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2014 Wind Turbine Blade Workshop

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FREE WiFi Available
Large Offshore Rotor Development: 
THE SANDIA 100-METER SERIES OF BLADE DESIGNS

Abstract

Design and development of large blades is very challenging due to economic, logistical, and technical barriers. This is a very challenging design problem, and one that becomes more challenging to do cost-effectively as blades grow even longer. Addressing these challenges is a major motivation behind this research. Sandia National Laboratories [Ref. 1] has been researching large blades at 100-meter length for several years and has documented several key design challenges [Ref. 2] for large blades in the course of this work, which include gravitational fatigue loading, panel buckling, and aerodynamic stability. Through a series of design studies for 100-meter blades, the goal has been to mitigate these technical challenges in order to achieve a light-weight, cost-effective, manufacturable, and aerothermically stable 100-meter blade design. The final study focused on the effects of flatback airfoils and blade slenderness with respect to these challenges.

Background on Sandia 100-meter Design Studies

This research began with an all-glass baseline 100-meter blade design study that produced the SNL100-00 baseline design [Ref. 2]. The baseline design was heavy and not cost-effective due to elevated design pressures on structural requirements for fatigue, buckling, and deflection. Thus a series of follow-on studies and improvements were pursued to evaluate pathways to achieve:

- a light-weight, cost-effective, manufacturable, and aerothermically stable 100-meter blade design.

THE FOLLOW-ON STUDIES INCLUDING THE CURRENT STUDY ARE SUMMARIZED AS FOLLOWS:

1. SNL100-01 blade: carbon fiber study [Ref. 6], CFD analysis of the baseline design [Ref. 4], flutter parametric study and flutter tool improvements [Ref. 3],
2. SNL100-02 blade: advanced geometry [SNL100-03: improved geometry with flatback airfoils.]
3. SNL100-03: Rev0: with same DU foils but with updated geometry
4. SNL100-03: Rev1: with flatback airfoils (more slender than Rev2)
5. SNL100-03: Rev2: with same DU foils but with updated geometry

The focus of the most recent study is design of blades with varying slenderness using flatback airfoils with attention to aerodynamic, structural, manufacturing, and economic trade-offs.

All-glass Baseline Blade: SNL100-00 114 ton weight Reference 2

Pre-Design Geometry for the SNL100-03 100-meter Blade

The final design study is focused on the effects of flatback airfoils and blade slenderness for SNL100-03.

100-METER DESIGN VARIANTS IN THIS STUDY:

- “Baseline”: SNL100-02 blade, up-scaled DOWC chord
- “Rev0”: With same DU foils but with updated geometry
- “Rev1”: With flatback airfoils (more slender than Rev2)
- “Rev2”: With flatback airfoils (more slender than Rev1)

The three new geometries were compared with respect to blade weight, loads, deflection, fatigue, buckling, flutter speed, and surface area on large prototypes. It should be stressed that neither the Rev1, Rev2, nor Rev2 designs are final designs as the tabulated data is intended to focus on the effects of airfoils and slenderness effects for similar layouts (identical for Rev0 & Rev2). Systematically optimized designs will be the focus of the subsequent work that leads to a final SNL100-03 design that meets the stated design objectives.

Manufacturing Cost Analysis

One example: An analysis of labor costs shows the growth in labor hours for area-driven manufacturing tasks such as paint prep and paint as blades grow longer [Ref. 5].

References

3. Griffith, D.T. and Johanns, W., "Lowest Panel Buckling Freq. Spar Fatigue @ 15% (years)" Structural and aerodynamic performance constraints were included in the design process to produce these blade geometries. AEP was constrained to be the same for all four design variants.
8. "Rev0": With flatback airfoils (more slender than Rev2)
9. "Rev1": With flatback airfoils (more slender than Rev2)
10. "Rev2": With flatback airfoils (more slender than Rev1)

Acknowledgement

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Project Website: http://largeoffshorerotor.sandia.gov

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Blade Reliability Collaborative

**Core Areas of Research**

**INSPECTION TECHNOLOGIES**
characterize blade defects and damage in manufacturing plants and in the field

**EFFECTS OF DEFECTS**
strength and service life

**LEADING EDGE EROSION**

**BLADE REPAIRS**
and aerodynamic performance

**STANDARDS AND PARTNERSHIPS**

**Partners**

- E\(\text{voZ}v\)\(v\text{w}\)\(v\text{h}\)\(v\text{J}D\)\(v\text{v}\)\(v\text{U}\)\(v\text{u}\)\(v\text{W}\)\(v\text{v}\)\(v\text{v}\)\(v\text{v}\)
- d\(\text{W}\)\(v\text{h}\) D & 'UZ')\(v\text{h}\)'U\(\text{h}\)\(v\text{UW}Z\)U \(v\text{v}\)\(v\text{Z}v\)o)\(v\text{U}v\text{v}\)\(v\text{v}\)\(v\text{v}\)

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[Image of a wind farm]
Continuous Reliability Enhancement for Wind (CREW) Database & Analysis Program

BENJAMIN KARLSON, JON WHITE, CHUCK CARTER, CARSTEN WESTERGAARD, SHAWN MARTIN
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Introduction

The “20% Wind Energy by 2030” report (Department of Energy, 2008) specifically discusses financial risks from increasing Operations and Management (O&M) costs and the impact of lower-than-expected reliability. With the Department of Energy sponsorship, Sandia National Laboratories established the CREW (Continuous Reliability Enhancement for Wind) program to benchmark the U.S. wind turbine fleet’s reliability and O&M performance, help prioritize technology improvement opportunities, and assess plant-level performance.

In 2013, an internal reassessment of the CREW effort was performed to identify the value of the benchmark, the gaps in the data, and opportunities to be better aligned with the wind industry. The reassessment found that wind plant owner/operators have been developing in-house reliability data collection tools with similar goals to the CREW project and that the original CREW strategy has been overtaken by a fast growing wind industry. However, a national reliability benchmark remains highly desirable for the wind industry to assist with their objectives of maximizing power performance yield, decreasing financial risk and uncertainty, and understanding reliability trends across turbine models, turbine components, geographical locations, and age.

Methods

Sandia partnered with Strategic Power Systems (SPS), whose ORAPWind© (Operational Reliability Analysis Program) software collects real-time data from wind plant partners, including information from their Supervisory Control and Data Acquisition (SCADA) systems. In 2014, another data pathway was added, for summarized data directly from owners/operators.

Data Aggregation Steps

1. Gather sufficient data (duration, breadth) to aggregate without violating anonymity.
2. Create individual plants models and perform time accounting.
3. Create the aggregate reliability model with event frequencies and durations, by weighing individual plants models by their number of turbine-days. Also, create aggregate time accounting by summing turbine hours across plants.

Data Collection

Sandia partnered with Strategic Power Systems (SPS), whose ORAPWind© (Operational Reliability Analysis Program) software collects real-time data from wind plant partners, including information from their Supervisory Control and Data Acquisition (SCADA) systems. In 2014, another data pathway was added, for summarized data directly from owners/operators.

Data Reporting Goals

PUBLIC BENCHMARK
- Wind Turbine (Other)
- Rotor/Blades
- Electric Generator Controls
- Gearbox
- Power Distribution Structures - Enclosures
- Braking System
- Balance of Plant
- Yaw
- Hydraulic Control
- Drivetrain

2013 Benchmark Results

Availability Time Accounting

- Generating: 83.0%
- Reserve Shutdown - Wind: 4.3%
- Reserve Shutdown - Other: 10.3%
- Scheduled Maintenance: 0.3%
- Unscheduled Maintenance: 1.0%
- Forced Outage & Unavailability: 1.1%

Downtime Event Summary, By System

Conclusions

- Results are stabilizing and generally align with other published industry metrics
- More owner/operators insight is critical to understand the complete reliability picture, including component-level issues

Expected Data partner Benefits

- Expand national benchmark to better represent the U.S. fleet and gather more owner/operator insight
- Develop technology-exploration platform to create software tools for the industry

Proposed Future Work

The investment costs for wind farm projects are high. The cost of O&M of wind turbines is partially a function of the reliability of the system components. CREW participation will benefit owner/operators through improved asset performance and reliability maximizing power performance yield, decreasing financial risk and uncertainty, and better understanding of reliability trends.

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The full Benchmark can be accessed at http://energy.sandia.gov/crewbenchmark
Wind Blade Material Testing

Figure 1. Constant Life Diagram of a biaxial glass-epoxy laminate under alternating axial stress. Publicly available data such as this represent thousands of tests conducted over years making it infeasible for most material suppliers to conduct on their own.

Figure 2 (left). A new subscale test fixture at Montana State University will enable testing to build a database of structural elements (inset) in addition to the existing coupon tests.

Figure 3 (below). A building-block approach to blade testing and simulation based upon a framework developed for aerospace will provide more accurate test data to improve design software and increase reliability of new blade designs.

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2a. Wind Turbine Blade RCS Reduction

The wind industry has successfully followed an evolutionary process moving toward minimum cost, minimum weight, and high-efficiency designs, but interference with radar systems remains a problem. Some objectives of this effort include:

- Decrease sensitivity
- Increase false tracks
- Replace or augment radar
- New wind turbine design, or layout
- High false alarm rates
- Integration questions

The integrated-absorber designs indicate that 20 dB or greater return loss can be achieved by integrating simple RAM into the existing blade fabrication processes. However, 20 dB return loss does not necessarily correspond to 20 dB RCS reduction for a complete turbine.

2b. Interagency Field Test & Evaluation

Objectives

The Interagency Field Test and Evaluation (IFTEL) program was established to investigate and address the concerns of growing interference of wind turbines on the Nation’s air surveillance radars. The program has three primary goals:

1. Investigate current wind farm / radar interference problem.
2. Collect data and increase technical understanding of interference issues to improve the understanding of the impact, and allow viable paths to increase the deployment of wind energy across the country.
3. Develop wind-turbine-radar-cross-section modeling capability for the purpose of reducing wind turbine RCS.

Technical Approach

DOE and DOD recognized the wind turbine / radar interference problem and began to formally address it in 2010. SANDIA partnered to conduct field test campaign over 2 years. A Request for Information (RFI) for proposed mitigation options was issued and responses collected.

3 Flight test campaigns were conducted at operational radar sites impacted by wind turbines.

Significant Findings

The integrated-absorber designs indicate that 20 dB or greater return loss can be achieved by integrating simple RAM into the existing blade fabrication processes. However, 20 dB return loss does not necessarily correspond to 20 dB RCS reduction for a complete turbine.

2c. TSPEAR

Objectives

Tool for Siting, Planning and Encroachment Analysis for Renewables. This effort to develop accurate wind turbine / radar interference models will ultimately improve the understanding of the impact, and allow viable paths to increase the deployment of wind energy across the country. The TSPEAR toolkit aims to support energy developers and government agencies who desire to design, analyze, track progress, and maintain configuration control of complex energy projects. The initial effort is to support wind energy analysis with regard to radar systems.

Technical Approach

TSPEAR is designed to be a web-based siting, planning and assessment tool that supports renewable energy deployment. It is envisioned to be a state-of-the-art suite integrating new and existing tools and databases with quantitative underpinnings to support decision making. This effort is organized into a multi-phase approach to properly develop the TSPEAR framework:

- Phase I: Development of TSPEAR foundational framework; inclusion of radar and proposed wind turbine-radar interference (WTRI) mitigation technologies
- Phase II: Addition of radar mitigation tools; connect to other databases (TBD)
- Phase III: Addition of radar mitigation tools; connect to other databases (TBD)
- Phase IV: Full implementation of TSPEAR framework

Significant Findings

Wind turbines cause problems for existing radars:

- Several potential mitigation strategies exist
- Several solutions show promise, no silver bullet

4. Summary of Results and Findings

As part of DOE’s approach to address siting barriers, Sandia has:

- Identified potential mitigation tools
- Developed a web-based framework (TSPEAR Phase I) with functional CARSR, Pilot Mitigation Projects. Additionally, Sandia will continue to improve upon the TSPEAR framework and incorporate other critical siting databases such as environmental, transmission, cultural, etc.

5. Proposed Future Work

The WTRI effort will continue as more wind farms are proposed near radar systems. Sandia is investigating the options for an offshore WTRI field test. Sandia will continue to support the strategic WTRI plan and will assist in any potential Pilot Mitigation Projects. Additionally, Sandia will continue to improve upon the TSPEAR framework and incorporate other critical siting databases such as environmental, transmission, cultural, etc.

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Reliability and Operations and Maintenance (O&M) Standards Development
Sandia National Laboratories, Wind Energy Technologies

Introduction

The National Standards Policy Advisory Committee defines a "Standard" as:
A prescribed set of rules, conditions, or requirements concerning definitions of terms; classification of components; specification of materials, performance, or operations; delineation of procedures; or measurement of quantity and quality in describing materials, products, systems, services, or practices.

The wind industry benefits from unbiased third parties engaging in the discussions about technical and performance criteria that inform Standards development. Sandia’s unique expertise, especially in high-performance computing and reliability data analysis, is needed to improve fact-based Standards which benefit market interactions.

Methods

Sandia has worked on a variety of Standards and Best Practices over the years. In FY2012-2014, the work included:

- IEC 61400-1 Design Requirements
- IEC 61400-26 Availability
- International Energy Agency (IEA) Task 33 Reliability Data Best Practices
- American Wind Energy Association (AWEA) Operations and Maintenance (O&M) Best Practices

Sandia’s resources and expertise in high-performance computing, along with a strategic partnership with the University of Texas-Austin, creates a modeling competence used to evaluate the IEC 61400-1 Design Requirements (Loads) Standard in an unbiased, fact-based environment. Sandia’s long history in reliability analysis and expertise from the CREW reliability project uniquely positions Sandia to contribute to Standards and Best Practices in reliability, availability, O&M, and data collection and reporting.

Results and Conclusions

IEC 61400-1 Design Requirements

The team created a 100-year loads database for a 5 mega-watt (MW) onshore turbine and a 64-year version for a shallow water offshore turbine. Their paper, “Decades of Wind Turbine Load Simulation,” won “Best Paper” at the American Society of Mechanical Engineers Wind Energy Symposium. A simpler extreme load extrapolation procedure was developed that reduces ambiguity from extrapolating a short term distribution to an extreme 50-year value; this is currently under consideration for the next Standard revision.

IEC 61400-26 Availability

The Time-Based Availability Standard (61400-26-1) and the Production-Based Standard (-2) have both been published. The Plant-Wide Availability Standard (-3) is in development, with Sandia contributing reliability block diagram models of wind power stations with both turbine and Balance of Plant components.

OUT YEARS

As IEC standards evolve to address certification topics more completely, Sandia will ensure that its core competencies of load definitions, turbine–to–turbine effects, and blades/testing will contribute to select IEC standards through our research products.

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Offshore Wind: Innovative Deep-water Vertical Axis Wind Turbine (VAWT) Rotors

1. Introduction

The availability of offshore wind resources in coastal regions along with a high concentration of load centers in these areas makes offshore wind energy an attractive opportunity. Reductions in cost of energy are crucial for the viability of offshore wind, and are likely to come from decreases in installation and O&M costs while increasing energy production. Wind turbine rotor design has a significant impact on these areas.

VAWTs held significant interest in earlier days of wind energy technology, but in the early 1990s the configuration was largely abandoned and the horizontal-axis wind turbine (HAWT) was adopted as the primary turbine configuration. The VAWT, however, is poised to complement the need for lower COE in the offshore wind arena. Placement of the gearbox and generator at the base of the tower lowers installation, platform, and O&M costs by having these components readily accessible at water level. VAWTs possess a simple design and insensitivity to wind direction, allowing for economical scaling to large sizes, further decreasing COE.

VAWT Design Tools

To remain a viable option for offshore wind energy, VAWTs will need to undergo significant development in coming years. Thus, a number of design tools are needed to aid in developing innovative offshore VAWT designs. The following VAWT design tools have been developed by Sandia National Laboratories (SNL) and project partners:

SNL OFFSHORE WIND ENERGY SIMULATION TOOLKIT (OWENS):
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine

SNL CODE FOR AXIAL AND CROSS-FLOW TURBINE SIMULATION (CACTUS):
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine

VAWE/CWIRe HYDRODYNAMICS AND PLATFORM DYNAMICS CODE:
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine

Analysis Framework

Flexible, modular analysis framework
- OWENS is the core driver code and structural dynamics module
- CACTUS is the aerodynamic module
- AeraDyn is the acoustic module
- drive-train modules

Tower Resonance In Vawt Designs

Tower resonance has historically been an issue for VAWT designs. Previous work employed experimentally observed rules of thumb to understand critical per-rev excitations for tower modes. An analytical expression for critical tower modes of an N-bladed VAWT was developed and verified using CACTUS aerodynamic simulations. Conventional “look-up” tables were developed for VAWT designers to understand critical per-rev frequencies that drive tower resonance.

Code Coupling

OWENS employs the above analysis framework, network sockets, and coupling algorithms to map to external software modules. These modules include:
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine

Baseline platform coupling verification procedures:
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine
- 6DOF(6-DOF) Turbine

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Conclusions

VAWTs are a potentially transformative technology for lowering the cost of energy for offshore wind. A number of design tools have been developed by Sandia National Laboratories to facilitate the development of innovative offshore designs. The OWENS toolkit provides a modular analysis framework for multi-physics simulation and a robust finite element structural dynamics formulation capable of considering arbitrary VAWT designs.

A greater understanding of critical per-rev tower excitations as a function of blade number was gained through this work and coupled rotor-support structure studies showed an opportunity to alleviate VAWT tower resonance concerns through innovative platform designs. Aeroelastic stability investigations showed wide VAWT designs and NLM do not appear to have aeroelastic instabilities within design operating ranges. Initial investigations suggest glass composite designs may be more susceptible to aeroelastic instability than carbon composite (likely due to the increased stiffness to mass ratio of carbon composites).

Future work will continue to develop and validate the OWENS toolkit as external modules and validation data sets become available. The aeroelastic stability analysis capability implemented in OWENS will also be enhanced and validated in future work.
Wake Imaging System

**Visualizing the Invisible**

**Figure 1:** Notional schematic of the Wake Imaging System deployed at the SWiFT facility. Each receiver system would measure a single component of the flow velocity as represented by the 10m x 10m viewing area in the wake of a 225 kW turbine.

**Figure 2:** Schematic of the intermediate-scale experiments in an outdoor test structure (top) and actual inside photograph of initial system tests showing the laser sheet scattering from the mineral oil aerosols (bottom).

**Planar Doppler Velocimetry**

A technique called Planar Doppler Velocimetry (PDV) was chosen to measure flow structures at the time and length scales needed at the SWiFT facility. A laser sheet illuminates the flow field which contains aerosols (natural or seeded) which scatter the laser light, shifting the frequency up or down based upon their velocity and direction (i.e. Doppler effect). A two-camera system with a filter that converts frequency shifts to intensity differences is used to create a velocity image with the help of software algorithms and calibration data. Unlike particle image velocimetry, the individual particles do not need to be tracked, however the optical system is much more complex. Instantaneous velocity images are possible.

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Wind Turbine Generator Modeling

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1. Introduction

Positive-sequence power flow and dynamic models are required for demonstrating compliance with system reliability criteria and for planning system expansions. As more wind power plants interconnect with the electric power system, it becomes increasingly important that they are properly modeled in dynamic studies. Generic, standard and publicly available models have not been readily available to the regional reliability organizations and grid operators who are responsible for maintaining the grid.

Development and validation of these planning models for wind power plants continues to be a high priority for the industry. NERC has clearly stated that developing and improving access to validated, non-proprietary planning models is a pre-requisite for large-scale integration of variable generation. With the availability of Wind Turbine Generator (WTG) models, planning of wind energy can be accomplished in a manner that allows for reliable power without an overbuilt system.

NERC POINT OF VIEW: “Validated, generic, non-confidential, and public standard power flow and stability (positive-sequence) models for variable generation technologies are needed. Such models should be readily validated and publicly available to power utilities and other industry stakeholders. Model parameters should be provided by variable generation manufacturers and a common model validation standard across all technologies should be adopted.”

Developing and improving validated, non-proprietary planning models is a prerequisite for large-scale integration of variable generation.

2. Technical Approach

The effort to develop and maintain standard public dynamic simulation models for the purpose of power system analysis has a wide industry reach. From the transmission planners who need the models for their mission to the wind manufacturers that own detailed proprietary models to the power system planners, the availability of Wind Turbine Generator (WTG) models, planning of wind energy can be accomplished in a manner that allows for reliable power without an overbuilt system. Sandia is the chair of the Renewable Energy Modeling Task Force (REMTF) within the Western Electricity Coordinating Council (WECC) that has been leading this effort.

Sandia is the lead U.S. delegate to the International Electrotechnical Commission (IEC) technical committee for electrical simulation models for wind power generation. Through these groups, Sandia has been able to successfully collaborate with industry to develop the second generation of generic WTG models.

3. Results

Model validation is generally a four step process:

1. Define the model structure
2. Implement the model
3. Compare against measured data
4. Then refine model or model parameters and repeat

We refer the reader to TR-1067: Model Validation Tool for a more complete guide. Sandia’s second generation of WTG models are based on the four steps above

The second generation of models were approved by the WECC in January 2013. Leading up to these approvals much work was done within the group to actually test and attempt to validate the model structures against field measured responses of various vendors’ equipment for single wind turbine generators. One example is shown in Figure 3 with the use of the EPRI Wind Turbine Generator Model Validation Tool.

The methods presented in this work aim to assist in determining the maximum short-circuit behavior of the entire plant at the point of common coupling.

4. Conclusions

In the end, the ultimate goal of these efforts is to have suitable models for wind power plants that adequately represent the dynamic behavior of the entire plant at the point of common coupling.

5. Summary of Results and Findings

- Validation efforts are underway and current techniques demonstrate that the physical models behave reasonably well for power system simulations
- Significant effort has been made to improve on the capabilities of the WECC and IEC groups

6. Current Work

- Continuing efforts include:
  - Improved short-circuit models for wind farms
  - Development of a data model for WECC/REMTF guides on wind models
  - Coordination and participation in industry effort is paramount
- NERC FAC-002: Wind Turbine Generator Modeling Task Force
- WECC/REMTF guides on wind models

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Figure 4 – Wind Turbine Generator Modeling Implementation

The second generation of WTG models have been implemented and released in GE’s PSLF, Siemens PTI PowerWorld, and PowerWorld.

Other wind models
- Phase 2 Wind Turbine Generator (WTG) Models

Deficiencies were identified in the initial generation of the generic wind turbine generator models in 2010. This led to both the WECC and IEC groups to focus on expanding the generation model to allow for a wider range of control strategies and has led to the creation of a second generation of models with a focus on the type 3 and type 4 WTGs.

An important new aspect of the second generation models is the decision by both groups to move towards a modular approach. That is, the models are made up of smaller modules that are truly generic and usable for any appropriate renewable generation system. This allows for additional versions to be developed for each module as changes are deemed necessary in the future. This also facilitates the differences between the two approaches (WECC and IEC) to be addressed simply through the development of different modules.

Phase 2 Wind Turbine Generator Modeling

Due to the longer history of use and experience with synchronous machines in the electric power grid, the short-circuit behavior of power plants using these types of machines is well understood compared to a wind power plant. It is the goal of this guideline to educate utility engineers on short-circuit modeling of wind power plants in order to increase the understanding of wind power plant behavior.

Figure 5 – Short-circuit for WTG models

Conventional generators are typically modeled on an individual basis, however, wind farms employ many machines that make modeling individual generators not practical.

The methods presented in this work aim to assist in determining the maximum short-circuit contribution from a wind power plant for system impact studies (verifying current is within interrupting ability of protection devices), relay coordination, and arc flash hazard studies.

Wind Turbine Blade Workshop
August 26th–28th

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The new open source baseline for rotor innovation and turbine-turbine interaction research

1. Purpose and Objectives
In order to capitalize the SWiFT investment, a modern designed blade must be benchmarked.

At the same time, the A2e Initiative is in need of unique rotor hardware at multiple size scales to support a long term (5-7 year) model validation campaign.

2. Impact
This project will lead to improved understanding of the relationships between rotor design and wind plant performance in terms of dynamic power and loads related to:
- \( \delta_{\text{B}} \)
- \( \delta_{\text{b}} \)
- \( \beta_{\text{h}} \)

The ultimate impact is on increased wind plant AEP and wind plant reliability.

3. Assumptions
A2e programs and wind plant performance is key to future industry success:
- \( Q_{\text{MW}} \) (MW-scale turbine rotor)
- \( Q_{\text{SWIFT}} \) (SWIFT rotor)

A variety of functionally scaled tests will allow for complex structures and their physics to be isolated and to maximize efficiency of test budgets

4. Challenges
Challenges associated with this problem include:
- \( K_{\text{MW}} \)
- \( z_{\text{MW}} \)
- \( Z_{\text{SWIFT}} \)

5. Approach
Wake Character from Vortex Method

Medium fidelity wake models are able to relate rotor and wake character in a quick-turnaround design environment

High fidelity wake models provide realistic previews of upcoming field tests and provides insights to needs of validation

6. Partners, Subcontractors, and Collaborators

7. Proposed Future Work
These rotors provide the industry with a relevant, open source baseline rotor testbed for public and proprietary research. The initial design represents only the beginning of an exciting future in exploration of wind energy technology innovations.

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