Towards updating the standards for small wind turbines, via IEA Wind Task 41

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Background

Recommendations on potential standards changes for distributed wind: driving research via IEA Task 41

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Background

- what is small?
  - rotor-swept area < 200 m^2 ?
  - smaller than what is covered in IEC 61400-1

- Standards
  - Small Wind Turbines: IEC 61400-2 (update starting 2022…)
    IECRE SG 554: OD 501-x
    ACP SWT-1 (prev. AWEA 9.1)
  - loads measurements: IEC 61400-13
    needs to be adapted for small turbines
  - conformity assessment: ~~IEC 61400-22~~ → IECRE: OD-502-1
  - power-performance testing: IEC 61400-12 [Ann. H]

context for ‘typical’ smaller turbines

(What was [not] addressed the first time around?)

- First generation of wind energy (~1970’s–80’s):
  - » hub heights in the atmospheric surface layer
  - » stall-regulated turbines
  - » observations limited (but cheaper/easier)
  - – wind conditions
    - large velocity perturbations
      - – nonlinear effects
      - – ‘strange’ statistics: $P(u)$ form, directional dependence
    - bottom-up flow problem
      - » many phenomena “look like” turbulence
    - measurement inadequacy
      - – sample length
      - – flow-distortion: instrument / externally
      - – different environment than turbine’s

picture courtesy of Nordic Folkecenter

IEA Wind Task 41: research / end-user context

from 2019-20 research priorities survey

- [H] Standardize/open markets for WTG >55kW, >200 m^2
  - Increase upper limit for small/DW; adapt 61400-2 for this
    - Need data! → report data/validation?
- [H] Aeroelastic models & validation
- [H] Loads testing* & characterization: adapt 61400-13 for DW
- [H/M] Duration testing (USA)
- [M/H] turbulence prescription, characterization, classes*;
- [M] performance
- [M] tower dynamics/interaction
- [M] separate classification for micro-turbines

what to do…

Key Technical Challenges and Gaps	Priority	Standard	Forum
Size limits / classifications are inappropriate or prohibitive	H	-2	Eu,Am
Certification and testing requirements	H	SG 554	Eu,Am
Conformity assessment is inadequate	H/M	SG 554	Eu
Validated aeroelastic modelling is lacking	H	-13 (-2)	Eu,Am
Loads testing and characterization	H	-13	Eu,Am
Turbulence prescription, characterization, and classes	H/M/L	-2	Eu,Am
Performance and conditions	M	-2	Eu
Tower dynamics/interaction	M	-2, -13	Eu
Limitations/applicability of simplified loads model (SLM)	M/L	-13 (-2)	Eu,Am
Blade testing	M/L	-23	(Am)
Acoustic/noise testing	L	(-11-2)	Eu
Safety and function testing	L	-2	(Am)

identified via 2019-2020 IEA Task 41 meetings

what to do…

Key Technical Challenges and Gaps	Priority	
Size limits / classifications are inappropriate or prohibitive	H	RPM, control, output, market; 2-3kW “gap”
Certification and testing requirements	H	duration, loads tests difficult! China example...
Conformity assessment is inadequate	H/M	Need a clear method (common approach)!
Validated aeroelastic modelling is lacking	H	--for design variety
Loads testing and characterization	H	COST!
Turbulence prescription, characterization, and classes	H/M/L	different regime, range of design/sizes
Performance and conditions	M	power curves; non-uniform flow
Tower dynamics/interaction	M	small turbine resonances…
Limitations/applicability of simplified loads model (SLM)	M/L	refine safety factors…vs. aero-elastic models
Blade testing	M/L	higher rotation rate issue, failures…
Acoustic/noise testing	L	tonal audibility: difficult test
Safety and function testing	L	are simple RPM and power control sufficient?

identified via 2019-2020 IEA Task 41 meetings

Research needed

To support adjustment of standards: scientific basis

- **Expansion and adjustment of size, types and classes; conformity assessment**
  - aggregate detailed measurements (speed, power, rotation rate, turbulence intensity)
    - » smaller turbines, also different topologies
  - parametric studies across turbine types/sizes → power (size) limits
  - survey lifetimes and failure rates
    - different microturbine topologies
    - different conditions

- **update *requirements* for certification & testing**
  - 'how much' duration testing is statistically relevant for microturbines
  - investigation and validation of less complex aeroelastic models (c.f. SWT-1)
    - @ multiple sites, conditions

Research needed

<u>To support adjustment of standards: scientific basis</u>

- **Aeroelastic models & validation**
  - identify measurement needs for key model inputs
    - » for different turbine configurations , sizes/classes
  - validation methodology

- **Loads testing & characterization**
  - how applicable are 61400-13 methods
    - per size, control system family, design topology
  - reduction of requirements for yaw and pitch control

Research needed

To support adjustment of standards: scientific basis

- **Turbulence prescription, characterization, and classes**
  - Re-examine NTM : 3D velocity measurements
    - *representative* sites, locations (with obstacles…)
    - what is '*representative*' ?
      - connect results, research, theory on atmospheric turbulence affected by obstacles
  - Evaluate select wind turbines using multiple aeroelastic codes
    - NTM input and synthesized (modelled) turbulence driven by observational statistics.
  - Compare loads (observed, modelled) for turbulence w/different peak length scales
    - across turbine classes/sizes
    - find key differences and metrics for input to both aeroelastic sims & SLM
  - Document results
  - Validating preliminary results with more datasets

Research needed

To support adjustment of standards: scientific basis

- **Performance & conditions**
  - for speed : validate obstacle models (more sites/conditions)
  - for turbulence and shear :
    - RANS/CFD use in different conditions ; improve simplified models
  - 3D velocity obs.,
    - power curves in different turbulence regimes
    - aeroelastic modelling

- **Tower dynamics / interaction**
  - modal tests → damping factors (different tower sizes, types, turbines)
  - Develop (simplified) method to model dynamics for free-yaw turbines + tower resonance

Research needed

<u>To support adjustment of standards: scientific basis</u>

- **Simplified Loads Model [SLM] : Applicability & limitations**
  - Investigate upper size limit & conditions
  - Develop fatigue load case for gyroscopic loads ← turbulence intensity input
    - yaw bearing (passive yaw), yaw error (active yaw),
    - power production & fault, normal shutdown, parked (low cycle/high fatigue)
    - different fatigue thresholds for on and off-grid turbines
  - Develop a specific set of SLM parameters for downwind-rotor turbines.
  - Reduce or eliminate SLM load cases, if they do not impact design.
  - Develop new assumptions for yaw rate that more accurately reflect measurement data.
  - parametric study on “300 N·m method”

Research needed

To support adjustment of standards: scientific basis

- **Blade Testing**
  - high-RPM effects (e.g. stiffening)
  - full-rotor testing method for micro turbines
  - strategy for reduction of safety factors via fatigue testing
    - review existing fatigue-test results
    - why do some blades fail in practice but not during tests ?

- **Noise testing**
  - simplified assessment method
  - tonal audibility question / value
  - applicability to VAWT / other topologies

Research needed

To support adjustment of standards: scientific basis

- **Safety & function testing** (supports duration test)
  - analysis of many existing test datasets
  - why only RPM & power needed for micro-turbines?
  - find patterns and trends
    - identify any needed changes to the safety and function test

Recommendations / results

- Update turbine classifications to fairly address different sizes and types.
- Change certification and testing requirements, per appropriate turbine classes and types.
- Conformity assessment : *clearly document* method/path to certification
  - » pending OD from SG554
- Validated aeroelastic models: model extension/research & clear validation path needed
- Loads testing and characterization: annex to IEC 61400-13?
- Turbulence: new class recommended
- Performance and conditions:
  - » 61400-2 accommodate multiple power curves
  - » reporting requirements harmonized with 61400-12-1, SG554 OD, SWT-1
- Tower dynamics/interaction: more research needed
- Update Simplified Loads Model (SLM): need more research
  - Development of SLM cases for VAWTs
  - Adapt SLM for microturbines
- Acoustic/noise testing: simplify/explain §F.5 of 61400-11 ;

Recommendations / results

Rotor swept area Nominal power	Micro < 5 m^2 < 2 kW	Small 5-50 m^2 2 – 11 kW	Medium 50-500 m^2 11-150 kW
PRINCIPAL ELEMENTS AND EXTERNAL CONDITIONS			
Streamline micro wind requirements	X		
Raise the size limit > 200 m^2 based on aeroelastic model and measurement data			X
Design class requirements	choose one	X	X
Normal Turbulence Model	X	X	X
STRUCTURAL DESIGN			
SLM	Use 300 N·m requirement	X	
Safety factors	investigate	X	
Aeroelastic model	NA	If aeroelastic model used, reduce duration test	Validated aeroelastic model required
Tower dynamics and interactions should be considered.	X	X	

Recommendations / results

Rotor swept area Nominal power	Micro < 5 m^2 < 2 kW	Small 5-50 m^2 2 – 11 kW	Medium 50-500 m^2 11-150 kW
TYPE TESTING			
Duration Testing	Reduced time with strength analyses	In different speed & turbulence ranges	Limited or no requirements
Power Performance	No site calibration, don't test past peak power	No site calibration	Can power curve be used to reduce loads test requirements?
Loads Testing		Minimum: tower loads testing should be performed	Streamline aeroelastic model validation req's
Acoustics Testing	No tonality	No tonality	X
Safety and Function Testing	RPM and power control only	X	[Possibly]
Blade Testing	Fatigue full rotor	Static, if fatigue test reduces safety factor	Fatigue

Thanks!