##### WETO.1.3.4.403 - Aeroacoustic Assessment of Wind Plant Control

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| **Project General Information** | |
| **Current Year CPS Agreement #:** *Auto-Filled in EERE SharePoint* | **EERE Crosscut:** *These are a list of integrated activities that change annually. Select the checkbox if this AOP project is a Grid Integration project. Crosscuts are many AOP Projects (i.e. different Tech Offices working with different Labs) that fund a single CPS Agreement.*  Advance Energy Storage Initiative  Advanced Manufacturing  Artificial Intelligence  Circular Economy  Critical Materials/Rare Earth Minerals  Cybersecurity  Energy-Water Nexus  Grid Modernization Initiative (GMI)  Grid Security  High-Performance Computing  Harsh Environment Materials Initiative  Quantum Information  STEM |
| **Prior Year CPS Agreement #:** *Auto-Filled in EERE SharePoint* |
| **Work Category:** AOP Project (Direct-Funded Lab Project) |
| **FOA Number:** Click here to enter text. |
| **Was this project Merit Reviewed? :** Choose an item. |
| **Merit Review Year:** Choose an item. |
| **If no Merit Review, provide Exemption Criteria:**  Choose an item. |
| **Project Start:** 7/1/2019 | **Is this a Grid Integration Project?**  **If checked select Thrust Area:** Choose an item. |
| **Planned Project End Date:** 9/30/2020 |

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| **Project Ownership and Performers** | |
| **EERE Project Lead Information** | **Lab Performer Information** |
| **Name:** Derby, Michael | **Name:** Nicholas Hamilton, NREL |

**Project Overview**

*This field contains high-level information regarding the project. It captures the issue, major R&D challenges, and any topic that is needed to provide the reader with a complete understanding of the project and how it supports the Office, Program, and Activity goals. If this is a multi-performer project, this section should include a description of each performer's role and responsibility.*

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| The aeroacoustic emissions of a utility-scale wind turbine operating under conditions that correspond to modern active plant-level controls will be assessed for the DOE-owned GE 1.5 MW wind turbine at NREL’s Flatirons Campus. Whereas active plant control utilizing wake deflection control strategies have been shown experimentally and computationally to produce 1-2% of additional AEP without significant changes in turbine structural loads, the potential impact on aeroacoustic emissions has yet to be quantified or completely understood. Active manipulation of turbine wakes is achieved by operating turbines at off-nominal set points, which necessarily impacts the 3D aerodynamic operation of the blades. Power losses induced by implementing wake control strategies on particular turbines are outweighed by the gains derived for other turbines in a wind plant by mitigating wake interaction, thereby elevating the aggregate energy extraction of the wind plant as a whole.  Off-nominal rotor control by yaw, thrust, pitch angle and/or rate of rotation is likely to induce local flow separation along the rotor blades and change the aerodynamic interaction with the local flow field. The extent to which active control induces additional aeroacoustic emissions from additional separation and other flow interaction dynamic effects must be quantified and then resolved. Given public concerns about wind turbine noise and the need for observational data required for regulators to establish noise restrictions, potential acoustic emissions resulting from active control must be understood prior to commercial deployment and the development of practical noise reduction methods and technology. Additional downstream acoustic propagation effects introduced by active yaw control must be investigated and understood for modern wind plant control strategies to be successfully implemented at the utility scale. |

**Project Objectives**

*This field contains the project-specific goals, objectives, and expected outcomes. For competitive awards, this field should include the goals, objectives and anticipated results that are determined from the award documentations.*

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| Aeroacoustic assessment project objectives are focused on quantifying the additional acoustic emissions introduced by implementing modern wind turbine and wind plant control strategies. Acoustic noise produced by wind turbines is one of the limiting factors on their operation and one of the constraints placed on development of wind plants. Specific FY20 objectives are to:   * Experimentally quantify the operational acoustic emissions resulting from a utility scale turbine operating under active wind plant control paradigms and ascertain the extent to which nominal operating emissions are exceeded. * Calibrate an existing semi-empirical acoustic propagation model to determine the impacts of a fully implemented active wind plant control deployment utilizing acoustic emission data obtained from experiments * Disseminate findings of aeroacoustic field observations for a utility-scale wind turbine operating under prescribed yaw offsets though peer-reviewed journal publications |

**Modality Summary**

*Provide the percentage amount for each TRL and modality level in the EERE Modality Matrix below. The percentage should equal* ***100%****. This matrix refers to the 9 types of project funding profiles/modes for research technology readiness levels and other program funding profiles in taking projects from Basic Research to Market Deployment.*

| **Modality #** | **Modality(s)** | | **Weight (%)** |
| --- | --- | --- | --- |
| 1 | Early-Stage R&D (TRL 1-3) | | |
| TRL 1 | Basic principles observed and reported: Scientific problem or phenomenon identified. Essential characteristics and behaviors of systems and architectures are identified using mathematical formulations or algorithms. The observation of basic scientific principles or phenomena has been validated through peer-reviewed research. Technology is ready to transition from scientific research to applied research. | 0% |
| TRL 2 | Technology concept and/or application formulated: Applied research activity. Theory and scientific principles are focused on specific application areas to define the concept. Characteristics of the application are described. Analytical tools are developed for simulation or analysis of the application. | 40% |
| TRL 3 | Analytical and experimental critical function and/or characteristic proof of concept: Proof of concept validation has been achieved at this level. Experimental research and development is initiated with analytical and laboratory studies. System/integrated process requirements for the overall system application are well known. Demonstration of technical feasibility using immature prototype implementations are exercised with representative interface inputs to include electrical, mechanical, or controlling elements to validate predictions. | 60% |
| 2 | Mid-Stage RD&D (TRL 4-6) | | |
| TRL 4 | Component and/or process validation in laboratory environment- Alpha prototype (component): Standalone prototyping implementation and testing in laboratory environment demonstrates the concept. Integration and testing of component technology elements are sufficient to validate feasibility. | 0% |
| TRL 5 | Component and/or process validation in relevant environment- Beta prototype (component): Thorough prototype testing of the component/process in relevant environment to the end user is performed. Basic technology elements are integrated with reasonably realistic supporting elements based on available technologies. Prototyping implementations conform to the target environment and interfaces. | 0% |
| TRL 6 | System/process model or prototype demonstration in a relevant environment- Beta prototype (system): Prototyping implementations are partially integrated with existing systems. Engineering feasibility fully demonstrated in actual or high fidelity system applications in an environment relevant to the end user. | 0% |
| 3 | Late-Stage RD&D (TRL 7-8) | | |
| TRL 7 | System/process prototype demonstration in an operational environment- Integrated pilot (system): System prototyping demonstration in operational environment. System is at or near full scale (pilot or engineering scale) of the operational system, with most functions available for demonstration and test. The system, component, or process is integrated with collateral and ancillary systems in a near production quality prototype. | 0% |
| TRL 8 | Actual system/process completed and qualified through test and demonstration- Pre-commercial demonstration: End of system development. Full-scale system is fully integrated into operational environment with fully operational hardware and software systems. All functionality is tested in simulated and operational scenarios with demonstrated achievement of end-user specifications. Technology is ready to move from development to commercialization. | 0% |
| 4 | Testing, Data Collection and Data Dissemination | | 0% |
| 5 | Strategic, Market and Techno-Economic Analysis | | 0% |
| 6 | Removing Deployment Barriers | | 0% |
| 7 | Technical Management | | 0% |
| 8 | Major Subcontracting | | 0% |
| 9 | Facility Costs | | 0% |
| **Project Total** | | | **100%** |

**Related Prime Awardee Projects**

*This type of project is* ***RARELY*** *used. They originate from FOAs. Related projects may be related in scope but* ***DO NOT*** *share the same Project Titles and Objectives. While the scope of the Labs might be similar, it is understood that the tasks are likely to be less interdependent than those seen in Multi-Performer Projects.*

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| **Office:** EE-4W Wind Energy Technologies Office | **Lab:** NREL |
| **Project Title** *(Can search for words found in title)***:** Aeroacoustic Assessment | |

**Multi-Performer Projects**

*When two or more Labs are working in partnership with each other to achieve a common objective/goal, their AOP Projects are considered Multi-Performer Projects. The source for these projects typically come from Directly Funded AOPs. The Labs share the same AOP Project Title and overall objective. However, the Lab tasks are distinct from each other yet are interdependent. Thus, the performances of these Labs can affect each other (i.e. a delay in a Lab’s project can impact the others) and the overall goal.*

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| **Office:** Choose an item. | **Lab:** Choose an item. |
| **Project Title** *(Can search for words found in title)***:** Click here to enter text. | |
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| **Office:** Choose an item. | **Lab:** Choose an item. |
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| **Office:** Choose an item. | **Lab:** Choose an item. |
| **Project Title** *(Can search for words found in title)***:** Click here to enter text. | |

**Milestones**

*EERE’s guidance is for each project to have one (1) Major Annual Milestone per year and Up to three (3) Progress Measures per year (envisioned to be quarterly during quarters where there is no Major Annual Milestone due).*

| **Milestone Name/Description** | **End Date** | **Type** |
| --- | --- | --- |
| 1.3.4.403, FY20Q1: Specify instrumentation needs to make point measurements for time- and frequency-domain assessment of aeroacoustic emissions of GE 1.5 MW wind turbine | 12/31/2019 | Quarterly Progress Measure (Regular) |
| 1.3.4.403, FY20Q2: 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. | 3/31/2020 | Quarterly Progress Measure (Regular) |
| 1.3.4.403, FY20Q3: Complete technical report on aeroacoustic code verifications using the updated framework of aeroacoustics module and physics models to interface with NREL modeling tools. | 6/30/2020 | Quarterly Progress Measure (Regular) |
| 1.3.4.403, FY20Q4: Submit article to peer-reviewed scientific publication detailing the aeroacoustic tests performed as part of the project and quantifying the changes in acoustic emission introduced by operating a utility-scale wind turbine in yawed conditions. | 9/30/2020 | Annual Milestone (Regular) |

**Go/No-Go Decisions**

*EERE’s guidance is for each project to have one (1) Go-No Go Milestone every 12-18 months.*

| **Name** | **Description** | **Criteria** | **Date** |
| --- | --- | --- | --- |
| Additional Aeroacoustic Testing | Determination on further active engagement to reduce active wind plant control emissions based on final assessment of observational data | Additional acoustic emission induced during wind plant control implementation that would require additional operational constraints | 9/30/2020 |
| Click here to enter text. | Click here to enter text. | Click here to enter text. | Enter a date. |

**Risks**

*The purpose of this page is to identify and document any risks that are associated with the AOP project.*

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| --- | --- | --- | --- |
| **Risk #1** | | | |
| Risk Name: Short observation window | | | |
| Status: Known | | Classification: Scope | |
| Risk Description: DOE 1.5 MW turbine is subject of several testing campaigns in FY20. All tests require favorable conditions to make the required observations. | | | |
| Response Plan: Extend observation window to collect data to make complete assessment possible. | | | |
| Risk Response: Mitigate | Risk Probability: Medium | | Risk Severity: Medium |
| Target Completion Date: 3/31/2020 | | | |
| **Risk #2** | | | |
| Risk Name: Model development delay | | | |
| Status: Known | | Classification: Schedule | |
| Risk Description: If numerical model to be developed in OpenFAST requires more time than expected, it could delay execution of modeling and validation of wind turbine noise under yawed conditions | | | |
| Response Plan: Prioritize model development subtasks to ensure that the most important components are completed first and that the resulting modeling framework is useable by the wind energy community. | | | |
| Risk Response: Avoid | Risk Probability: Low | | Risk Severity: Low |
| Target Completion Date: 6/30/2020 | | | |
| **Risk #3** | | | |
| Risk Name: Click here to enter text. | | | |
| Status: Choose an item. | | Classification: Choose an item. | |
| Risk Description: Click here to enter text. | | | |
| Response Plan: Click here to enter text. | | | |
| Risk Response: Choose an item. | Risk Probability: Choose an item. | | Risk Severity: Choose an item. |
| Target Completion Date: Click here to enter a date. | | | |

**Project Impacts**

*The purpose of this section is to identify and document how this newly planned/created project will impact the target audiences.*

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| **Deliverable/Product or "output" Description:**  Primary outputs of the Aeroacoustic Assessment project are a detailed dataset of field observations contrasting acoustic emissions of the DOE 1.5MW turbine on site operating under nominal and yawed conditions, an updated aeroacoustics model designed to interface with the current release of OpenFAST, and a journal article describing the methods used and insights derived from field testing. |
| **Audience/Customer:**  DOE, National Renewable Energy Laboratory, International Energy Agency |
| **Audience Use: (Outcome, or Impact, what is the intended use of "output" by Audience/Customer)**  Guidance on expected addition acoustic noise produced during wind plant control strategy implementation |
| **Communications/Outreach Strategy (to reach target audience):**  An NREL technical report or journal article describing the updated OpenFAST aeroacoustics module aligned with the Q3 project milestone and an article detailing scientific advancement of understanding of aeroacoustic emissions of wind turbines operating in off-nominal conditions as demonstrated by experimental data in the Journal of Renewable and Sustainable Energy or in the Journal of the Acoustical Society of America submitted by the end of FY2020. |
| **Does this project involve significant industry engagement?**  *(Significant industry engagement is defined as any direct contact, input, or collaboration with)* |
| **Description of Engagement:**  Reporting of field observations at NREL, assessment of observational data following suggested methods by IEA working groups, IEC and ANSI Standards, dissemination through conference presentation and peer-reviewed publication |

**Tasks**

*The purpose of this page is to identify and document any tasks that are associated with the AOP project. The primary reason tasks are included in the AOP Tool is for EERE Project Leads to determine that the task can result in major changes in deadlines or schedules. Note: Planned Cost amounts provided in this AOP write up are initial estimates and final cost plans will be submitted into the EERE AOP SharePoint site.*

| **Name** | **Description** | **FY20 Planned Cost** | **FY21 Planned Cost** | **FY22 Planned Cost** |
| --- | --- | --- | --- | --- |
| **Aeroacoustic Modeling and Observations** | The aeroacoustics project will be executed as three components of a single task, and roughly correspond to experimentation, numerical modeling, and instrumentation development.  **Subtask #1: Experimental Assessment of Turbine Level Noise and Propagation from Active Plant Control**  Validation of active wind plant control is currently under investigation as part of an existing multi-year program plan with NextEra. Considering future use of wake steering should consider acoustic emissions, which remain a constraining factor in the approval process for wind plant development and operation. Acoustic emission data will be collected concurrent at NREL’s Flatirons campus using the DOE-owned GE 1.5MW wind turbine along with meteorological observations and turbine performance data to provide a holistic assessment of performance enhancement and acoustic impacts under a diverse set of operating paradigms and atmospheric conditions.   * Procurement of instrumentation for measurement of 8-12 points in proximity to the GE 1.5 MW wind turbine * Deploy instrumentation, data acquisition system * Measure acoustic emissions for turbine under nominal and yawed operating conditions.   **Subtask #2: Numerical Assessment of Plant-Level Noise and Propagation from Active Plant Control**  A “Semi-Empirical Aeroacoustic Noise Prediction Code for Wind Turbines” (see NREL/TP-500-34478) was developed more than a decade ago as a module in the FAST simulation tool. This module utilizes acoustic emissions obtained empirically through experiment means with a simple propagation model to predict sound levels at prescribed radial positions. An updated module will be developed to operate under the current OpenFAST architecture to perform wind plant aeroacoustic assessment of active wind plant control. The OpenFAST module will be calibrated utilizing observations obtained from the experimental results in Subtask #1, and its accuracy quantified. Using the tuned model, an assessment of the acoustic emissions for a utility-scale plant will be undertaken to quantify the potential impact of plant-level active control implementation.   * Incorporation of an updated aeroacoustic module into OpenFAST and calibration using field observations * Numerical assessment of acoustic emissions of a wind plant assuming full implementation of yaw control   **Subtask #3: Advancement of Observational Capabilities for Aeroacoustic Emissions from Utility-Scale Wind Turbines**  Acoustic measurement technology has progressed in recent decades and has many applications for wind energy technology. For example, a phased array measurement system can be used to pinpoint sources of high acoustic emissions from turbine rotors. Future aeroacoustic assessment efforts may focus on source location identification, especially for off-nominal turbine operation, or novel turbine or blade designs. In anticipation of needing to resolve the potential sources of acoustic emissions with active rotor control, a small investment will be made in assessing the current state of the acoustic array hardware and software and a detailed plan for revitalizing the capability for anticipated implementation should it become necessary. If acoustic source identification is deemed a priority for future research by NREL/DOE, instrumentation will be updated, and additional equipment will be acquired to ensure that the necessary observations of acoustic emissions can be made.   * Assessment of existing technology and potential alternatives * Procuring additional acoustic measurement technology as necessary | $388,517 | $Enter Cost | $Enter Cost |

**Subcontractors**

*The purpose of this page is to identify and document any subcontractors that are associated with the AOP project.* *Note: Planned Cost amounts provided in this AOP write up are initial estimates and final cost plans will be submitted into the EERE AOP SharePoint site.*

| **Name** | **Responsibility** | **Sub**  **Type** | **Start**  **Date** | **End**  **Date** | **FY20 Planned Cost** | **FY21 Planned Cost** | **FY22 Planned Cost** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Click here to enter text. | None planned for FY20 | Choose an item. | Choose a date | Choose a date | $Enter Cost | $Enter Cost | $Enter Cost |
| Click here to enter text. | Click here to enter text. | Choose an item. | Choose a date | Choose a date | $Enter Cost | $Enter Cost | $Enter Cost |

**Travel**

*The purpose of this page is to gather and calculate all the travel expenses associated with the AOP Project.* *Note: Planned Cost amounts provided in this AOP write up are initial estimates and final cost plans will be submitted into the EERE AOP SharePoint site.*

| **Month** | **FY** | **Travel Type** | **Destination** | **Purpose** | **Estimated Cost** |
| --- | --- | --- | --- | --- | --- |
| Dec | 2020 | Domestic | San Diego, CA | Acoustical Society of America, 178th Meeting | $1500 |
| Jul | 2020 | Domestic | TBD | IEA Task update meeting | $1500 |
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**Financials**

*The purpose of this page is to gather and calculate all the costs associated with the AOP Project. A majority of this section will be populated by the project coordinator team based on information provided in the completed OCFO Pricing Tool or extracted from EPP Plans. Please complete the OCFO pricing tool or EPP Plans in accordance with the AOP development schedule. Note: Planned Cost amounts provided in this AOP write up are initial estimates and final cost plans will be submitted into the EERE AOP SharePoint site.*

**Project Financial Details**

| **FY 2020**  **Budget Authority (Planned)** | **FY 2021 Budget Authority (Planned)** | **FY 2022 Budget Authority (Planned)** |
| --- | --- | --- |
| $ Enter BA | $ Enter BA | $ Enter BA |

**Project Cost Plan**

*(Optional: final cost plans will be submitted into the EERE AOP SharePoint site)*

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **FY20** | | | | | | | | | | | |
| **OCT** | **NOV** | **DEC** | **JAN** | **FEB** | **MAR** | **APR** | **MAY** | **JUN** | **JUL** | **AUG** | **SEP** |
| $Enter Cost | $Enter Cost | $Enter Cost | $Enter Cost | $Enter Cost | $Enter Cost | $Enter Cost | $Enter Cost | $Enter Cost | $Enter Cost | $Enter Cost | $Enter Cost |

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| --- | --- | --- | --- |
| **FY21** | | | |
| **Q1** | **Q2** | **Q3** | **Q4** |
| $Enter Cost | $Enter Cost | $Enter Cost | $Enter Cost |

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| --- | --- | --- | --- |
| **FY22** | | | |
| **Q1** | **Q2** | **Q3** | **Q4** |
| $Enter Cost | $Enter Cost | $Enter Cost | $Enter Cost |

**Project Cost Breakdown**

*(Optional: final cost plans will be submitted into the EERE AOP SharePoint site)*

| **Category** | **FY20 Planned Cost** | **FY21 Planned Cost** | **FY22 Planned Cost** |
| --- | --- | --- | --- |
| In-House Labor | $Enter Cost | $Enter Cost | $Enter Cost |
| Subcontracts | $Enter Cost | $Enter Cost | $Enter Cost |
| Travel | $Enter Cost | $Enter Cost | $Enter Cost |
| Capital Equipment | $Enter Cost | $Enter Cost | $Enter Cost |
| Supplies | $Enter Cost | $Enter Cost | $Enter Cost |
| Other | $Enter Cost | $Enter Cost | $Enter Cost |
| **Total** | **$Enter Cost** | **$Enter Cost** | **$Enter Cost** |