Important Considerations When Designing a New Small or Medium Scale Wind Turbine

Distributed Wind Energy Association Annual Conference
25 February 2025

Drew Gertz

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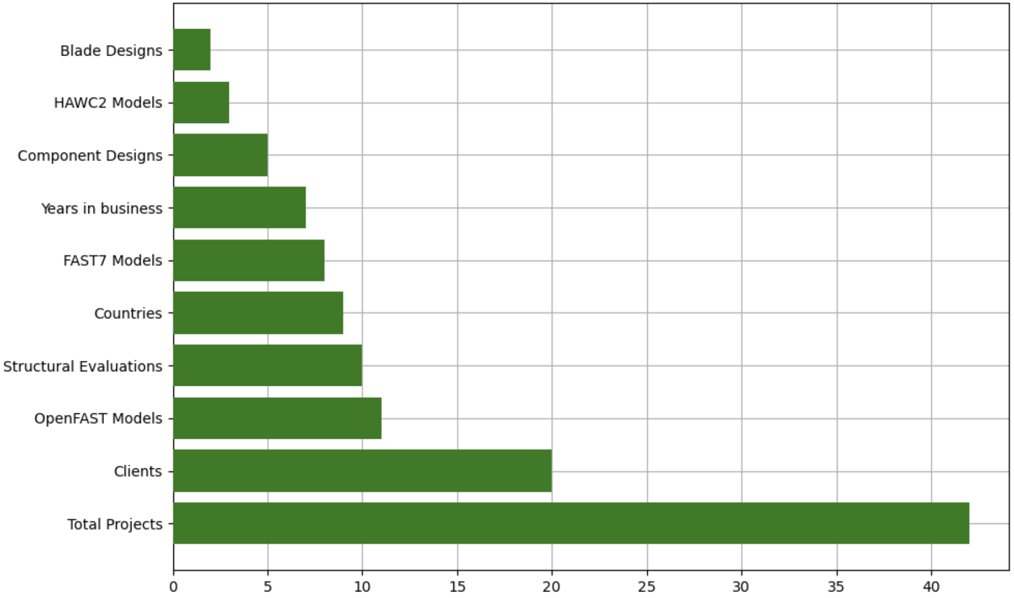
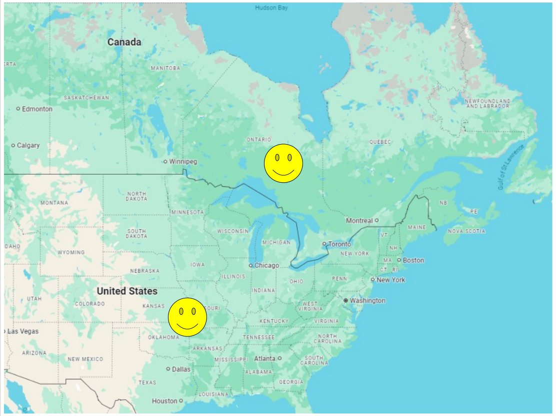
Outline

- Company introduction
  - Team
  - Services
  - Experience
- Lessons learned analyzing a bunch of other people's designs

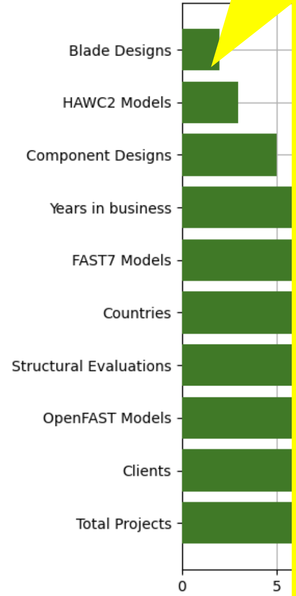
Northwind Engineering – Since 2017





- Aeroelastic modeling (OpenFAST, HAWC2)
- Computational fluid dynamics (OpenFOAM)
- Structural analysis
- Mechanical design

Northwind Engineering – Since 2017



Small Wind Certification Council (ICC-SWCC™)
Small Wind Certification Program

Manufacturer:
Kodair Wind Designs, Ltd.
Wind Turbine Model:
KW20 (240 VAC, 1-phase, 50/60 Hz.)
Certification Number:
SWCC 22-02

SMALL WIND SW CC CERTIFICATION COUNCIL
CERTIFIED

Rated Annual Energy
Estimated annual energy production assuming an annual average wind speed of 5 m/s (13.4 mph), a Rayleigh wind speed distribution, sea-level air density and 100% availability. Actual production will vary depending on site conditions.

58,508 kWh/year

Rated Sound Level
The sound level that will not be exceeded 95% of the time, assuming an annual average wind speed of 5 m/s (11.2 mph), a Rayleigh wind speed distribution, sea-level air density, 100% availability and an observer location 60 m (~ 200 ft) from the rotor center.

41.8 db(A)

Rated Power
The wind turbine power output at 11 m/s (24.6 mph) at standard sea-level conditions.

20.3 kW

Certified for Conformance with Standard:
ACP 101-1-2021

For ICC-SWCC Summary Report, Certificate and current certification status visit: www.smallwindcertification.org

- Aeroelas
- Computa

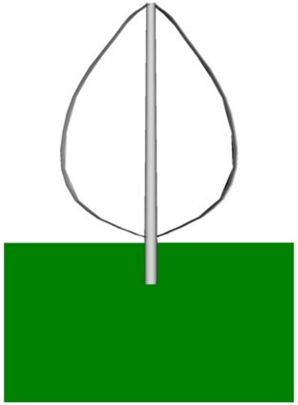
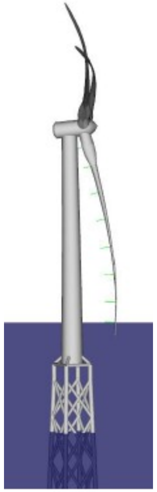
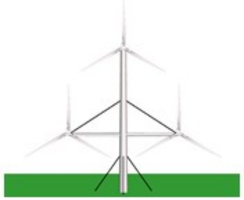
Bread and butter: Aeroelastic modeling

- FAST7 / OpenFAST

- QBlade

TECHNISCHE UNIVERSITÄT BERLIN

- HAWC2

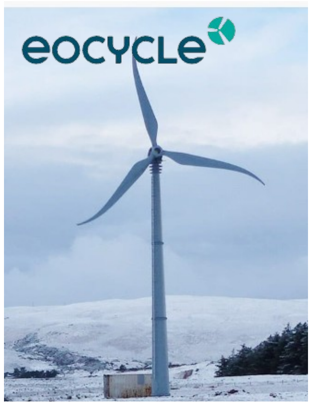
DTU

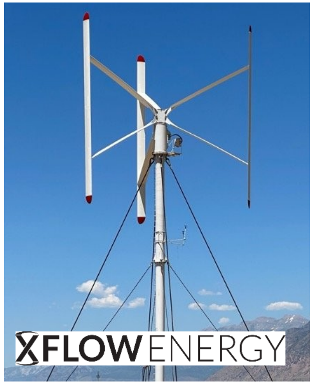
- ✔ HAWTs
- ✔ VAWTs
- ✔ Active / passive yaw
- ✔ Active pitch

- ✔ Variable speed
- ✔ Tail fins
- ✔ Furling
- ✔ Tip brakes

- ✔ Tethers / guy wires
- ✔ Flexibility, structural dynamics
- ✔ Turbulent inflow, gusts, etc.

Diverse range of modeled turbines and features





Team

Drew Gertz, MASc.

CEO / Principal consultant

Specialty: Aeroelastic modeling

13+ years experience in wind turbine modeling and design

Several years R&D experience in Danish wind industry (Siemens, DTU)

Extensive aeroelastic modeling experience in FAST7, OpenFAST, HAWC2

Experience in mechanical design (CAD/FEA), blade design & performance, measurements & analysis

Joseph Spossey, B.Eng

Testing, inspection and certification of wind turbines

Michael Shives, PhD.

CFD, multi body dynamics

Giorgio Demurtas, PhD.

Wind turbine controls

Ali Hassan Khan, PhD.

Mechanical engineer

Specialty: CFD

Industry experience simulating Vertical (VAWTs) and Horizontal (HAWTs) axis wind turbines in CFD

Experience in mechanical design (CAD, FEA)

Mohammed Fajar, M.Eng

Blade structural design and manufacturing

Prof. Paolo Schito, PhD.

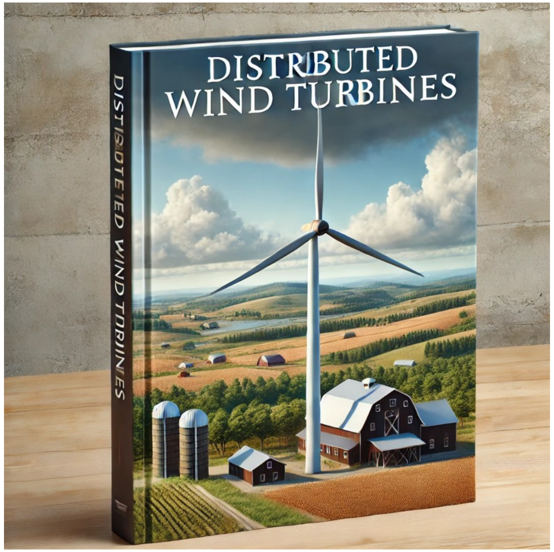
CFD, fluid structure interaction

Christos Dimitropoulos, MSc.

FEA / mechanical testing

"Distributed wind turbines" book by IET Press

- Collaborative effort to increase the awareness of distributed wind energy
- Editors: David Wood and Mark Runacres
- Dropping July 2025
- Other topics
  - Standards
  - Wind and turbulence
  - Aeroelastic modeling
  - VAWTs
  - Site assessment
  - Manufacturing
  - Sustainable materials
  - And more!



The Institution of Engineering and Technology

Chapter 1

Designing Distributed Wind Systems

Drew Gertz[1]

Lessons learned analyzing a bunch of other people's designs

Wind turbine standards: Not just to line the litter box

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- Design to the standards, even if you don't plan to certify

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- Design to the standards, even if you don't plan to certify
- Forces to consider off-design, fault, extreme situations, redundancy, control responses, etc.
  - Perform an FMEA

Design situation	DLC	Wind condition		Other conditions	Type of analysis
1) Power production	1.1	NTM	$V_{in} < V_{hub} < V_{out}$ or $3 \times V_{ave}$		F, U
	1.2	ECD	$V_{hub} < V_{design}$		U
	1.3	EOG_{50}	$V_{in} < V_{hub} < V_{out}$ or $3 \times V_{ave}$		U
	1.4	EDC_{50}	$V_{in} < V_{hub} < V_{out}$ or $3 \times V_{ave}$		U
	1.5	ECG	$V_{hub} = V_{design}$		U
2) Power production plus occurrence of fault	2.1	NWP	$V_{hub} = V_{design}$ or V_{out} or $2{,}5 \times V_{ave}$	Control system fault	U
	2.2	NTM	$V_{in} < V_{hub} < V_{out}$	Control or protection system fault	F, U
	2.3	EOG_1	$V_{in} < V_{out}$ or $2{,}5 \times V_{ave}$	Loss of electrical connection	U
3) Normal shutdown	3.1	NTM	$V_{in} < V_{hub} < V_{out}$		F
	3.2	EOG_1	$V_{hub} = V_{out}$ or $V_{max,shutdown}$		U
4) Emergency or manual shutdown	4.1	NTM	To be stated by the manufacturer		
5) Extreme wind loading (standing still or idling; or spinning)	5.1	EWM	$V_{hub} = V_{e50}$	Possible loss of electrical power network	
	5.2	NTM	$V_{hub} < 0{,}7\ V_{ref}$		
6) Parked and fault condition	6.1	EWM	$V_{hub} = V_{e1}$		
7) Transport, assembly, maintenance and repair	7.1	To be stated by the manufacturer			

Key

F analysis of fatigue loads

U analysis of ultimate loads

International Electrotechnical Commission, IEC 61400-2: Wind Turbines - Part 2: Small Wind Turbines, 3rd ed., Geneva, Switzerland: IEC, 2013.

Wind turbine standards: Not just to line the litter box

- Design to the standards, even if you don't plan to certify
- Forces to consider off-design, fault, extreme situations, redundancy, control responses, etc.
  - Perform an FMEA
- Ensures appropriate load levels and material properties in structural verifications

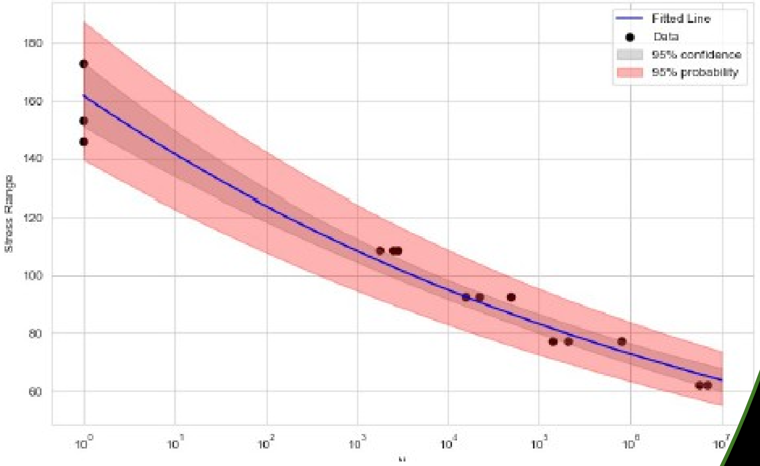

Table 7 – Partial safety factors for loads

Load determination method (see 5.2)	Fatigue loads, γ_f	Ultimate loads, γ_f
1. Simplified equations	1,0	3,0
2. Simulation model	1,0	1,35
3. Full scale load measurement	1,0	3,0

Table 6 – Partial safety factors for materials

Material characterisation	Fatigue strength, γ_m	Ultimate strength, γ_m
Full characterisation	1,25[a]	1,1
Minimal characterisation	10,0[b]	3,0

[a] Factor is applied to the measured fatigue strength of the material.

[b] Factor is applied to the measured ultimate strength of the material.

Wind turbine standards: Not just to line the litter box

- Design to the standards, even if you don't plan to certify
- Forces to consider off-design, fault, extreme situations, redundancy, control responses, etc.
  - Perform an FMEA
- Ensures appropriate load levels and material properties in structural verifications
- Document document document
- Certification takes time

Don't fall in love

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- Make design decisions objectively

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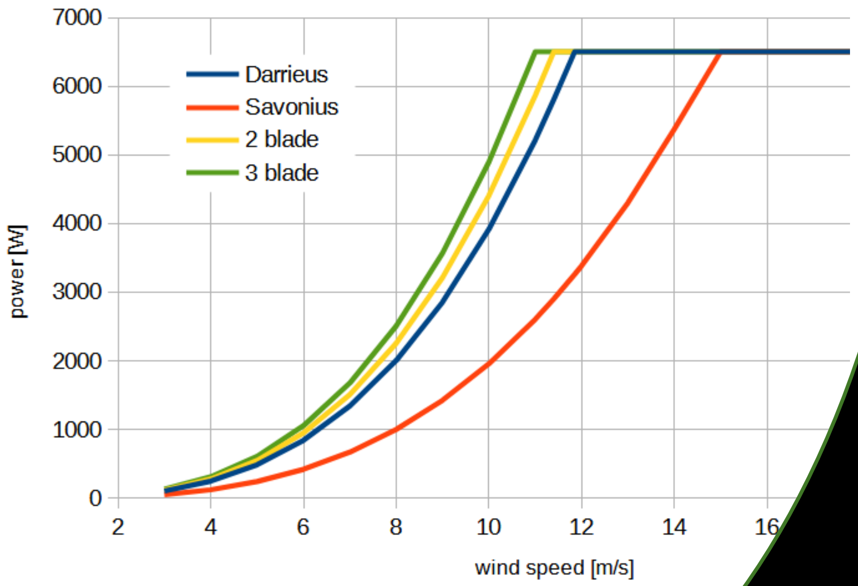
- Many trade-offs to consider:
  - Number of blades
  - upwind vs. downwind
  - Active / passive / fixed / independent pitch
  - Active / passive yaw
  - HAWT vs. VAWT
  - Variable / constant speed
  - Geared vs. DD
  - welded vs cast



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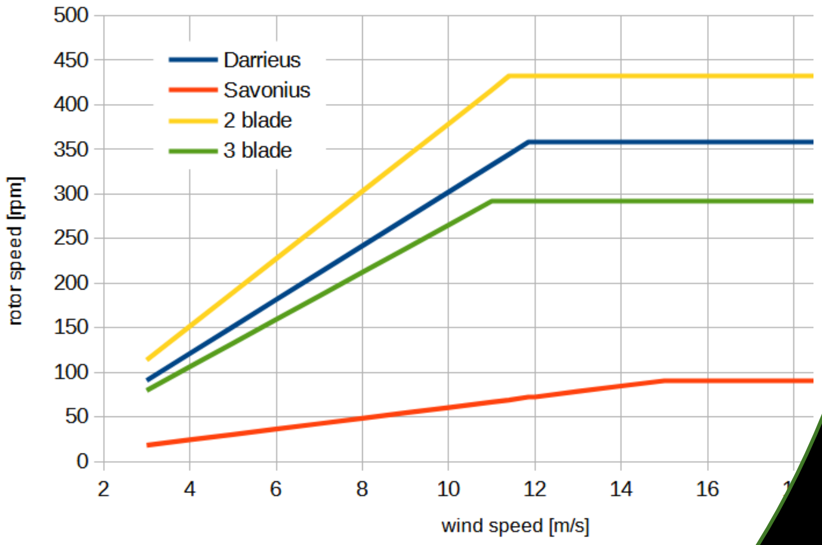

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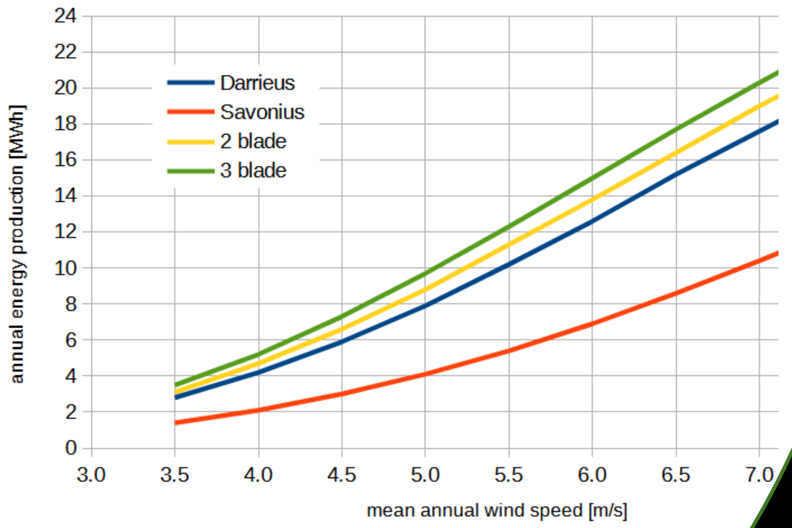

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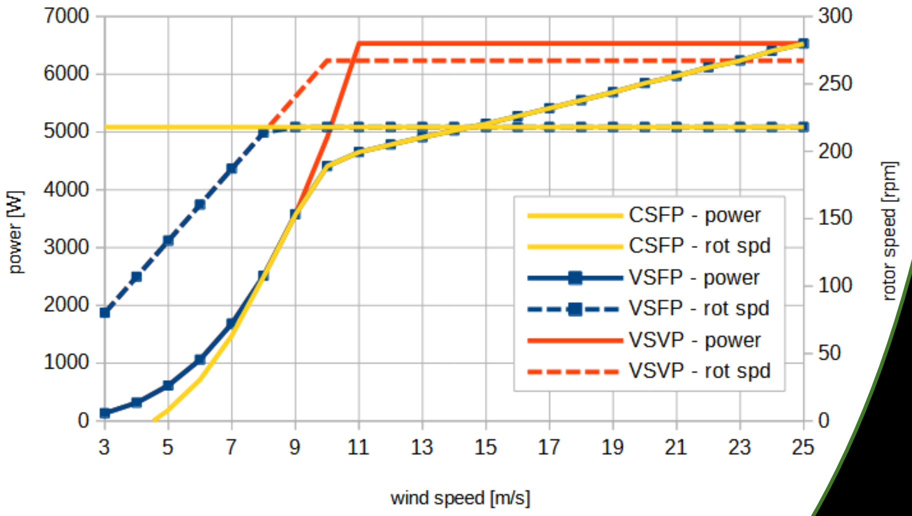

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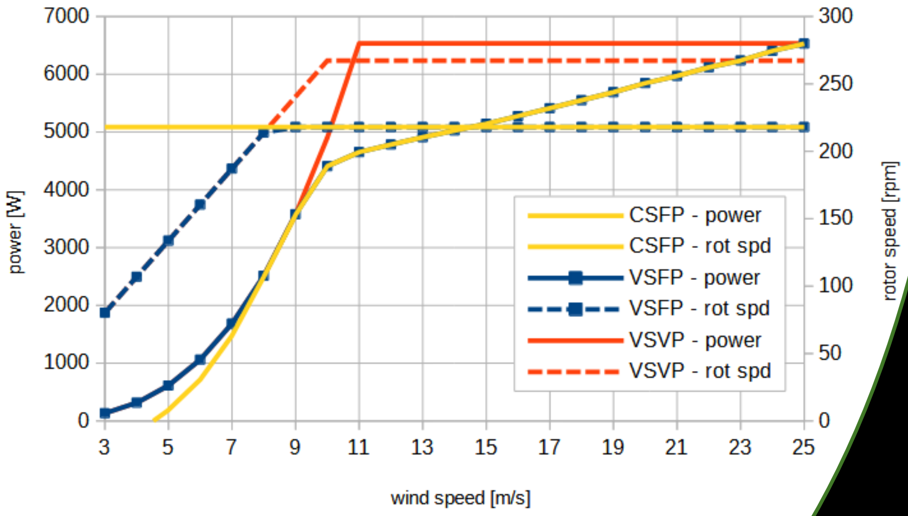
  - welded vs cast
- Consider market / competition / regulations
- Perform sensitivity studies. Understand cost vs. benefit
- Track cost / AEP / LCOE. Be realistic



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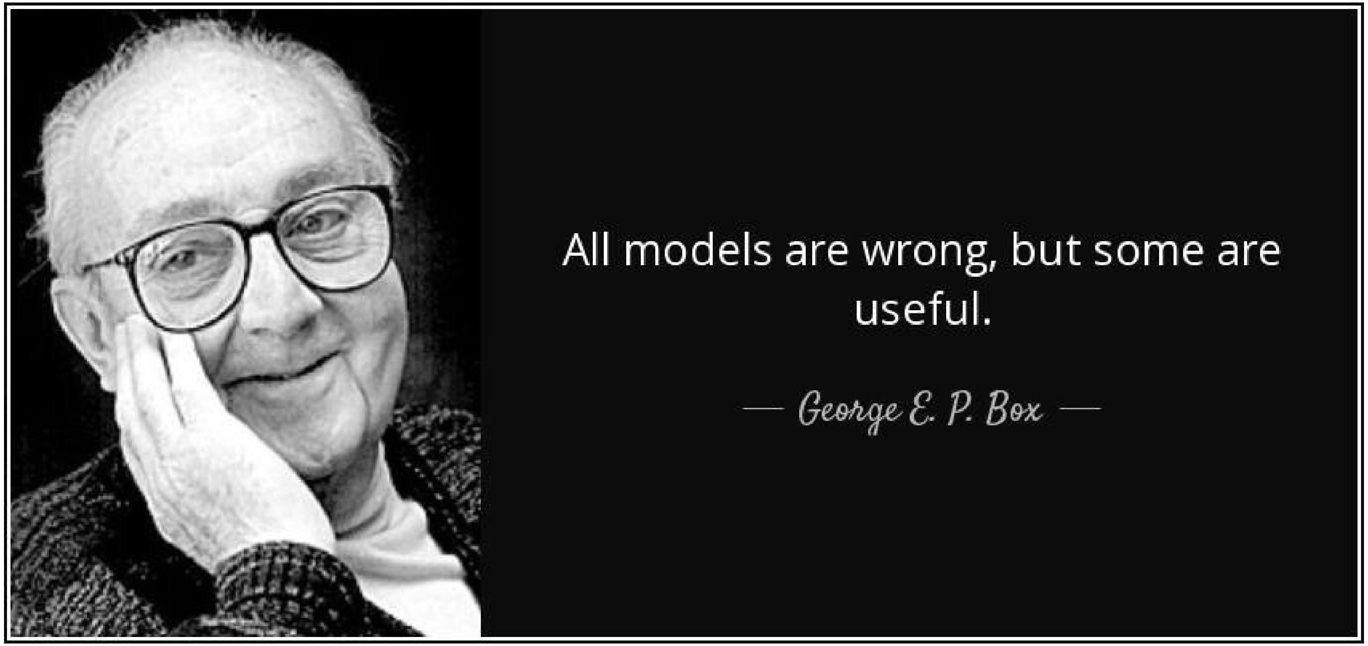
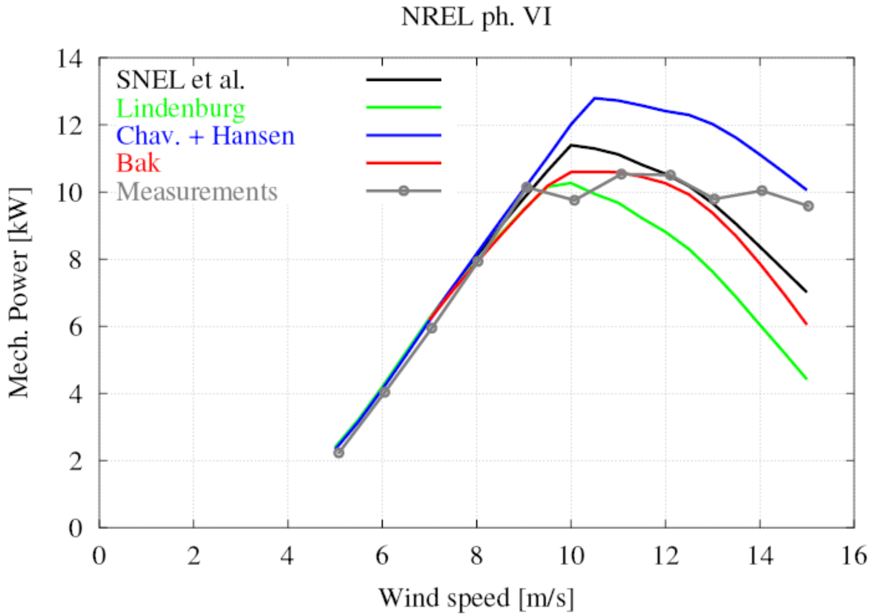
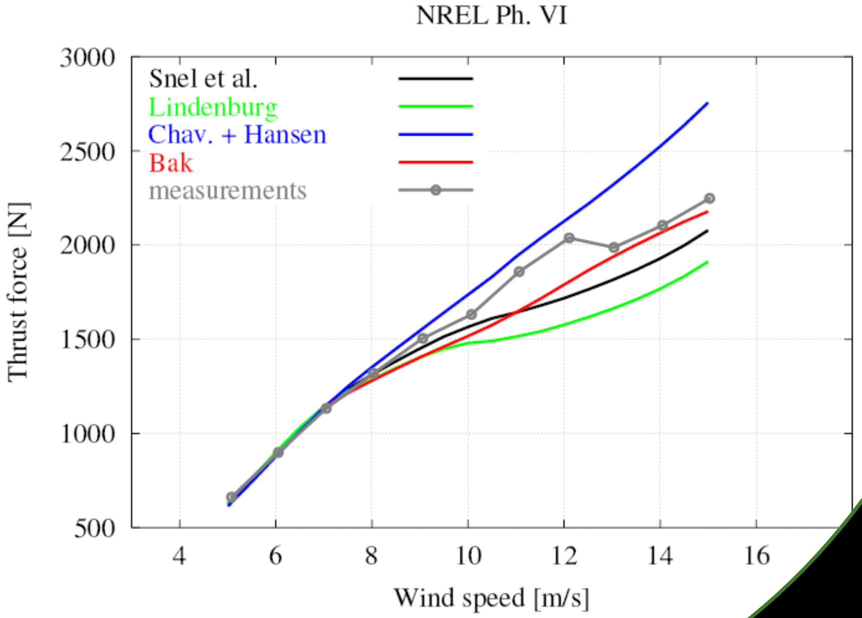
Don’t bet the farm on the model before validating



Don’t bet the farm on the model before validating

- Power and loads are notoriously difficult to predict in stalled conditions

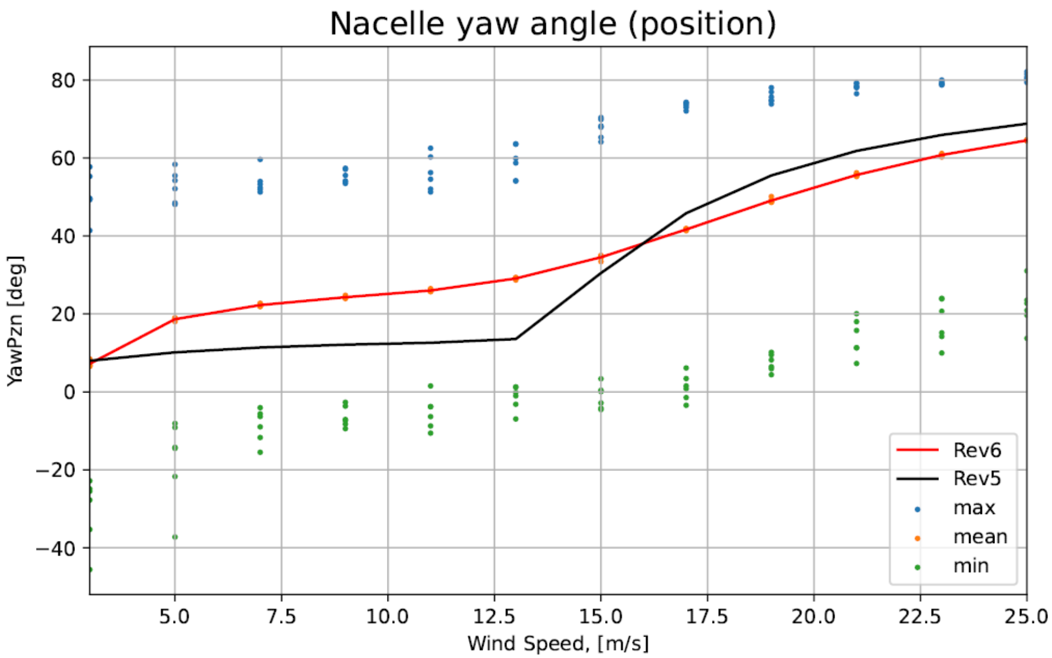




C. Bak, J. Johansen, and P. B. Andersen, "Three-Dimensional Corrections of Airfoil Characteristics based on pressure distributions," presented at the European Wind Energy Conference & Exhibition (EWEC), Athens, Greece, Feb. 27 – Mar. 2, 2006.

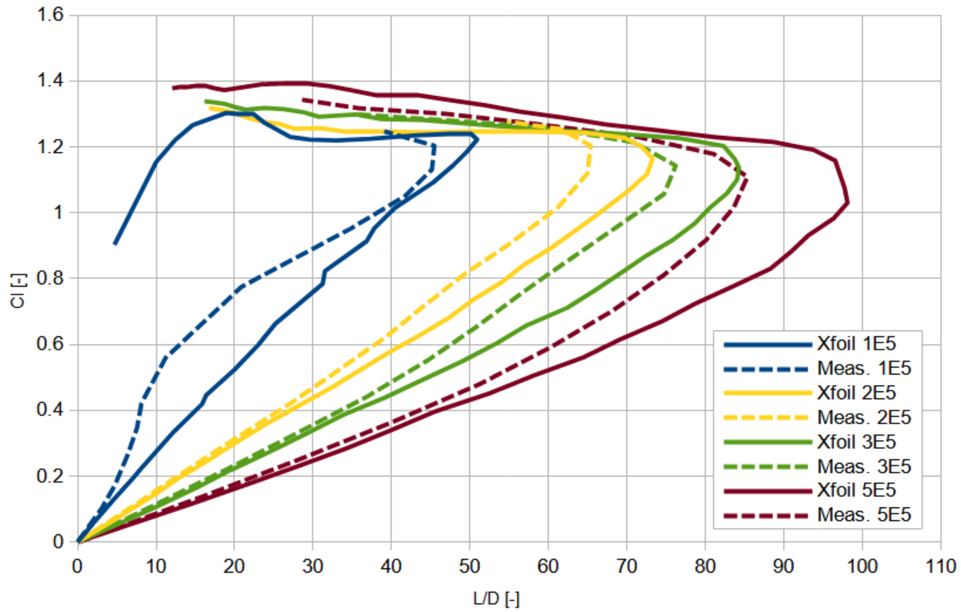
Don’t bet the farm on the model before validating

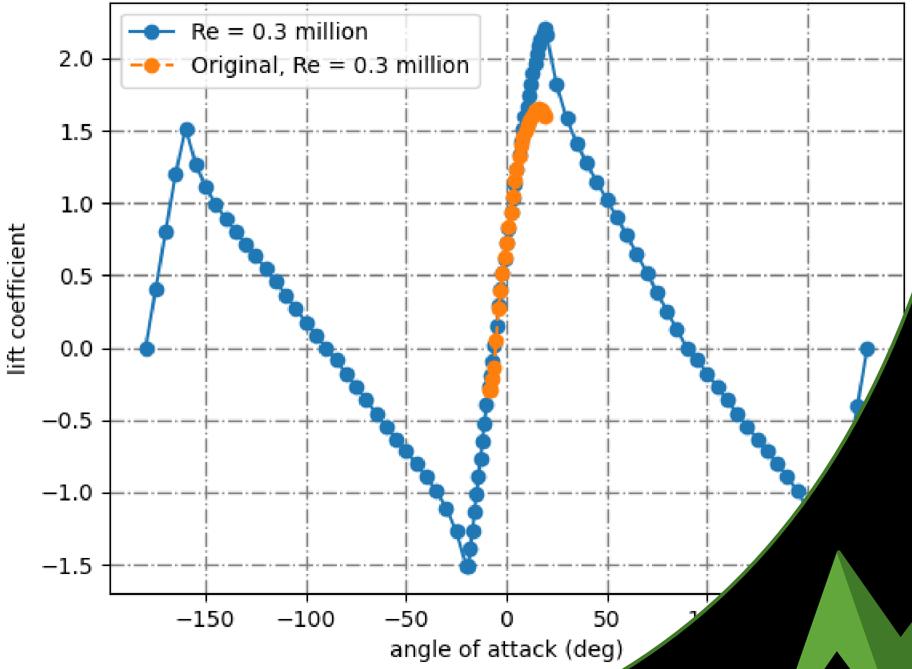
- Furling combines extreme yaw with deep stall → significant uncertainty



Don't bet the farm on the model before validating

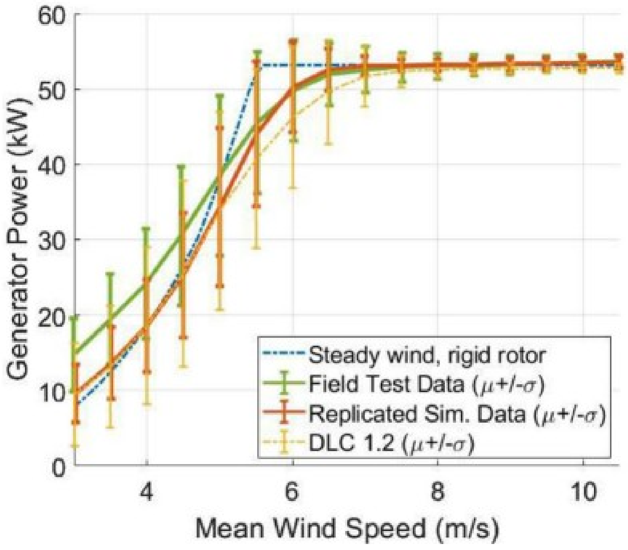
- Airfoil coefficients → uncertainty in 2D polars, 3D effects, extrapolation

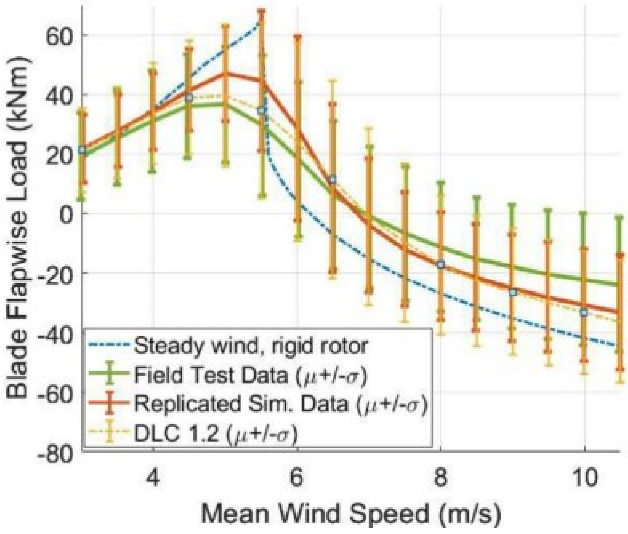




Don't bet the farm on the model before validating

- Controller response – measurements vs simulations





M. Phadnis, D. Zalkind, and L. Pao, "Advanced wind turbine control development using field test analysis for generator overspeed mitigation," Wind Energy, vol. 2023, Sep. 2023.

Prototyping and testing: Because the Titanic looked good on paper too

Prototyping and testing: Because the Titanic looked good on paper too

- Prototype/test/validate before locking design
- Measure at least enough channels to validate your model
- Be prepared to make changes
- First measurement campaign should not be for certification

Good vibrations?

There are no good vibrations

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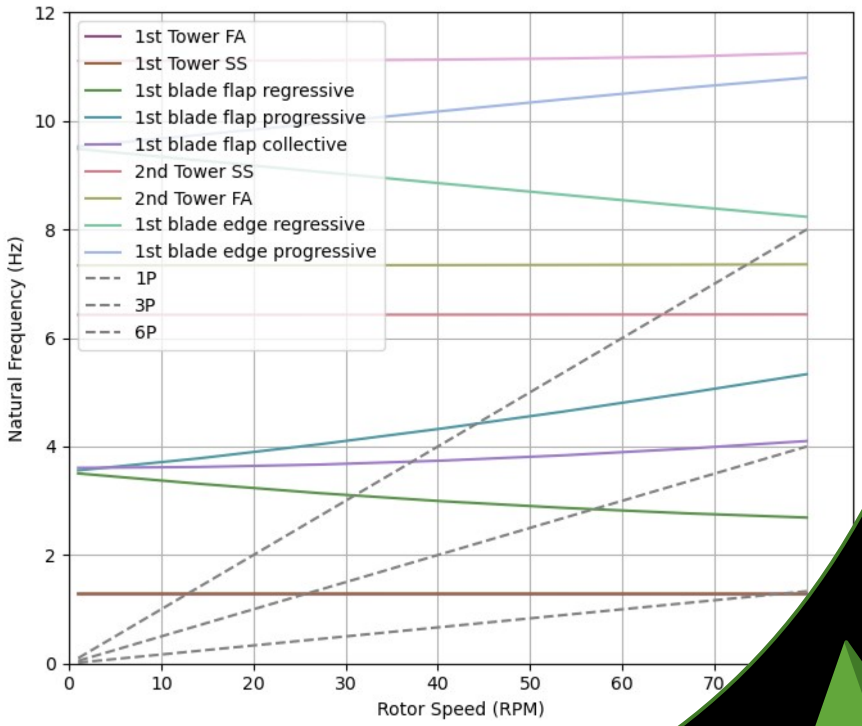
- Perform resonance analysis

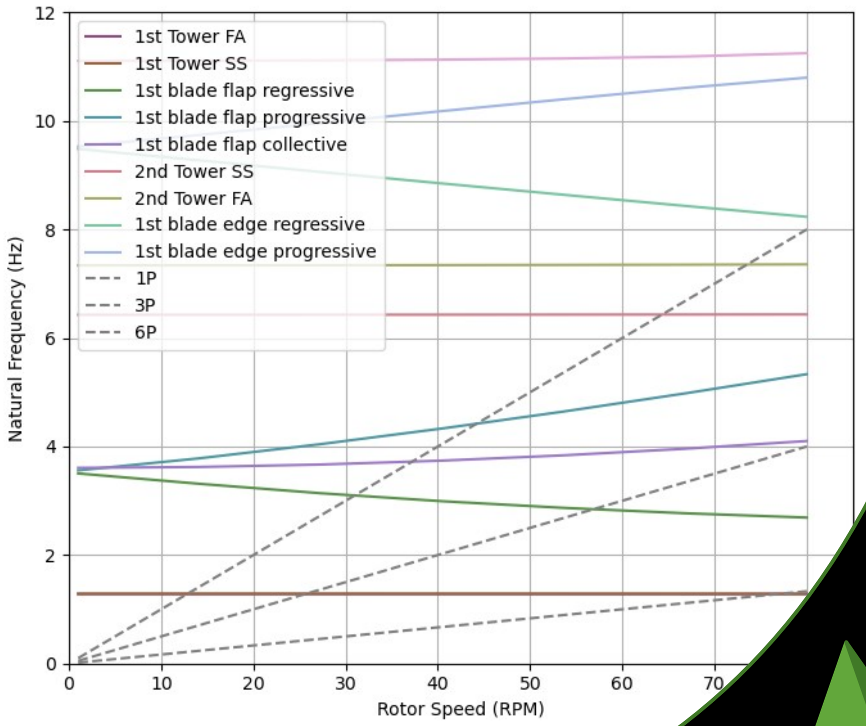
There are no good vibrations

- Perform resonance analysis
- Ensure safe margin between forcing frequencies and system natural frequencies



There are no good vibrations

- Perform resonance analysis
- Ensure safe margin between forcing frequencies and system natural frequencies
- Before locking design



Make Jagger Proud

Make Jagger Proud

- Be sure about starting up
- Evaluate starting torque
  - Rotor standstill torque
  - Drivetrain resistance

Make Jagger Proud

- Be sure about starting up
- Evaluate starting torque
  - Rotor standstill torque
  - Drivetrain resistance
- Ensure satisfactory start up wind speed

Thanks!

Drew Gertz
Principal consultant / CEO
Northwind Engineering OÜ

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