FY2005 DOE Wind Program
Implementation Meeting

Small Wind Research Turbine (SWRT)
November 17, 2004 – Dave Corbus
Rationale for SWRT testing and furling model development

• Poor understanding of small turbine loads and dynamic behavior especially furling
• Lack of high quality data sets for small turbine model development and validation
• Wind turbine aero-elastic models did not include furling
• Test procedures unique to small turbines need to be addressed
SWRT testing and model development approach

• **SWRT Test**
  • Most comprehensive small turbine test
  • Three different turbine configurations tested

• **Upgrade FAST model to include furling**
  • Perform model comparisons between FAST and ADAMS
  • Perform model validation between FAST-SWRT model and SWRT data
SWRT test description

- Flap and edge blade strain gages
- Yaw slip rings and encoder
- Furl Sensor
- Sonic anemometer junction box
- Shaft sensor
- Tower leg load cell “washers”
- Rotor slip ring, encoder, and amplifiers
SWRT shaft sensor - first accurate small turbine thrust measurements
Pre-testing turbine characterization

- Data for modeling included:
  - Tail assembly and main frame:
    - Weight, Cg, bi-filar, moment of inertia about yaw axis
  - Magnet can Cg and moment of inertia estimated in Solidworks
  - Tail damper properties
  - Exact turbine geometries
  - Blade modal test
Max and Mean Furl vs. Mean Wind Speed
10-minute data files

Mean Wind Speed m/s

Furl, deg

Max Furl  Furl
SWRT furling event – time series plot

- sonicwsmet (m/s)
- Furl (deg)
- ShftThrus2 (N)
- yaw error (deg)
- RotorSpd (RPM)

Wind Speed & Furl Angle

Shaft Thrust

Yaw Error

Rot Rotor RPM

Time, seconds
Furling and inflow

SWRT Config "A" Furling Angle & Coh TKE vs Ri

- Furling angle
- Mean Coh TKE
- Max ART Response

2-80m layer Ri

Furling angle (deg)

Hub Mean Coh TKE (m²/s²)
FAST model  furling upgrades

What? ▪ New to FAST is the availability of a lateral offset and skew angle of the rotor-shaft, rotor-furling, tail-furling, and tail inertia and aerodynamics

Why? ▪ Requested by SWT manufacturers.
 ▪ Recommended action from the NWTC Furling Workshop, July, 2000.

How? ▪ Polled users of FAST and SWT community for potential needs.
 ▪ Redeveloped FAST’s equations of motion to incorporate furling; then codified changes.
 ▪ Dynamics verified via comparisons to ADAMS
FAST vs. SWRT 10-minute mean/max rotor thrust force

[Graph showing the comparison between test mean, test max, FAST Mean, and FAST Max rotor thrust forces as a function of mean windspeed.]
FAST vs. SWRT 10-minute mean/max rotor RPM

![Graph showing FAST vs. SWRT 10-minute mean/max rotor RPM](image)
FAST vs. SWRT 10-minute mean yaw error

![Graph showing FAST vs. SWRT 10-minute mean yaw error](image-url)
FAST vs. SWRT 10-minute mean/max furl angle

- Mean Windspeed, m/s
- Furl Angle, deg

- Test mean
- Test max
- FAST Mean
- FAST Max
Rotor thrust for one 10-minute file of Configuration B with resistor load – 17.6 m/s average wind speed
Rotor speed for same 10-minute time period
Rotor yaw angle for the same time period
Tail furl angle for the same time period

Furl Angle, deg

Time, s
Outreach and industry participation examples

- **SWRT test results and FAST model available on NWTC website**

- **Windward Engineering**
  - Use SWRT data analysis results and FAST model to provide modeling capabilities to industry

- **Bergey Windpower**
  - Testing results used for turbine development
Accomplishments

- FAST furling model available
- 2 ASME papers completed documenting SWRT test and FAST modeling results
- Better understanding of small wind turbine dynamic behavior, including thrust and furling
- Better test procedures for small turbine testing
- Questions still remain on FAST furling model validation and small wind turbine modeling in general
Future Work

- **SWRT testing completed**
  - Further SWRT analysis
    - model comparison for final configuration C
    - Run FAST model with TurbSim to better quantify inflow effects
  - Final SWRT technical report
  - Windpower paper for 2005
    - will include some IEC 1400-2 comparisons

- **Other NWTC code developments will help both small and large wind turbine modeling efforts**
  - Non-linear generalized dynamic wake model, TurbSim for turbulent inflow, future FAST modifications

- **Planning for future wind tunnel test to get more detailed data such as wake data?**