Distributed Wind Aeroelastic Modeling (dWAM)

Brent Summerville, NREL
Tuesday, Feb. 28, 2023
Distributed Wind 2023 National Laboratory–Industry Discussion Session
dWAM Team

Subcontractors

Distributed Wind Energy
OEM Partners
dWAM Overview

Aeroelastic modeling is the primary method for the structural and performance assessment of any wind turbine. Despite the advantages afforded by aeroelastic modeling tools, their use in the distributed wind energy industry is limited.

- Started from NREL *Aeroelastic Modeling for Distributed Wind Turbines* project with Damiani and Davis (2022) researching current needs, including input from an industry workshop.
- NREL with partner lab, Sandia National Laboratories, to address top needs.
- **Outcome**: Advancements in dWAM will accelerate the design and certification process for developing optimized and reliable distributed wind turbines.

<table>
<thead>
<tr>
<th>Budget</th>
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<tbody>
<tr>
<td>NREL</td>
<td>$1,270,000</td>
</tr>
<tr>
<td>Sandia</td>
<td>$280,000</td>
</tr>
<tr>
<td><strong>Total over 2 years</strong></td>
<td><strong>$1,550,000</strong></td>
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**Period of Performance**
2 years (NREL Fiscal Years 2023 and 2024)
Approach and Outcome

Distributed wind = small, medium and large turbines.
- Modeling for the large turbine archetype is well-tuned in OpenFAST.
- dWAM will focus on the needs of small and medium wind turbine archetypes.

Top Distributed Wind Archetypes
- Three-bladed, upwind with active pitch and active yaw
- Three-bladed, upwind with stall control and active yaw
- Three-bladed, upwind with stall control and passive tail
- Three-bladed, downwind with stall control and passive yaw

Example
- Utility scale
- QED, NPS
- Bergey, Sonsight
- Eocycle M, Skystream

Model Improvements
- Improved Physics for Distributed Wind Archetypes
- Vertical-Axis Wind Turbine (VAWT) Modeling
- Automated Campbell Diagram Capabilities (ACDC)

Validated Reference Turbines
- Advanced Reference Turbines for Distributed HAWT Archetypes (ARETHA)
- Research Turbine Data for Model Validation
- Code Comparison for Verification

Improved User Experience
- Design Load Basis Guidance With Real-World Failure Mode Research
- Improved OpenFAST Documentation
- VAWT-Specific Scripts and Guidance
- ACDC Tools

Impacts Realized
- Optimized, Certified Designs
- Improved Reliability
- Lower Cost of Wind Energy

Images from NREL
Validation

All collaborating OEMs have received WETO/NREL funding via the *Competitiveness Improvement Project (CIP).* (NREL CIP 2023)

**Three modern distributed wind turbines** coming to NREL’s *Distributed Integrated Energy Laboratory (DIEL)* at Flatirons Campus under the *Flatirons Distributed Wind Turbine Installation* project will serve as the baseline for new reference turbines and for model validation.

**A: passive-yaw, upwind, stall HAWT**
(Bergey Excel 15)

**B: passive-yaw, downwind, stall HAWT**
(Ecycle M26)

**C: active-yaw, upwind, stall HAWT**
(QED PHX-20)

**Pika T701**
NREL is working to re-install Pika T701 at Flatirons Campus as a second turbine for tail vane modeling validation (Jeroen/Scott W. leading).

**XFlow Energy**
XFlow has installed a prototype 25-kW VAWT at Windward Engineering’s test facility in Spanish Fork, Utah, for VAWT model validation.
Tail vane modeling
- Emmanuel Branlard, NREL, Lead
- Translating validated mathematical model from Wood/Hammam into OpenFAST implementation

Yaw friction modeling
- Rick Damiani, RRD Engineering, Lead
- Developing improved code for passive yaw archetypes

VAWT code development
- Kevin Moore, Sandia, Lead
- Hannah Ross, NREL, Lead; Andy Platt, NREL, leading coupling effort
- Positive collaboration between Sandia and NREL

ACDC code development
- Derek Slaughter, NREL, Lead
- Collaborating with Technical University of Denmark (DTU) and German Aerospace Center (DLR) including mode visualization

Creation of validated reference turbines
- Abhineet Gupta, NREL, Lead
- Starting with the Bergey Excel 15 OpenFAST model

Improvements in user experience
- Andy Platt, NREL, Lead, OpenFAST documentation
- Kevin Moore, Sandia, Lead, VAWT modeling documentation

Distributed wind turbine failure mode workshop
- Robert Preus, Advanced Renewable Technology, Lead
- Subcontract nearly executed
- Part of Design Load Basis guidance document

Delta fin yaw angle predictions using the full model (black line), reduced model (red line), and experimental results (blue dots). From D. Wood, M. Hammam.
Distributed Wind Aeroelastic Modeling (dWAM)

Introduction

Aerodynamic modeling is the primary method for the structural and performance assessment of large wind turbines. Such modeling involves a combination of the influence of fatigue and the wake effect on turbine performance and power output, considering the need for high fidelity and speed in numerical code. One of the most promising ways to improve aerodynamic modeling is to develop distributed wind energy industry standards.

Objective

The objective is to improve the aerodynamic modeling tools for distributed wind turbines to enable the design and certification of optimized turbines with a competitive cost of energy.

Components of the Project

- Advanced Reference Turbines for Distributed Wind Turbine Arrays (A2WTA)
  - Focus on modern, traditional wind turbines
  - Develop and validate aeroelastic code for predicting rotor tip vortex effects
  - Develop aeroelastic code for predicting tower and other structures

- Virtual Wind Turbine Testbed (VWTT)
  - Develop virtual wind turbine testbeds for testing aeroelastic models
  - Test models in real-world conditions

- Wind Turbine Data Archiving and Analysis (WTDAA)
  - Collect and analyze wind turbine data for improving models
  - Develop predictive models for wind turbine performance

Future Outcomes

- Development of a comprehensive dataset for wind turbine performance
- Improved understanding of wind turbine behavior in complex environments
- Development of a virtual wind turbine testbed for testing and validation
- Improved accuracy of wind turbine models

Partners

- National Renewable Energy Laboratory
- Technical University of Denmark
- RWTH Aachen University
- Wind Power Australia
- Virginia Tech
- University of Maryland
- University of California, Berkeley
- University of Washington
- University of Minnesota

NREL fact sheet (NREL 2023)
Thank you
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NREL/PR-5000-85446
