**Overview**

The aeroacoustic emissions of a utility-scale wind plant operating under active plant-level controls will be assessed as part of the ongoing NextEra field measurement campaign. Whereas active plant control utilizing both wake deflection and induction 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 total 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 any potential conflicts with limitations 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 acoustic propagation effects introduced by active yaw and or thrust control must be investigated and understood for modern wind plant control strategies to be successfully implemented at the utility scale.

**Program Goals:**

* *Determine the degree to which implementation of active wind plant control adversely impacts wind plant aeroacoustic emissions and limits the viability and deployment of active control and increased AEP.*
* *If active wind plant control is found to have significant aeroacoustic emissions impacting public acceptance and potential deployment, develop an R&D strategy to assess the underlying physics driving emissions and alternative mitigation strategies.*

**Program Objectives:**

* *Quantify experimentally the operational acoustic emissions resulting from two utility scale turbines operating under active wind plant control paradigms and ascertain the extent to which nominal operating emissions are exceeded.*
* *Calibrate an existing empirical acoustic propagation model to determine the impacts of a fully implemented active wind plant control deployment utilizing acoustic emission data obtained from experiment.*
* *Assess current experimental capability using phased acoustic arrays to identify sources of emission from active control implementation on rotors for future mitigation quantification.*

**Program Tasks:**

**Task #1: Experimental Assessment of Turbine Level Noise and Propagation from Active Plant Control**

**Estimated cost $300K**

**Experimental Approach**. Validation of active wind plant control is currently under investigation as part of an existing multi-year program plan with NextEra. The current research initiative will be augmented to include aeroacoustic emission and propagation measurements as part of the on-going field measurement campaign. Acoustic emission data will be collected concurrent 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. The equipment required for high-quality acoustic monitoring is widely available and relatively inexpensive. Significant investment is required in data analysis of the acoustic emissions records and validate of models against observations. In addition to developing acoustics measurement and analysis expertise internally, data collection and reduction will be supplemented with services provided by established external experts. Major elements of Task #1 include and are not necessarily limited to:

* Development of detailed timeline and cost plan
* Coordination with the existing NextEra experimental campaign
* Procurement of instrumentation for simultaneous measurement on two to three utility-scale turbines consisting of 10-12 acoustic measurement points per turbine
* Subcontract services for acoustic data collection and data reduction to subsidize internal work

**Task #2: Assessing Plant Level Noise and Propagation from Active Plant Control**

**Estimated cost $150K**

**Numerical Approach**. 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. For initial assessment of aeroacoustic emissions and propagation, a simple model is preferable to the time and investment that would be required for a more physically accurate model based on high-fidelity numerical simulations. The updated module will be added to OpenFAST 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 Task #1, and its accuracy quantified. Using the tuned model, an assessment of the acoustic emissions at Peetz will be used to quantify the potential impact of plant-level active control implementation. Major elements of Task #2 include and are not necessarily limited to:

* Incorporation of an updated aeroacoustic module into OpenFAST and calibration using field observations
* Assessment of acoustic emissions at Peetz assuming full implementation of active control
* Go/No Go determination on further active engagement to reduce active wind plant control emissions based on final assessment

**Task #3: Experimental Assessment of Acoustic Emission Sources**

**Estimated cost $50K**

**Experimental Approach**. Significant investments have been made by the wind program in developing a phased array measurement system to pinpoint sources of high acoustic emissions from turbine rotors. 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 deemed necessary, instrumentation will be updated or modernized, and additional equipment will be acquired to ensure that the necessary observations of acoustic emissions can be made. Major elements of Task #3 include and are not necessarily limited to:

* Assessment of existing technology and potential alternatives
* Updating phased array system and data acquisition hardware
* Procuring additional acoustic measurement technology as necessary.