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NATIONAL RENEWABLE ENERGY LABORATORY

Vindicator Lidar Assessment for Wind Turbine Feed-Forward Control Applications

Cooperative Research and Development Final Report

CRADA Number: CRD-09-352

NREL Technical Contact: Dr. Alan Wright

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Cooperative Research and Development Final Report

In accordance with Requirements set forth in Article XI.A(3) of the CRADA document, this document is the final CRADA report, including a list of Subject Inventions, to be forwarded to the Office of Science and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

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CRADA Title: Vindicator Lidar Assessment for Wind Turbine Feed-Forward Control Applications

Parties to the Agreement: Catch the Wind, Inc.

Joint Work Statement Funding Table Showing DOE Commitment:

Estimated Costs	NREL Shared Resources
Year 1	$ 100,000.00
Year 2	$ 130,000.00
Year 3	$ 150,000.00
TOTALS	$ 380,000.00

Abstract of CRADA Work:

Collaborative development and testing of feed-forward and other advanced wind turbine controls using a laser wind sensor.

Summary of Research Results:

Researchers at the National Renewable Energy Laboratory (NREL) are designing, implementing, and testing advanced feed-forward controls for multi-megawatt wind turbines that will help reduce the cost of wind energy. Past wind turbine controllers have depended on turbine feedback measurements to determine the controller pitch commands. In this setup, wind speed disturbances can only be corrected after their effects have been detected in the turbine's loads and dynamic response, which causes a delayed control response due to turbine and pitch actuator dynamics. Light Detection and Ranging (LIDAR) systems can provide an advanced wind-speed measuring sensor that provides information regarding the approaching wind field to the controller in advance, thereby increasing the controller's available reaction time and allowing pitch actuation to occur in advance to mitigate wind disturbance effects. Feed-forward control algorithms that use these "look ahead" wind speed measurements can improve load mitigation and controller performance compared to feedback only controllers.

The objectives of the work in this CRADA were to assess a particular commercial LIDAR; the Catch the Wind "Vindicator" LIDAR system for providing wind information ahead of the turbine for use in advanced feed-forward control algorithms. In this activity, the Catch the Wind Vindicator LIDAR unit was mounted to the nacelle of the 3-bladed Controls Advanced Research Turbine (CART3) located at the National Wind Technology Center near Golden, Colorado. Data from this unit was collected during turbine operation and compared to anemometer data collected on the upwind meteorological tower. After

assessing the accuracy and potential of this LIDAR for use in advanced feed-forward control algorithms, a preliminary feed-forward control algorithm was implemented in the CART3 software and field testing was initiated. The LIDAR data stream was integrated into the CART3 data system so that online measured wind-speed data could be fed directly to the control algorithm. Field testing over a several month period showed that inclusion of the LIDAR measurement into the control system led to further rejection of the wind-speed disturbance at low frequencies compared to feedback alone. In addition, this advanced wind-speed information improved the controller's ability to mitigate critical fatigue loads, a key step in reducing wind turbine cost of energy.

These field tests provided confidence that this LIDAR technology could be used to obtain load reductions using feed-forward controls that use the LIDAR wind-speed measurements ahead of the turbine to improve performance.

Subject Inventions Listing: N/A

Report Date: 11/18/2013

Responsible Technical Contact at Alliance/NREL: Dr. Alan Wright (303-384-6928)

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