NREL
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Distributed Wind Aeroelastic Modeling (dWAM)

Brent Summerville, NREL

Tuesday, Feb. 28, 2023

Distributed Wind 2023 National Laboratory–Industry Discussion Session

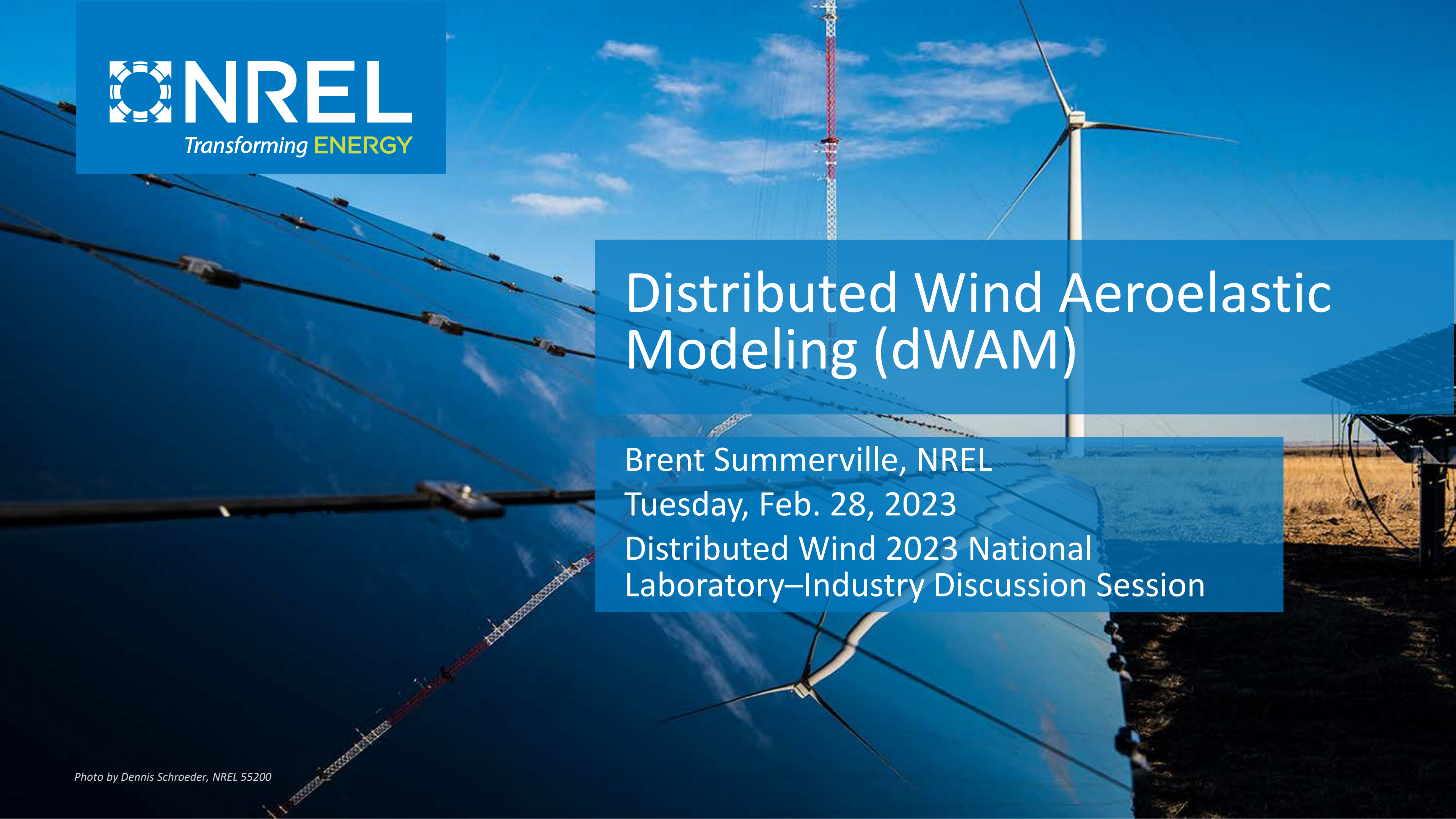

Photo by Dennis Schroeder, NREL 55200

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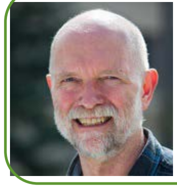
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dWAM Overview

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.

Image from Windward Engineering

Budget	
NREL	$1,270,000
Sandia	$ 280,000
Total over 2 years	*$1,550,000*

Period of Performance

2 years (NREL Fiscal Years 2023 and 2024)

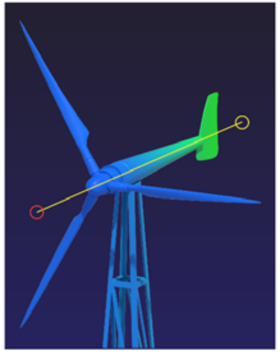
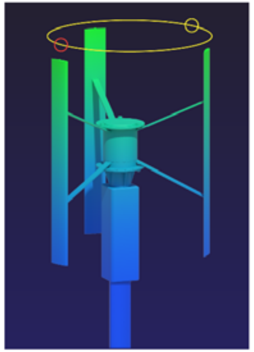
Approach and Outcome

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.

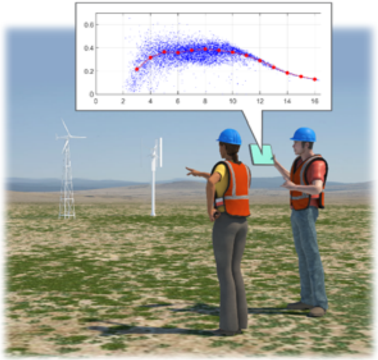
Top Distributed Wind Archetypes	Example
Three-bladed, upwind with active pitch and active yaw	Utility scale
Three-bladed, upwind with stall control and active yaw	QED, NPS
Three-bladed, upwind with stall control and passive tail	Bergey, Sonsight
Three-bladed, downwind with stall control and passive yaw	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)

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

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

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

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.

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.

dWAM Status

Tail vane modeling

- Emmanuel Branlard, NREL, Lead
- Translating validated mathematical model from Wood/Hammam in 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

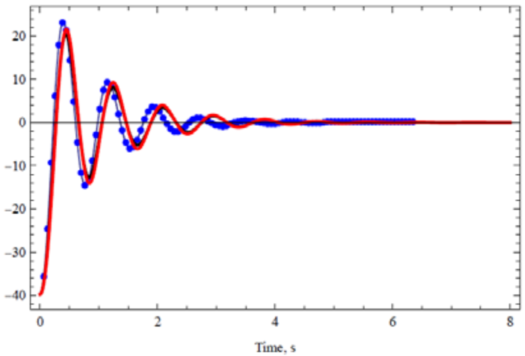
- Abhineet Gupta, NREL, Lead
- Starting with the Bergey Excel 15 OpenFAST model

Improvements in user experience

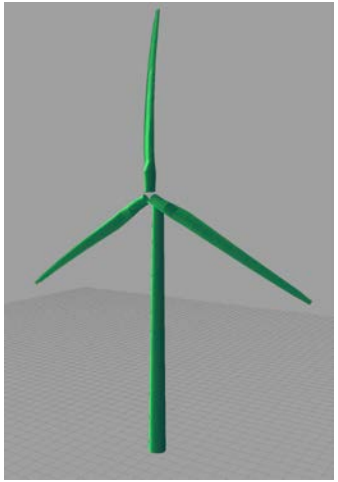
- Andy Platt, NREL, Lead, OpenFAST documentation
- Kevin Moore, Sandia, Lead, VAWT modeling documentation

Distributed wind turbine failure mode workshop

- Robert Preus, Advanced Renewable Technology, Lead
- Subcontract nearly executed
- Part of Design Load Basis guidance document

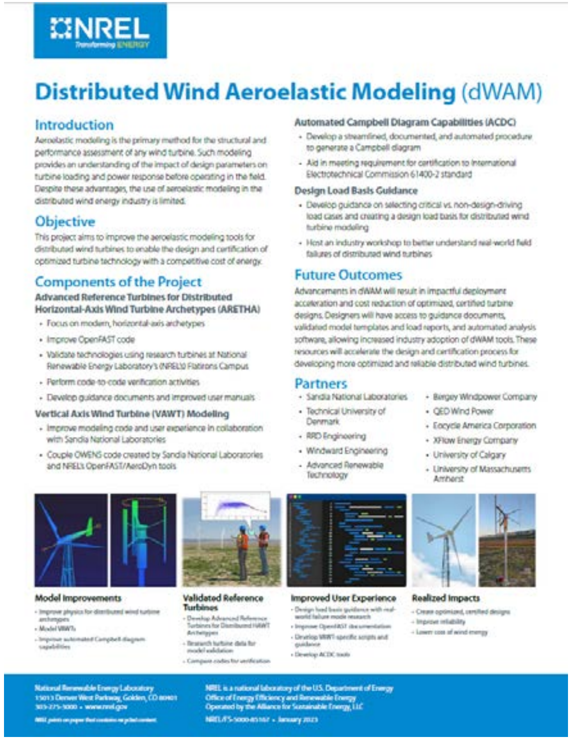


Delta fin yaw angle predictions using the full model (black line), reduced model (red line), and experimental results (blue dots). *From D. Wood, M. Hammam*.



Turbine visualization sample from ACDC effort. *Image from Derek Slaughter, NREL*

Questions?



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Distributed Wind Aeroelastic Modeling (dWAM)

Introduction

Aeroelastic modeling is the primary method for the structural and performance assessment of any wind turbine. Such modeling provides an understanding of the impact of design parameters on turbine loading and power response before operating in the field. Despite these advantages, the use of aeroelastic modeling in the distributed wind energy industry is limited.

Objective

This project aims to improve the aeroelastic modeling tools for distributed wind turbines to enable the design and certification of optimized turbine technology with a competitive cost of energy.

Components of the Project

Advanced Reference Turbines for Distributed Horizontal-Axis Wind Turbine Archetypes (ARETHA)

- Focus on modern, horizontal-axis archetypes
- Improve OpenFAST code
- Validate technologies using research turbines at National Renewable Energy Laboratory's (NREL's) Flatirons Campus
- Perform code-to-code verification activities
- Develop guidance documents and improved user manuals

Vertical Axis Wind Turbine (VAWT) Modeling

- Improve modeling code and user experience in collaboration with Sandia National Laboratories
- Couple OWENS code created by Sandia National Laboratories and NREL's OpenFAST/AeroDyn tools

Automated Campbell Diagram Capabilities (ACDC)

- Develop a streamlined, documented, and automated procedure to generate a Campbell diagram
- Aid in meeting requirement for certification to International Electrotechnical Commission 61400-2 standard

Design Load Basis Guidance

- Develop guidance on selecting critical vs. non-design-driving load cases and creating a design load basis for distributed wind turbine modeling
- Host an industry workshop to better understand real-world field failures of distributed wind turbines

Future Outcomes

Advancements in dWAM will result in impactful deployment acceleration and cost reduction of optimized, certified turbine designs. Designers will have access to guidance documents, validated model templates and load reports, and automated analysis software, allowing increased industry adoption of dWAM tools. These resources will accelerate the design and certification process for developing more optimized and reliable distributed wind turbines.

Partners

- Sandia National Laboratories
- Technical University of Denmark
- RRD Engineering
- Windward Engineering
- Advanced Renewable Technology
- Bergey Windpower Company
- QED Wind Power
- Eocycle America Corporation
- XFlow Energy Company
- University of Calgary
- University of Massachusetts Amherst

Model Improvements

- Improve physics for distributed wind turbine archetypes
- Model VAWTs
- Improve automated Campbell diagram capabilities

Validated Reference Turbines

- Develop Advanced Reference Turbines for Distributed HAWT Archetypes
- Research turbine data for model validation
- Compare codes for verification

Improved User Experience

- Design load basis guidance with real-world failure mode research
- Improve OpenFAST documentation
- Develop VAWT-specific scripts and guidance
- Develop ACDC tools

Realized Impacts

- Create optimized, certified designs
- Improve reliability
- Lower cost of wind energy

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dWAM fact sheet (NREL 2023)

Bergey Excel 15 in Blowing Rock, NC
Photo courtesy Nelson Aerial Productions and PNNL

Thank you

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