NREL
NATIONAL RENEWABLE ENERGY LABORATORY

CENER/NREL Collaboration in Testing Facility and Code Development

Cooperative Research and Development Final Report

CRADA Number: CRD-06-207

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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.

CRADA Number: CRD-06-207

Parties to the Agreement: CENER-CIEMAT Foundation

CRADA Title: CENER/NREL Collaboration in Testing Facility and Code Development

Joint Work Statement Funding Table Showing DOE Commitment:

Estimated Costs	NREL Shared Resources
Year 1-4	$ 1,412,151.00
Year 5-6	$ 531,652.00
TOTALS	$ 1,943,803.00

Abstract of CRADA Work:

Under the funds-in CRADA agreement, NREL and CENER will collaborate in the areas of blade and drivetrain testing facility development and code development. The project shall include NREL assisting in the review and instruction necessary to assist in commissioning the new CENER blade test and drivetrain test facilities. In addition, training will be provided by allowing CENER testing staff to observe testing and operating procedures at the NREL blade test and drivetrain test facilities. CENER and NREL will exchange blade and drivetrain facility and equipment design and performance information. The project shall also include exchanging expertise in code development and data to validate numerous computational codes.

The Centro Nacional de Energías Renovables (CENER) is a corporation organized under the laws of Spain with a principal place of business at 31621 SARRIGUREN, Navarra Spain.

Summary of Research Results:

In the area of controls and system identification, NREL and CENER researchers jointly collaborated to create and test new algorithms for closed loop system identification on NREL's CART test turbine. The algorithms were installed and debugged until they reached a successful operational state and continue to be tested. Such algorithms will be critical to further advance wind energy – particularly in the wind plant setting.

The NREL-CENER CRADA activities related to the Code Development tasks involved the improvement, verification, and validation of wind turbine computer-aided engineering (CAE) tools, particularly the FAST tool developed and supported by NREL as sponsored by the U.S. DOE. While not all work planned was completed, the collaboration was still mutually beneficial. The ongoing communication and information exchange expedited the development and improved the results of projects both at NREL and CENER. Specific accomplishments from these tasks are as follows:

- NREL hosted José Azcona Armendáriz of CENER between September and December 2008 to initiate work under the CRADA and to train CENER on the modeling of floating wind turbines.
- NREL and CENER mutually shared FAST source code improvements.
- CENER shared with NREL the results of a verification of FAST against GH Bladed.
- NREL collaborated with CENER under the International Energy Agency (IEA) Wind Task 23 Offshore Code Comparison Collaboration (OC3) project, including checking each other's FAST results and working together to develop the OC3-Hywind spar model used in Phase IV of OC3.
- NREL and CENER shared information on approaches to enable numerically stable and convergent coupled simulation of different tools. This information was used by CENER to enable the coupling between FAST and PSCAD for modeling the impact of grid faults on wind turbines and between FAST and OPASS for modeling mooring dynamics of floating wind turbines, and laid the groundwork for establishment of the new FAST modularization framework by NREL.
- NREL and CENER mutually shared presentation material for training on FAST that both institutions have used to host wind turbine modeling workshops.
- CENER provided NREL information on second-order beam theory for modeling tower and blade structural dynamics, although NREL chose geometrically exact beam theory over second-order theory in NREL's development of FAST's nonlinear beam finite-element module, BeamDyn.
- CENER shared with NREL the results of validation of FAST against data from the Unsteady Aerodynamics Experiment (UAE) under IEA Wind Task 20.
- CENER provided NREL information on recent improvements and validation of unsteady aerodynamics, including dynamic stall, that NREL will be using to improve FAST's aerodynamics module, AeroDyn.
- NREL and CENER collaborated to establish a recommended test matrix for combined wind-wave experimental tests of offshore floating wind turbines in a wave basin, aimed at FAST validation. Although no test data has yet been exchanged, there are plans to exchange data and collaborate on validation under the IEA Wind Task 30 OC5 (OC3 continued, with correlation) and InnWind projects.
- Researchers at CENER used NREL's wind turbine aeroacoustics model to validate against wind tunnel and field data. The results demonstrated the relative accuracy of the NREL's simulation tool.

In the area of blade and dynamometer/drivetrain testing, there were multiple in-person meetings and discussions on facility design while both NREL and CENER were building up their own testing capabilities. Testing methodologies were also discussed and exchanged, which improved the methods for both parties. NREL staff did visit the facilities while under construction at CENER and vice versa to provide input, further review and guidance. Lastly, equipment designs were discussed and NREL loaned a piece of blade equipment, called the UREX, to CENER, for proof testing, comparison with their blade testing system, and to gain a better understanding of the technology. The UREX system has since been returned to NREL. For the drivetrain testing aspect there were specific discussions on no-torque loading systems, which has since been implemented in both NREL's and CENER's facilities.

Lastly, in the area of wind plant modeling, researchers at both NREL and CENER ran benchmark cases within the IEA Task 31: Wakebench efforts, which were compared to those of other international researchers and field data. Such comparisons provide insight into the performance of different simulation tools and possible areas for improvement.

Subject Inventions Listing: None

Report Date: 11/7/2014

Responsible Technical Contact at Alliance/NREL: Patrick Moriarty

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