTIVELY

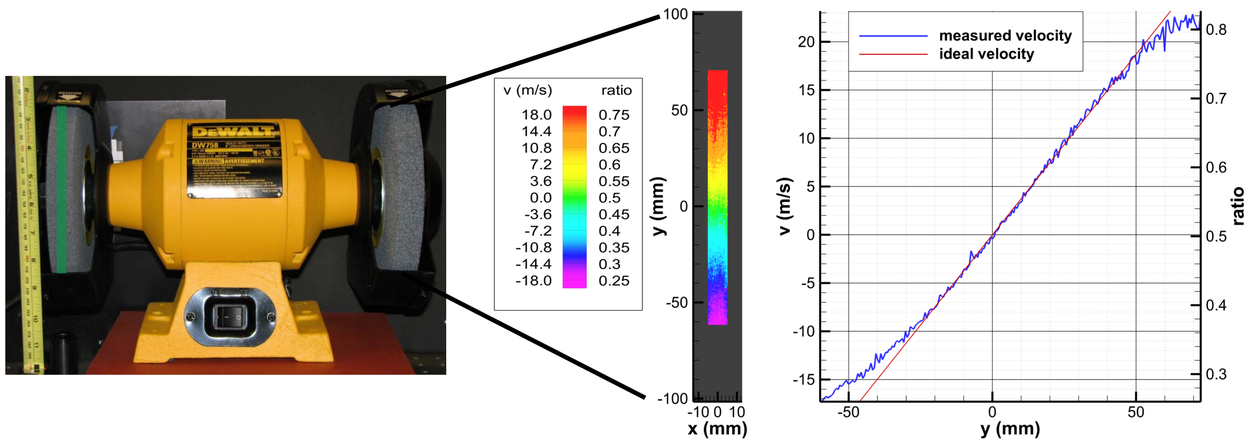


FIGURE 5 – A GRINDING WHEEL WAS USED AS A KNOWN VELOCITY TARGET TO TEST THE SYSTEM ON IN THE LAB. A CALIBRATED VELOCITY IMAGE WAS OBTAINED AS SHOWN IN THE MIDDLE PLOT. THE NON-LINEAR PORTIONS OF THE VELOCITY IN THE RIGHT PLOT ARE DUE TO DYNAMIC RANGE LIMITS OF THE SYSTEM AND HAVE BEEN RESOLVED.

4. SUMMARY OF RESULTS AND FINDINGS

- Commercial measurement systems were found to be inadequate to measure near-wake flow features
- A technique called Planar Doppler Velocimetry was selected
- Hardware development has followed a risk reduction approach to from lab to field scales
- The project leverages millions of dollars of investment from other sources in Sandia's equipment, facilities and especially the technical experts in laser sensing, aerosol sciences and flow measurement systems.
- An external advisor from NASA Langley that developed PDV, Jim Meyers, was added as a technical advisor.

5. PROPOSED FUTURE WORK

The system will be moved to the next scale testing in a pseudo-outdoor area in order to:

- Test system on more representative scale
- Refine aerosol dispersion system
- Determine system sensitivity
- Address any field-deployment issues that might arise

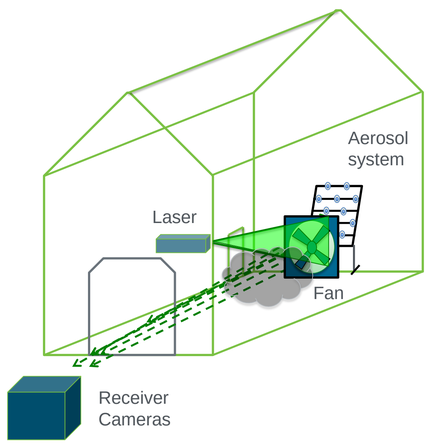


FIGURE 6 – THE NEXT PHASE WILL INCORPORATE SEEDING OF AEROSOLS INTO A FLOW CREATED BY A FAN. THE STRUCTURE WILL ALLOW FOR CONTROLLED AEROSOL CONCENTRATIONS AND PROVIDE LASER SAFETY WHILE WORKING AT MORE REPRESENTATIVE FIELD SCALES