U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2021 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
WIND ENERGY TECHNOLOGIES OFFICE

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

T25 - Aeroacoustic Assessment of Wind Plant Control

Wind – Atmosphere to Electrons (A2e)

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August 4, 2021

FY21 Peer Review - Project Overview

Project Summary:

- Wind turbine noise emissions impact social acceptance of wind energy and development of wind plants close to human settlements
- Wind plant controls being implemented more and more frequently to optimize power performance
- Yawing wind turbines changes the three-dimensional aerodynamic interactions between blades and atmosphere, and therefore aeroacoustic emissions
- Wind plant noise emissions could lead to curtailment, negating benefits of wind plant controls and delaying wind plant development

Project Objective(s) 2019-2020:

- Develop new experimental capability for aeroacoustic measurements
- Simulate experimental conditions to assess expected changes in noise emission and outline data requirements

Overall Project Objectives (life of project):

- Quantify changes in aerodynamic noise generation due to yawed wind turbine operation

Project Start Year: FY 2019
Expected Completion Year: FY 2021
Total expected duration: 2 years

FY19 - FY20 Budget: $500,000

Key Project Personnel:
Nicholas Hamilton, PI
Pietro Bortolotti, Modeling
Jason Roadman, Experiment
Eric Simley, Data QA/QC

Key DOE Personnel: Michael Derby,
Ben Hallisey

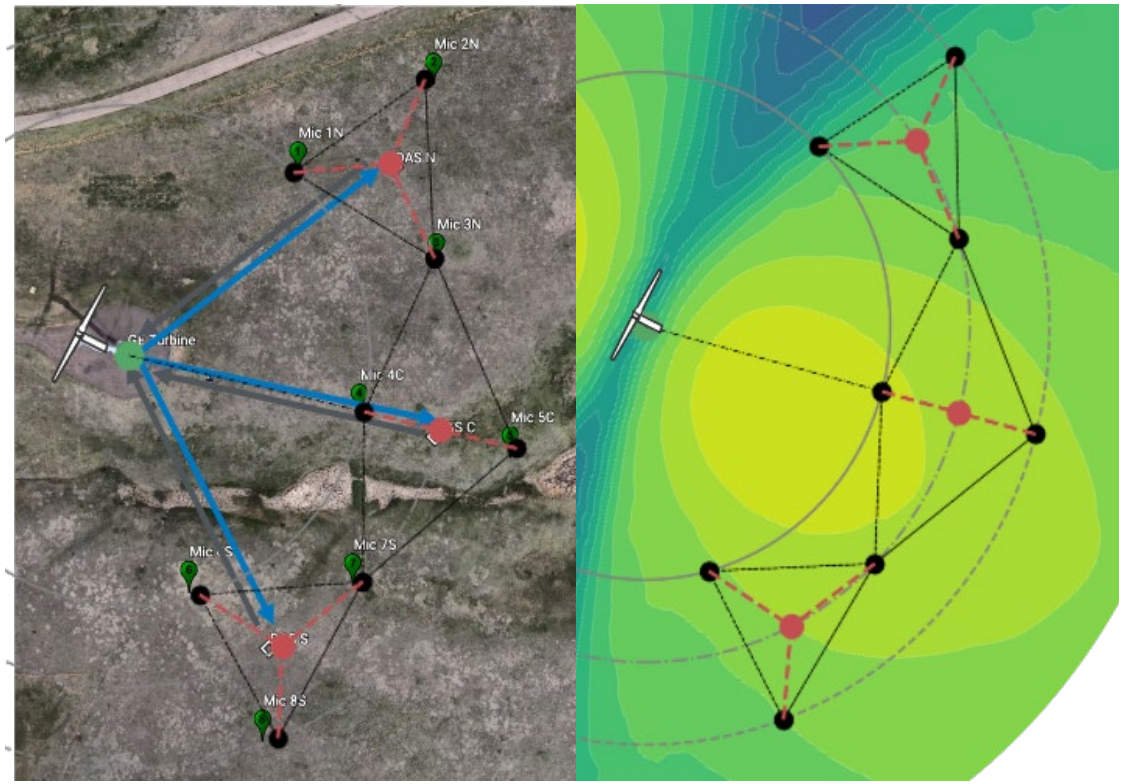
DOE 1.5 MW wind turbine used for aeroacoustics research, NREL Flatirons Campus

Project Impact

Quantifying the changes to aeroacoustic noise emissions that arise during imposed yaw offsets will outline the viability of wind plant control strategies in noise-controlled wind plants.

The main objectives of the project are to:

- Develop new experimental capability for aeroacoustics
- Validate aeroacoustic noise generation models implemented in OpenFAST
- Create a unique public dataset combining noise measurements, atmospheric conditions, and wind turbine operation



New experimental capability for aeroacoustic measurements shown at the Flatirons Campus (left) and overlaid with simulation results (right).

Program Performance – Scope, Schedule, Execution

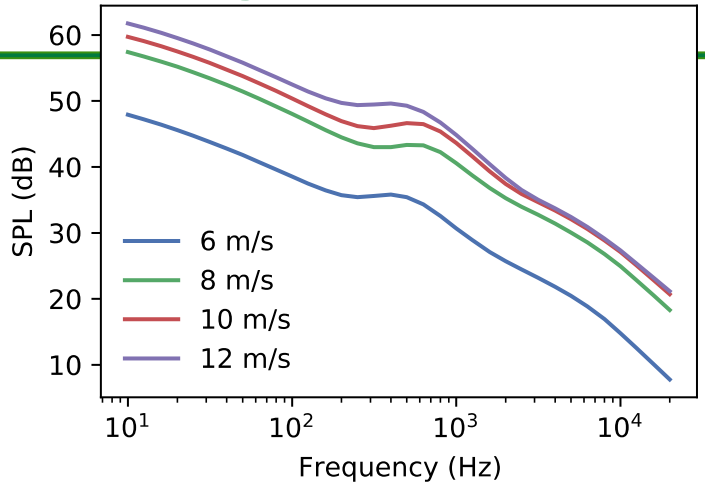
The Aeroacoustic Assessment of Wind Plant Controls project team successfully executed all milestones and deliverable goals for FY19 and FY20

NREL	Description of Milestone
FY19	4. NREL will complete a detailed plan for aeroacoustic measurements of a utility scale wind turbine operating under conditions specified in modern wind plant control strategies by September 30, 2019.
FY20	1. Specify instrumentation needs to make point measurements for time- and frequency-domain assessment of aeroacoustic emissions of GE 1.5 MW wind turbine. 2. Deploy instrumentation around DOE-owned GE 1.5 MW wind turbine at NREL Flatirons Campus and begin data acquisition, quality assurance, and quality control processes for audio data. 3. Run aeroacoustic noise generation and propagation models included in OpenFAST module for full experimental matrix (by wind speed and yaw offset). Identify physics or results that merit validation and uncertainties in model formulation for future research.* 4. Assess viability of additional observations to validate model accuracy and reduce uncertainty. Recommendations for measurements and remaining areas for model development or validation will be collected for future aeroacoustics research.*
FY21	1. Redeploy instrumentation around DOE-owned GE 1.5 MW wind turbine at NREL Flatirons campus, begin data acquisition, quality assurance, and quality control processes for audio data. 2. Complete validation of the implementation of aeroacoustics models in OpenFAST against experimental noise data collected for the GE 1.5 MW wind turbine, make quality-controlled data available to the public through the A2e DAP.

* Project was extended into FY21 due to COVID-related restrictions on operations. During Q3 and Q4 of FY20, the project team pivoted to focusing on simulation of the experiment and developing future research priorities.

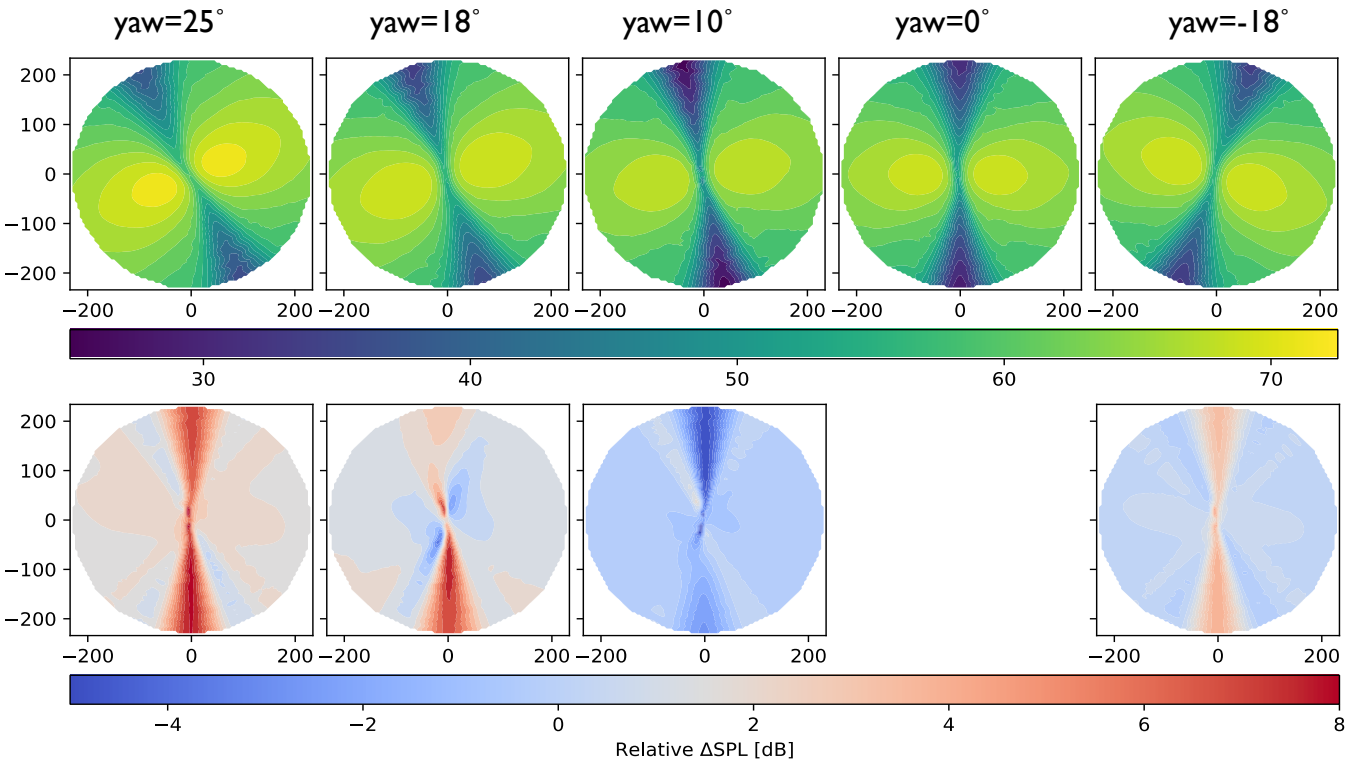
Program Performance – Accomplishments & Progress

A virtual experiment supported the measurement plan, developed expected ranges of changes in noise emission and spectra at each of the specified microphone locations.

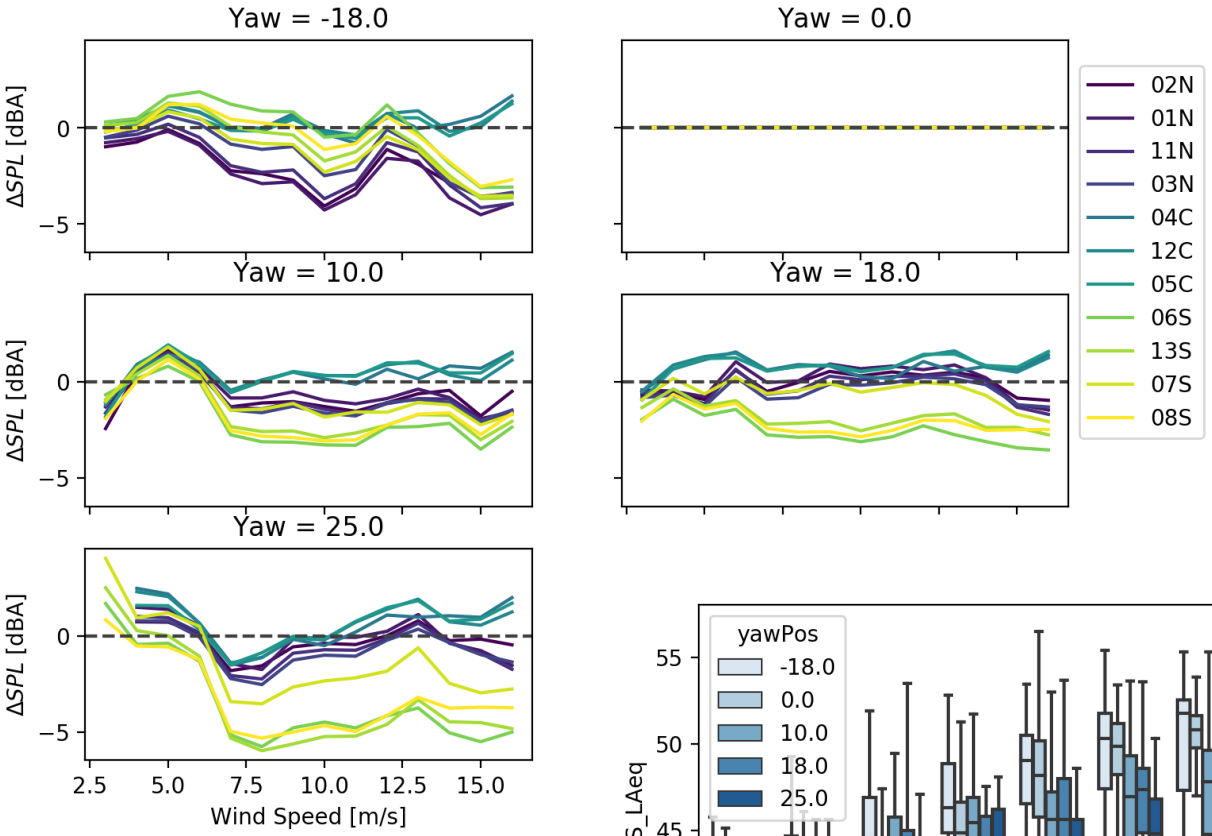


Virtual experiments suggest:

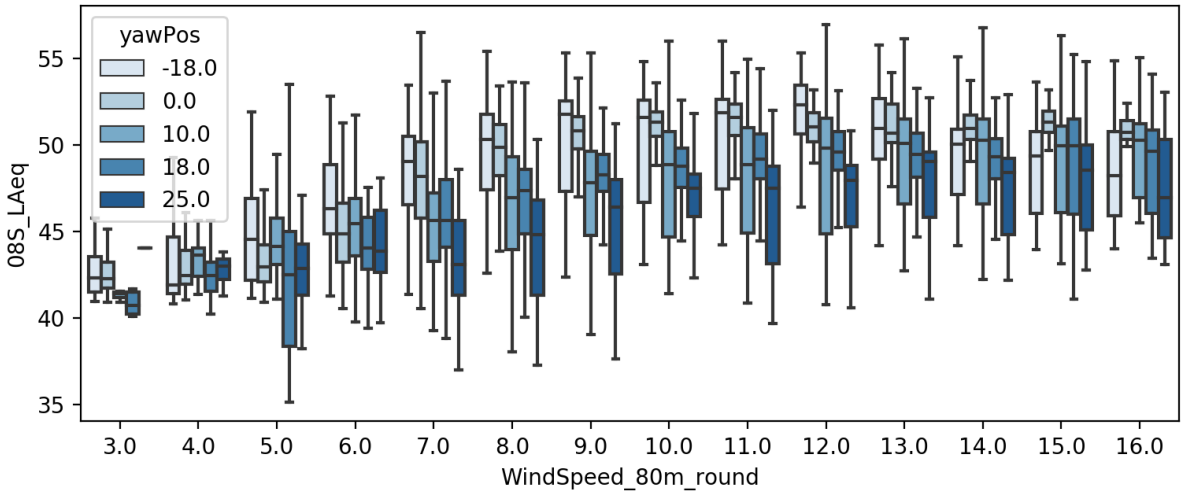
- Asymmetry in noise emission with yaw
- Decrease in noise for small positive offset
- Substantial increase in noise for aggressive yaw offsets
- Primary noise mechanism are turbulent inflow and trailing edge noise



Program Performance – Accomplishments & Progress



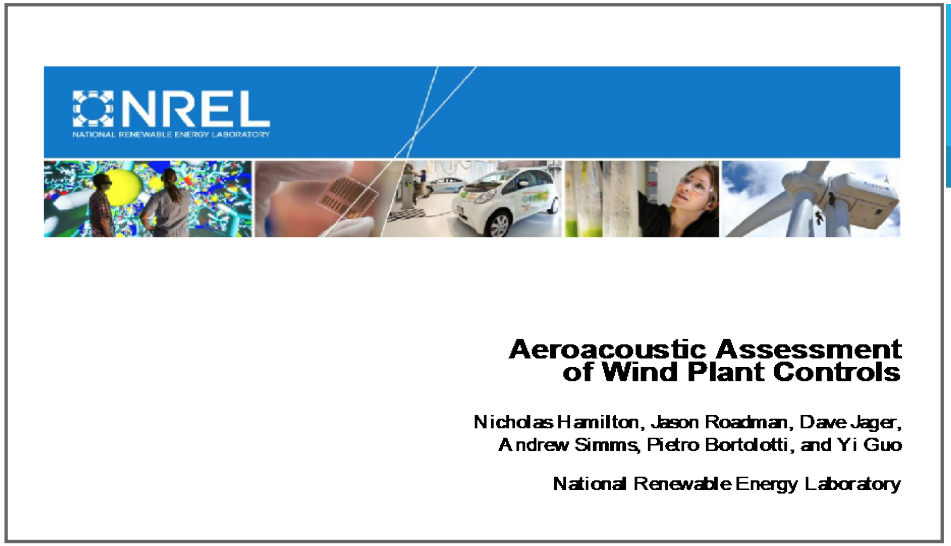
Counter to results of the virtual experiment, noise emissions from the DOE 1.5 MW turbine decrease for all yaw headings. Changes in noise emissions are attributed to decreased rotor speed and changes 3D aerodynamic interactions



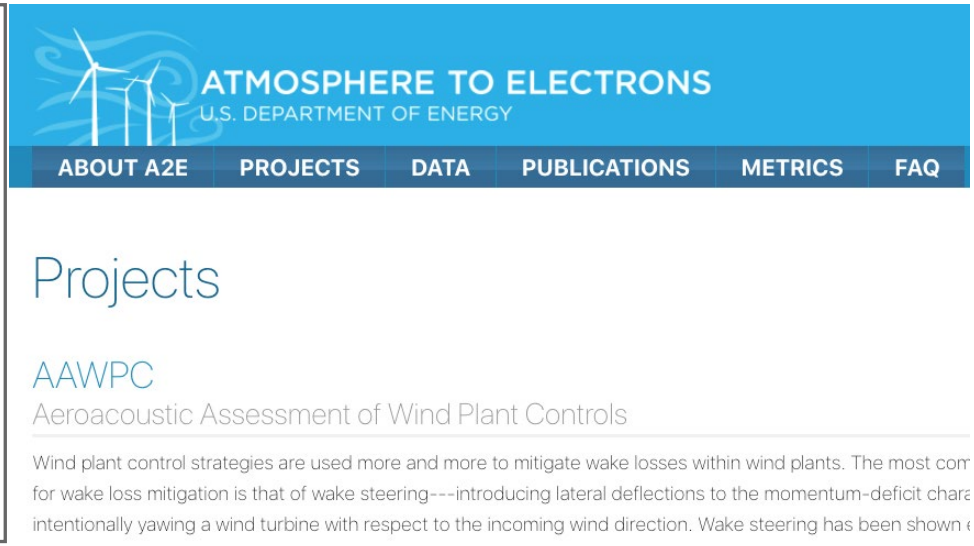
Wind turbine noise is separated from background noise and shows significant changes with yaw offset from the incoming flow.

Project Performance - Upcoming Activities

Project closed in FY21 Q2
Summary project report and public data set:



https://www.nrel.gov/docs/fy21osti/79664.pdf



https://a2e.energy.gov/projects/aawpc

Future aeroacoustics research will be integrated into the WETO portfolio:

- **Big Adaptive Rotor** (Nick Johnson, NREL) – compare results from downwind turbine to results of AAWPC project
- **Rotor Aerodynamics, Aeroelastics, and Wake** (Jonathan Naughton, UW) – Time series analysis of turbulent inflow, turbine response, and emissions
- **American Wake Experiment** (Pat Moriarty, NREL) – Wind Plant aeroacoustic phenomena, propagation, constructive interference

Stakeholder Engagement & Information Sharing

In developing our measurement plan and new experimental capability, we've been in regular contact with:

- Instrumentation developers
- Wind turbine aeroacoustics consultancies
- Wind plant owner/operators
- Wind turbine manufacturers
- International research community
- Standards commissions

Key Takeaways and Closing Remarks

Project Impact:

- Developed new experimental capabilities for the lab
- Quantified a *reduction* in noise emission under yawed operation
- Created expertise for theory, simulation, and measurement of wind turbine noise
- Position NREL and the DOE labs to take on additional aeroacoustics research challenges
- Produced a unique data set and an NREL technical report for detailed documentation

Project Performance:

- The NREL aeroacoustics team **successfully executed all milestones** and deliverable goals
- Managed COVID-related delays, used extension to execute virtual experiment and refine measurement plan

Stakeholder Engagement:

- The project connected with the international wind turbine noise research community, turbine manufacturers, and wind plant developers