U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Small Business Vouchers

Project ID #T19

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Sandia National Laboratories

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U.S. DEPARTMENT OF ENERGY | NNSA

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FY17-FY18 Wind Office Project Organization

"Enabling Wind Energy Options Nationwide"

Technology Development

- Atmosphere to Electrons
- Offshore Wind
- Distributed Wind
- Testing Infrastructure
- Standards Support and International Engagement
- Advanced Components, Reliability, and Manufacturing

Market Acceleration & Deployment

- Stakeholder Engagement, Workforce Development, and Human Use Considerations
- Environmental Research
- Grid Integration
- Regulatory and Siting

Analysis and Modeling (cross-cutting)

Project Overview

T19: Small Business Vouchers

Project Summary

- **SkySpecs:** Evaluate advanced drone-deployed nondestructive inspection methods.
- **Micron Optics:** Demonstrate wind turbine fiber-optic data acquisition in real-world operating environment.
- **GroupNIRE:** Develop remote grid services controller utilizing rotor inertia.

Project Objective & Impact

- National lab staff working with U.S. small businesses to advance product offerings by transfer of technology and knowledge.

Project Attributes

Project Principal Investigator(s)

Ray Ely and Josh Paquette (SkySpecs)
Jon White and Brandon Ennis (Micron)
David Schoenwald and Jon Berg (Group NIRE)

DOE Lead

Michael Derby

Project Partners/Subs

SkySpecs
Micron Optics
Group NIRE

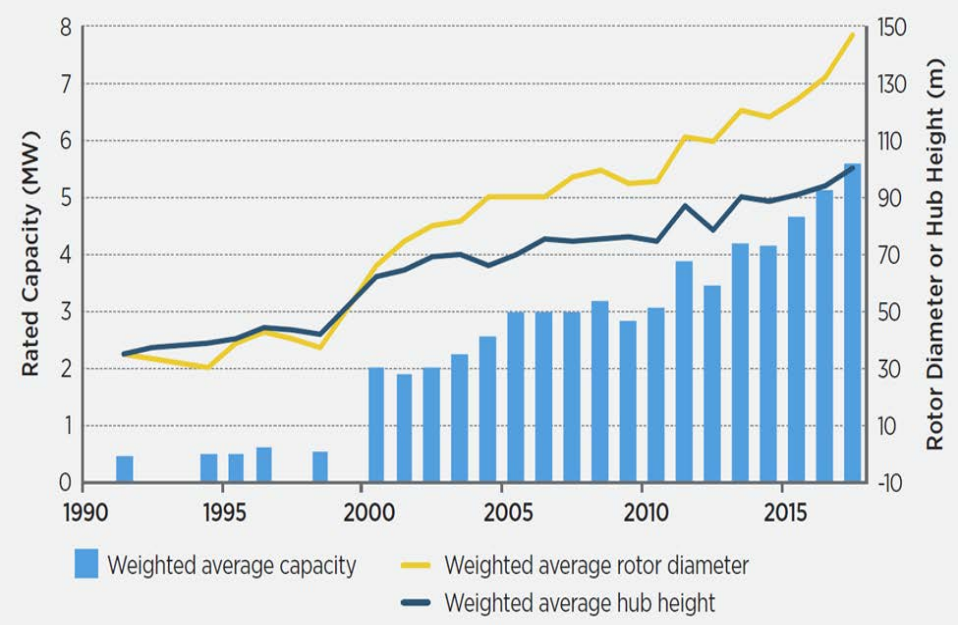
Project Duration

1 year

SkySpecs

Technical Merit and Relevance

- **The Wind Industry has a growing need for operations and maintenance, including inspections and repairs**
  - Wind Energy market sharing continues to grow
  - Average rotor diameters, and associated blade costs, have increased
  - Off-shore wind creates new maintenance challenges
  - Many blades are reaching their designed 20-year lifetime



U.S. Department of Energy. "Wind Vision: A New Era for Wind Power in the United States," DOE/GO-102015-4557, April 2015.

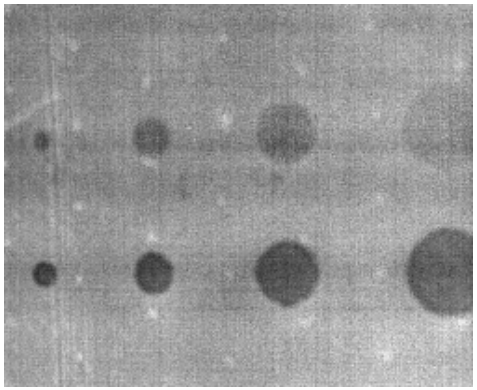
- **Current inspection practices are limited**
  - Mostly ground-based visual inspection (i.e., cameras on tripods)
  - SkySpecs has developed drone-based visual inspection systems
- **A need exists for fast and reliable surface and subsurface (i.e., nondestructive) inspection systems, in order to identify and repair damage before the damage propagates, resulting in more costly repairs**

Approach and Methodology

- Performed an extensive trade study to identify potential inspection methods
- Selected the thermography inspection method using miniature infrared cameras
  - Small and lightweight (fits on SkySpecs's existing drone and gimbal)
  - Inspections can be performed at a distance from the blade which mitigated potential drone/wind blade control and collision concerns
  - Proven history of inspecting fiberglass and carbon fiber structures
- Evaluated concepts for thermal stimulus and selected solar radiation (i.e., sun/shade)
- Demonstrated thermal stimulus concept works in a benchtop setting

FLIR IR Camera (15 g)

(320 X 256 pixels)



Thermal Stimulus Benchtop Demonstration

Solar Radiation Thermal Stimulus

Accomplishments and Progress

- Demonstrated a drone-deployed thermography system can detect find flaws approx. 0.25” deep during benchtop testing
- Developed software for processing the raw infrared camera data
- Performed hardware and software integration on SkySpecs drone platform
- Conducted initial field testing with SkySpecs

Thermography System Integration

Initial Field Testing

Communication, Coordination, and Commercialization

- Released SAND report SAND2018-3116 Development and Evaluation of a Drone-Deployed Wind Turbine Blade Nondestructive Inspection System
- Presented findings at 2018 Sandia Wind Blade Workshop
- Conducted follow-on discussions with SkySpecs about integrating the technology into their business model
  - More customers have begun asking about IR inspections
  - Some financial challenges due to the extra inspection time required

Micron Optics

Technical Merit and Relevance

- Wind turbine control systems would benefit from active load measurement to inform control decisions
- Requires robust data acquisition and reliable sensors
- The performance of Micron Optics fiber optic strain sensors paired with the Hyperion interrogator can be validated at SWiFT

Hyperion

cRIO Controller

Approach and Methodology

- Install Micron Optics fiber optic interrogation system, Hyperion, at SWiFT
- Utilize the system during an experimental campaign
- Develop operational calibration method for wind turbine loads from strain gages

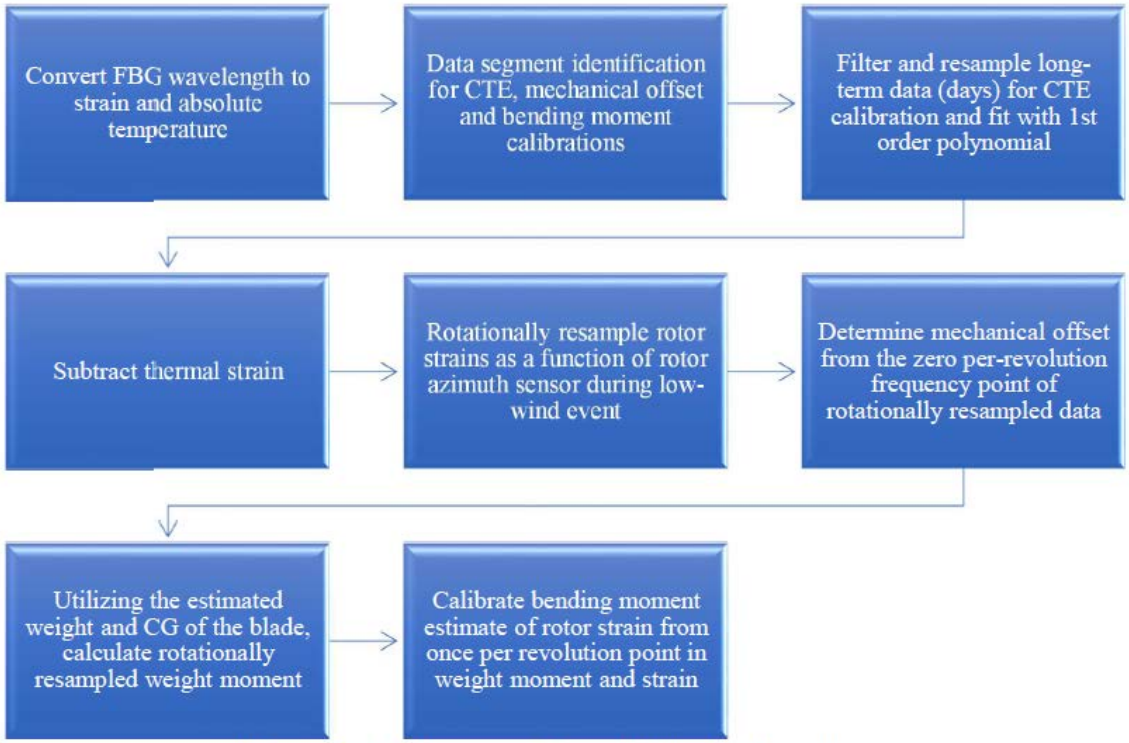
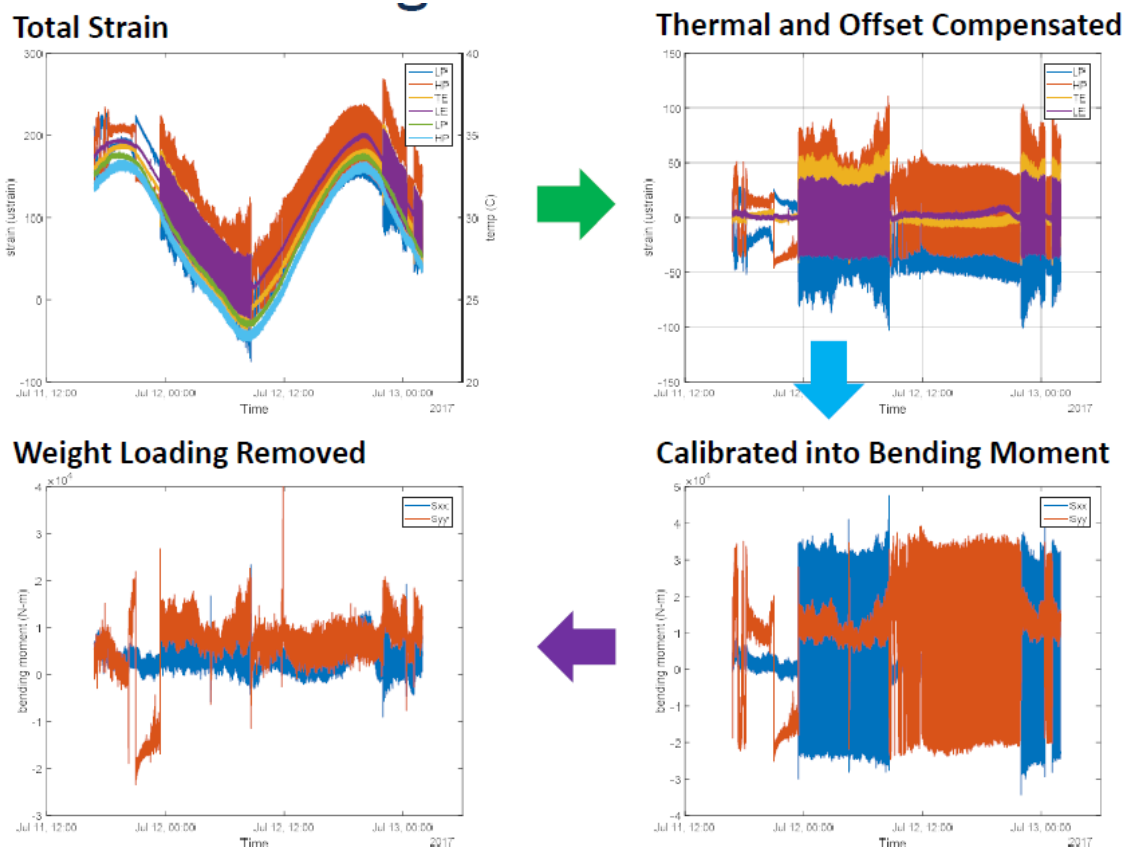


Figure 3. Strain data correction and calibration flow chart.

Accomplishments and Progress

- Data acquisition of operational strain gage measurement during a test campaign at SWiFT
- Operational calibration method developed and assessed to perform accurately



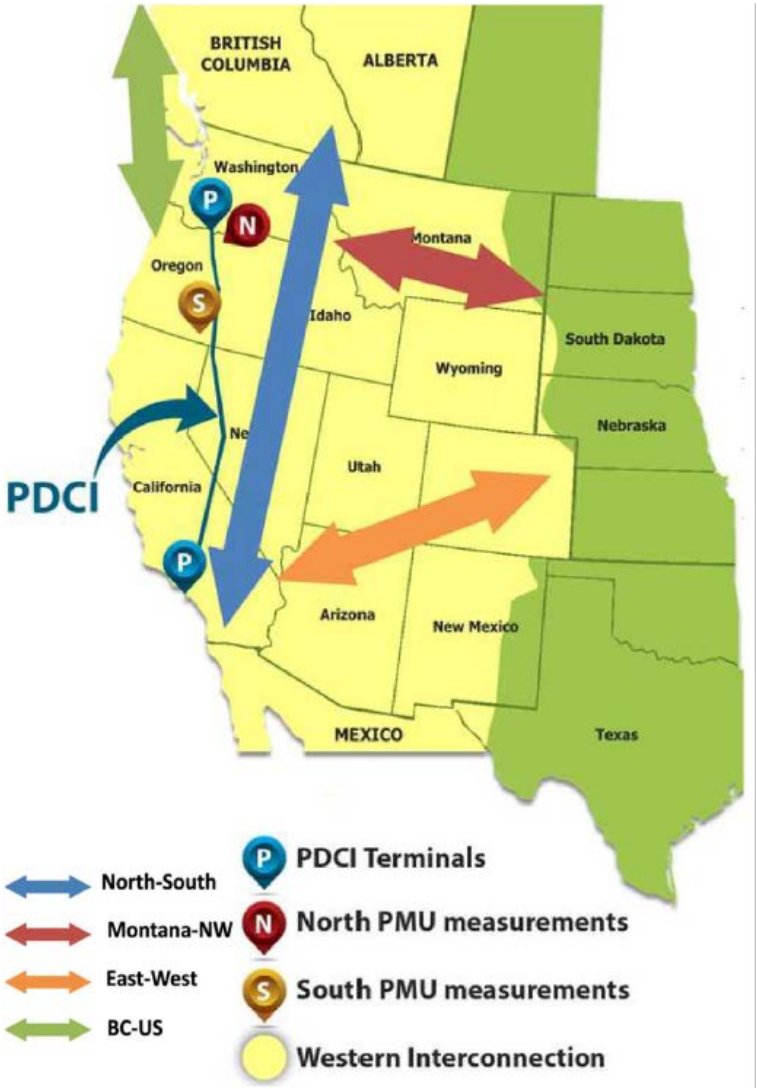
Communication, Coordination, and Commercialization

- **Work resulted in summary report delivered to Micron Optics on the blade load calibration process**
- **Work resulted in direct publication of calibration methodology and data analysis of fiber optic strain from the Wake Steering experiment at SWiFT**
  - "Estimation of Rotor Loads Due to Wake Steering," AIAA SciTech Conference
- **Calibration of strain sensors was used in two international, peer-reviewed publications**

GroupNIRE

Technical Merit & Relevance

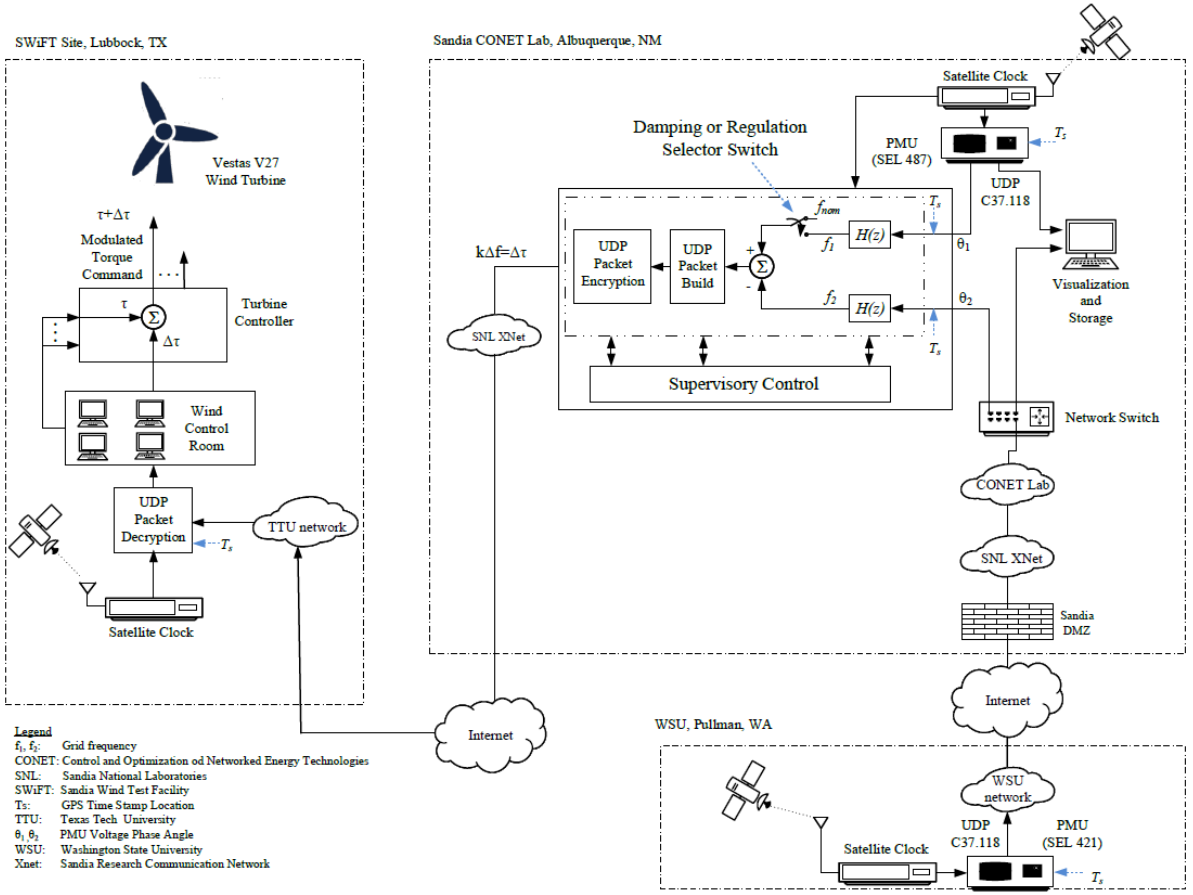
- Wind energy displaces synchronous generation
- Concern about decline of several grid-quality services inherent to synchronous generation
- Wind turbines have high potential to contribute to grid services through inertial energy storage in the rotor
- Control systems to utilize this require further development
- Build upon prior work which used power modulation to provide damping of oscillation in the US Western Interconnection



From SAND2018-5248PE

Approach and Methodology

1. Establish controller in Sandia CONET* lab with necessary feedback control algorithms
2. Test power modulation on SWiFT wind turbine emulator to verify safe operation
3. Establish network connectivity between SWiFT and CONET, characterize network quality (latencies, corrupted data, time stamps), and asses real-time feedback control performance.
4. Obtain streaming PMU data from two geographically-separated locations.
5. Determine system oscillatory mode(s) of interest and create feedback control test plan for wind turbine power modulation.
6. Obtain streaming SWiFT turbine data of power and time-of-arrival of CONET control commands.
7. Test and monitor feedback control of wind turbine power modulation



From SAND2018-7178

*Control and Optimization of Networked Energy Technologies

Accomplishments and Progress

From SAND 2018-7178

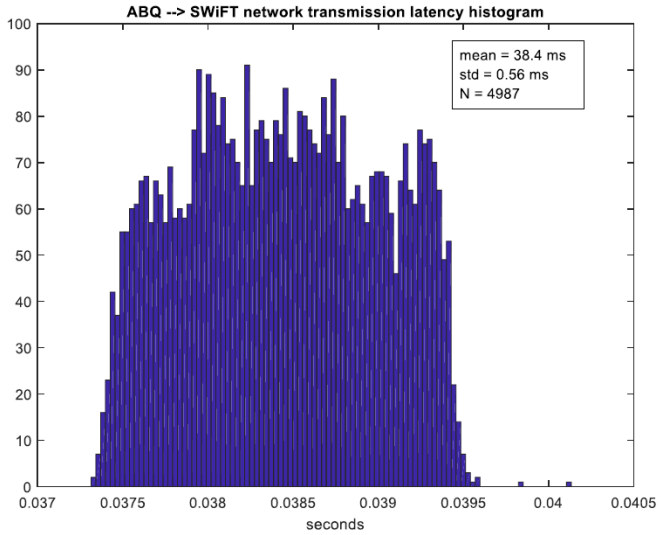


Figure 9 Network Packet Transmission Latencies, ABQ to SWiFT.

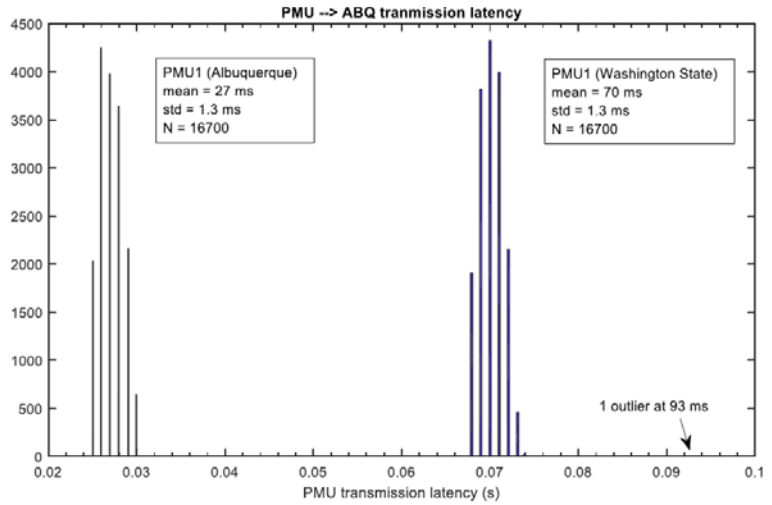


Figure 10 Network packet transmission latencies, PMUs to ABQ.

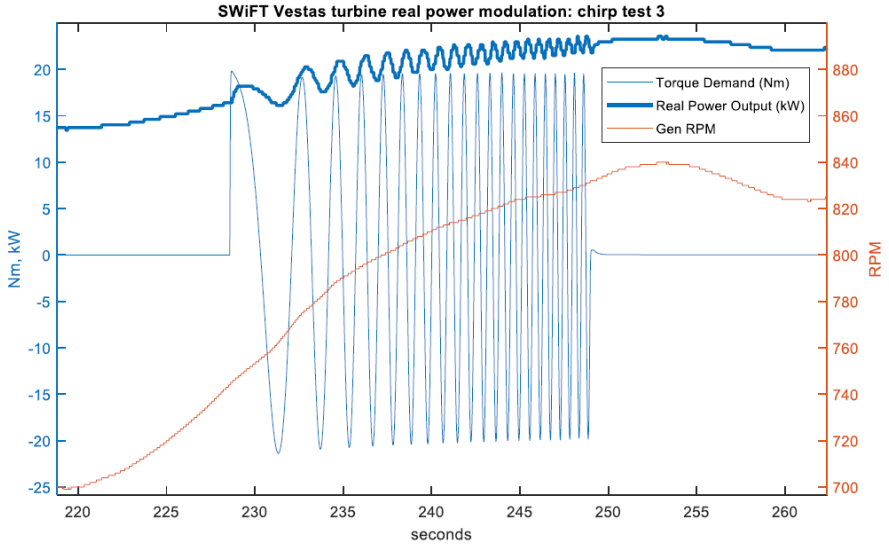


Figure 12 Chirp Test (0.1 To 2Hz) With T = 0.125 And 20Nm Peak Modulation.

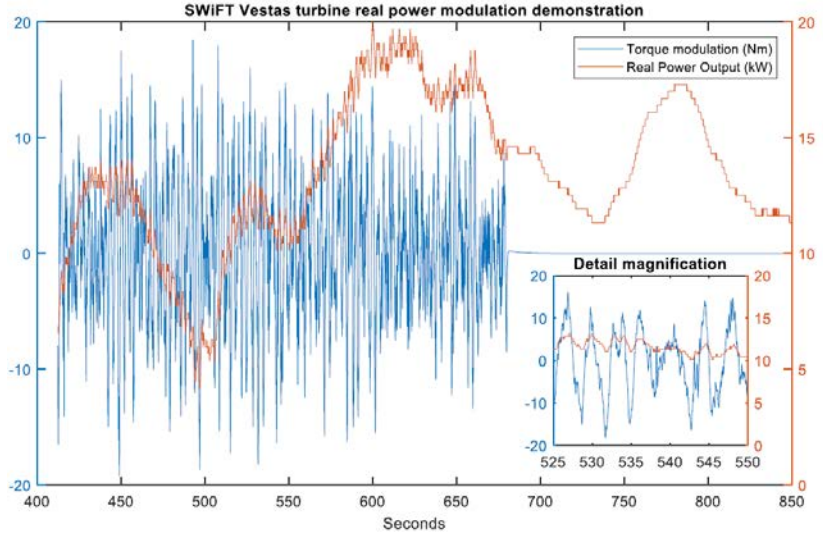


Figure 14 Torque Modulation (Received at the Turbine Nacelle) and Power Output.

Communication, Coordination, and Commercialization

- Discussed the possibility of commercialization with wind turbine manufacturers
- Interest in offering wind turbines with grid service capability
- Power purchase agreements often do not incentivize wind turbine operators to provide grid services
- Sandia is continuing to explore communication and commercialization strategies