DOE / SNL Scaled Wind Farm Technology (SWiFT) Facility at TTU

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SWiFT exists to:

- Reduce turbine-turbine interaction and wind plant underperformance
- Develop advanced wind turbine rotors
- Public open-source to advance simulation capabilities

Facilities:

- Three variable-speed variable-pitch modified wind turbines with full power conversion and extensive sensor suite
- Two heavily instrumented inflow anemometer towers
- Site-wide time-synchronized data collection
Outline

- What is the SWiFT Facility?
- What research projects use SWiFT?
- How can I use SWiFT?
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Location, Location, ... Location

- 7.5 m/s at 50 m, Class 5 Wind Site!
- Consistent South Wind, 180.5° Average
Layout
SWiFT Wind Turbines

Hardware

- Collective Pitch System
- 300 kW Variable Speed Generator
- AC-DC-AC Full Scale Convertor
- National Instruments controllers
- Complete turbine / rotor state instrumentation
- Fiber Optic blade sensing system
Why this size?

A cost-efficient size for which research can be directly scaled to larger, more costly and time-consuming sizes.

Requirements:

- Operation at Reynolds Number (scaling parameter) between $10^6$ and $10^7$
- Tip speeds approaching 80 m/s for acoustics and large rotor projects
- Variable-speed variable-pitch operation
- Minimal cost and time associated with research operations
- Highly reliable turbine
- Minimal restrictions on publication and intellectual property
SWiFT Wind Turbines

Control Software

- Open Source Code
- Modularized by Subsystem
- EtherCAT up to 1000 Hz
- All DAQ signals available for control
- Running on NI Veristand
- Parameterized Variable Speed and Torque Controller
- Maintains all original safety systems and alarms
Met Mast Configuration
Experimental Research Test Site at Lubbock, Texas

Inflow Characterization

Met mast sensors
3D Sonic: ATI SAT/3A Sonic Anemometer
Cup: Thies Wind Sensor First Class Advanced (IEC 61400)
Vane: Thies Wind Direction Sensor First Class
T: 592 Met One Temperature sensor
BP: 992 Met One Barometric Pressure sensor
RH: 593 Met One Relative Humidity sensor
DPR: ATI PAS-821 DataPacker

Met mast heights*
58.5 m: 3D Sonic
56.5 m: T, RH
45 m: 3D Sonic, Cup
31.5 m: 3D Sonic, Cup
29.5 m: 3D Sonic, Vane
27.5 m: T, RH, BP
18 m: 3D Sonic, Cup
10 m: 3D Sonic
2 m: T, RH, BP

Guy wires
Radius 47.5 m
57.91 m
45.11 m
29.87 m
14.63 m

DnV IEC standard boom arm

0.368 m
30 deg
0.425 m
Guy wires
Networking Infrastructure

- GPS synced measurements
- Up to 1000 Hz
- Currently 500+ channels
- Centrally logged data
- Fiber optic data transfer
- Localized deterministic control loops
Control Building

- Central control and operations
- 700 sq. ft. with 2 temporary offices for proprietary work
- Electrical troubleshooting lab
Experimental Preparation Lab

- 4,500 sq. ft. environmentally controlled high-bay experimental rotor preparation
- 1,000 sq. ft. machine shop
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- How can I use SWiFT?
SWiFT Baselining

- Detailed analysis of fundamental turbine-turbine interaction
- Calibration and verification of public open-source wind turbine / plant model
- Data quality analysis and troubleshooting
The National Rotor Testbed is a rotor innovation to enable technology acceleration.

Baseline blades represent functionally scaled-down aerodynamics and structural dynamics of a modern megawatt-scale rotor.

Baseline blade design is public and open.

Enables research in: wake interactions, aero-acoustics, inboard aerodynamics, controls, aeroelastic dynamics.
Wake Imaging Measurement System

- Capture detailed 3-D flow structures that convect downwind
- High spatial resolution: 16,000 data points per sample
- Imaging allows for fast scanning sufficient to capture sub-rotor scale turbulent flow structures
- Enables direct comparison with high-fidelity and engineering level models
Future SWIFT Research Ideas

- Partnership opportunities:
  - Rotor design for wind plant (wake reduction)
  - Quiet rotor design
  - Active / passive load control
  - CM and SHM validation testbed
  - Blade repair validation rotors
  - Stealth rotor
  - Advanced materials rotor testing
  - Component field testing (sensors, blades, controllers, etc.)
  - Land-based offshore simulator
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How to partner

- SWiFT is open to all partnership opportunities:
  - Partners include industry, academia, laboratories, etc.
  - Facility has been designed to minimize research cost
  - Public, public / proprietary and solely proprietary all possible
- Partnership agreements include:
  - Work For Others (WFO)
  - Collaborative Research and Development (CRADA)
  - Memorandum of Understanding (MOU)
  - Joint Funding Opportunities (FOA)
Partnership Examples

- **Vestas** installed a turbine owned by Vestas and managed by Sandia as a technology accelerator for their product development (rotors, acoustics, wind plant control)

- **National Instruments** is co-developing cRIO hardware and Veristand software for distributed control

- **ABB** is using power electronics equipment to improve wind market products
Thank you!
Backup Slides
Aerodynamic Scaling

The diagram illustrates the relationship between Reynolds Number and Rotor Blade Radius (meter) in the context of wind turbines. It shows different turbine configurations, such as SNL V27 (original) and SNL V27 (modified), along with their corresponding Reynolds Numbers (1.0E+06, 2.2E+06, 1.7E+06) and Tip Velocity (77.9 m/s, 61.0 m/s). The graph also includes SNL Micon 65 with a Reynolds Number of 4.1E+05 and a Tip Velocity of 51.5 m/s. The tip velocities range from 50.0 m/s to 80.0 m/s, and the rotor blade radius is measured from 5 to 40 meters.
Cost Efficiency

Rotor and Mold Cost Multiplier from V27 Baseline

- 20 m Rotor (115 kW) 0.4x
- 27 m Rotor (225 kW) 1.0x
- 47 m Rotor (660 kW) 5.3x
- 70 m Rotor (1.5 MW) 17.4x

Cost Multiplier vs. Rotor Diameter (meter)
Crane Cost Comparison

<table>
<thead>
<tr>
<th>Research Scale (225 kW)</th>
<th>Megawatt Scale</th>
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<tbody>
<tr>
<td>Costs</td>
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<td>$5,000 v. $250,000</td>
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<tr>
<td>Scheduling</td>
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<td>Days v. Months Ahead</td>
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<td>Testing Risk</td>
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<td>Low v. High</td>
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National Open-Source Research Asset

DOE / SNL Rotor Blade Designs
Feasibility Proof
Technology Demonstration
Commercialization

TRL-1 TRL-2 TRL-3 TRL-4 TRL-5 TRL-6 TRL-7 TRL-8 TRL-9

Basic Research Technology Development Sub-Scale Testing

DOE / SNL Advanced Blade Testing at NREL-NWTC
DOE / SNL FAST / ADAMS Model of V27
DOE / SNL SWIFT Facility at TTU
Research-Scale Examples of Success

- “Light detection and ranging measurements of wake dynamic Part I & II” 2011
- LIDAR Scanning of 95 kW Turbine Wake
- Decomposition of Wake Deficit

- CX / TX / BSDS Blade Family Study
- Fabrication and Testing at the 115 kW Scale

Result: 24% reduction in damage equivalent load and initiated industrial use of carbon, flatback airfoils and twist-bend coupling.
DOE/SNL/TTU Partnership

Wind Science and Engineering Research Center (WISE) has a 40 year history in wind-related research and development

Unique Capabilities and Facilities

- Distributed Wind Resource Assessment
  - 2x mobile Doppler research radars
  - Distributed Wind Resource Assessment

- Large-scale Test Infrastructure
  - 200 meter anemometer tower
  - MW Wind Turbines
Variable-Speed Upgrade

Fixed Speed

Variable Speed (Open-source)

1: 23.4 50 Hz
1: 27.6 60 Hz

Gearbox

Induction Generator

480 V

1287 RPM (50 Hz GB)
1520 (60 Hz GB)

PM Or Induction Generator

250 – 300 kW

Power controller

Main controller

Turbine systems

DOE/SNL

Full scale converter

ACS-800-17 regenerative drive

Capacitor bank

225 kW – 6 poles
1008 RPM 50 Hz
1209 RPM 60 Hz

101 A 50 Hz
335 A 60 Hz

50 kW – 8 poles
760 RPM 50 Hz
906 RPM 60 Hz

396 A 50 Hz
335 A 60 Hz

Variable Speed Upgrade

Gear box

PM Or Induction Generator

Full scale converter

ACs-800-17 regenerative drive

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Vestas

U.S. Department of Energy

Turbine systems

Main controller

Turbine systems

Power controller

PM Or Induction Generator

Full scale converter

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Sandia National Laboratories

Vestas

U.S. Department of Energy

Turbine systems

Main controller

Turbine systems

Power controller

PM Or Induction Generator

Full scale converter

ACS-800-17 regenerative drive

Sandia National Laboratories

Vestas

U.S. Department of Energy
Re-purposed Assembly Building
Site Construction
Anemometer Tower
SWIFT Array Long-Term Plan

Phase 1
Vestas Turbine

Phase 1
DOE/SNL Turbines
SWIFT Array Long-Term Plan

Phase 2
SWIFT Array Long-Term Plan

Phase 3
Phase 4

SWIFT Array Long-Term Plan