Vertical-Axis Wind Turbines Revisited: A Sandia Perspective
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Part I: Sandia VAWT Pioneers
Original SNL VAWT Program

- Early 1970’s to mid 1990’s
- Started with Savonius rotors, Moved Quickly to Full-Darrieus Rotors
- Succession of Designs: Leading to the Very Successful 17-m, 100 kW Full-Darrieus VAWT
- Successful Commercialization
  - Most notable: FloWind
    - Over 500 VAWTs Deployed: Primarily in Altamont Pass
    - 170 19-m Turbines in their Fleet
- Culminated with Design of the 34-m Research VAWT Test Bed
  - Commercialization
    - The Point Design
    - FloWind EHD Turbine
- Sandia consulted for the 3.5 MW Eole VAWT project
34-m VAWT Test Bed

- Located in Bushland, TX
  - Dedicated: May, 1988
  - Decommissioned: Spring, 1998

- Rotor: 34-m Dia, 50-m Height

- Performance:
  - Variable Speed: 25 to 38 rpm
  - Rated Power: 500 kW
  - Peak Rotor Cp = 0.42

- Heavily Instrumented
  - 72 Strain, 25 Environmental,
    22 Performance, 29 Electrical

- Large Database, Many Publications
Important Contributions

- Demonstrated a Full-System Approach to Design of Wind Turbine
  - VAWT Specific Airfoils: Sandia NFL Airfoil Family

- Innovative Instrumentation and Data Analysis Techniques
  - Natural Excitation Technique (NeXT) for Modal Testing of Large Structures
  - Fatigue Material Database

- Extensive set of VAWT design codes with accompanying validation data sets

- Manufacturing: largest open-cell extrusions ever made at that time
Goodbye, for now, VAWTs

- FloWind goes bankrupt in mid 1990s
- DOE eliminates VAWT research program
- Why were VAWTs unsuccessful?
  - Difficult market conditions of that time
  - Economics of sub-MW, land-based wind energy
    - Longer blades, larger rotor weight per kW
    - Relatively poor fatigue performance of aluminum blades
    - Slightly lower demonstrated aerodynamic performance
Retrospective Report

Available at energy.sandia.gov
Part II: The Case for Offshore VAWTs
Offshore Wind Economics

Lifecycle Cost Breakdown for a Shallow-Water Offshore Wind Project

Offshore Design Challenge: O&M Costs > 25% of the Total Project Cost

- **Horizontal Axis Wind Turbine (HAWT):**
  - Drivetrain at tower top
  - Yaw and blade pitch systems add complexity
  - Outcome: Larger O&M cost

- **Vertical Axis Wind Turbine (VAWT):**
  - No yaw and blade pitch systems
  - Drivetrain at tower base
  - Outcome: Smaller O&M cost
The most reliable component is the one that’s not there.

- Eb Rechtin
Offshore Design Challenge:
Foundation Costs > 20% of Total Project Cost

Outcome:
Relatively expensive platform, mooring, and foundation

Outcome:
Relatively inexpensive platform, mooring, and foundation

Horizontal Axis Wind Turbine (HAWT)

Vertical Axis Wind Turbine (VAWT)

Higher CG

Lower CG
Operating cyclical gravity loads and resulting fatigue impact increase with rotor size.

Outcome: Blade weight becomes increasingly difficult design challenge with larger rotors.

Operating cyclical gravity loads and resulting fatigue impact are minimal.

Outcome: Blade weight does not limit rotor size.

Offshore Design Challenge: Increased Supporting Infrastructure Cost Demand Larger Rotors

Horizontal Axis Wind Turbine (HAWT)

Vertical Axis Wind Turbine (VAWT)
Wind direction can vary significantly across a large rotor, which attempts to align with the wind.

Outcome: Rotor performance decreases with size

VAWT rotor energy capture is insensitive to wind direction.

Outcome: Rotor performance insensitive to size

Offshore Design Challenge: Increased Supporting Infrastructure Cost Demand Larger Rotors

Horizontal Axis Wind Turbine (HAWT)

Vertical Axis Wind Turbine (VAWT)
Part III:
European Offshore VAWT Efforts

Aerogenerator Project – UK, Wind Power Ltd.

DeepWind Project – EU, led by DTU-Wind

Nenuphar - France
New, 5-year, DOE Project Initiated in late 2011: Innovative Offshore Vertical-Axis Wind Turbine Rotors

Goal: Demonstrate that 20% reduction in COE is feasible by development of large, deep-water offshore VAWT system

Technical focus of the project is the rotor subsystem
Work Packages

- Preliminary Design of Novel Offshore VAWT Rotor (What does it look like?)
- Floating VAWT System and COE Analysis (What does it cost?)
- Materials and Manufacturing (How do you build it?)
- Proof-of-Concept Testing (Can it work?)
Partners

- DNV
- Iowa State University
- The University of Maine
- tpi
- Sandia National Laboratories
- AT&T
**Requirement:** Time-domain aero-hydro-elastic model for a VAWT of general configuration

**Approach:**
- *A modular finite element framework* for an offshore wind energy design tool
- VAWTGen mesh generator capable of arbitrary configurations
- Coupling of structural dynamics with aerodynamic models of varying fidelity
- Improvement of SNL NuMAD to model VAWT blades
VAWTGen Sample Meshes
Design Challenges

- Cost-effective aerodynamic brake for overspeed prevention
- Lightweight, multi-MW VAWT rotors
  - Reduce or eliminate the tower
  - Molded and/or pultruded composite blades
  - Resonances and stability!
- Aerodynamically efficient VAWT rotors
  - Avoid designs with large parasitic drag sources
- Floating System Design
  - Example: DTU-Wind rotor/spar-buoy solution
Questions?