Research Priorities
Domestic and International Standards for Distributed Wind Technology

Draft

January 20, 2020

Completed in conjunction with IEA Wind Technical Collaboration Program
Task 41-Enabling Wind to Contribute to a Distributed Energy Future

The following table outlines a longer-range research plan based identified challenges of existing standards for small and distributed wind technology, most specifically the International Electrotechnical Commission [IEC] 61400-2 Standard. The table also identifies potential international stakeholders or efforts already underway to conduct research related to the challenges identified within the standard. This list of challenges will be revised following further consultations within IEA Task 41, as part of planned standards focused meetings in Asia and North America and through engagement with additional stakeholders. A final objective would be to develop more detailed research plans for at least high priority challenges and identify an organization and funding mechanism to implement those plans in collaboration with relevant Task 41 and wider industry members. For further information please see the associated document, Updating International Standards for Distributed Wind Technology, a document associated with the Internal Energy Agency, Wind Technical Collaboration Program Task 41-Enabling Wind to Contribute to a Distributed Energy Future. This document is built around the structure of the IEC 61400-2 standard.

As a means of clarification, historically the first edition of IEC 61400-2 had an upper bound of 40 m^2 or approximately 10 kW. The second edition expanded this size limit to 200 m^2 or approximately 55 kW, which was based on existing data from small wind turbines under 200 m^2. It is believed that given current technology, certification requirements and the need for industry wide innovation, a different classification scheme may be needed. For the basis of discussion, the following terms and size ranges have been used. Further dialog and scientific assessment will be needed to define specific size thresholds criteria.

- Micro wind turbines - up to 5 m^2 - ~2 kW
- Small wind turbines - 5-50 m^2 - 2 - 11 kW

- Medium wind turbines - 50-500 m^2 – 11 - 150 kW

The upper size limit for the which IEC – 61400-2 applies would likely be defined by where standard practice as defined for wind turbines that fall within IEC – 61400-1apply.

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PRINCIPLE ELEMENTS AND EXTERNAL CONDITIONS					
		Open global markets for certified micro wind turbines.			
1	5	With few exceptions, micro wind turbines must meet the same requirements as turbines having up to a 200 m^2 RSA. This required technical rigor and the costs associated with certification limit the number of certified micro turbines. Additionally, micro-turbines likely have different operational and life requirements which separate them from larger turbine models. At the same time, global markets for micro turbines are expanding and manufacturers (and the market more generally) would benefit from global markets requiring certified micro wind turbines.	A separate classification for micro wind turbines is likely needed. This will require technical justification to determine the specific requirements for this turbine class. Research needs will include: ➢ Conduct parametric studies to inform size limits ➢ Develop streamlined micro wind requirements ➢ Document recommended text for consideration of future IEC 61400-2.	Task 41 partners: China—Inner Mongolia University of Technology? Spain—Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas? Denmark -	Medium Lead: ?
		Open markets for certified turbines above 55 kW with a common standard.			
2	1	Small wind turbines up to 100 kW (and potentially larger) have benefited from national, federal, state, and local financial incentives. But only turbines below 200 m^2 RSA have a clear path to certification, with the Small Wind Certification Council and Intertek offering certification services and	The current upper limit of 200 m^2 RSA should be increased as appropriate, which will require a multi-year effort including ongoing consultations with interested parties and the following research efforts:	Task 41 partners: Denmark—Denmark Technical University?	High Lead: U.S.

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		numerous accredited and unaccredited test laboratories providing data. During the creation of IEC 61400-2, Windward Engineering, the National Renewable Energy Laboratory (NREL), and Energy research Centre of the Netherlands (ECN) conducted a study to better determine and understand loads by using existing datasets to reduce costs. The largest turbine considered in this study was 200 m^2, which is why it is the upper limit of IEC 61400-2 and so many country standards that are based on IEC 61400-2. This has adversely impacted turbines above 55 kW (approx. 200 m^2 RSA) from entering the U.S. and other financially incentivized markets such as Italy, United Kingdom, etc. because the cost to certify turbines is quite high and the lack of defined paths to allow turbine improvements without requiring a new certification is unclear.	➢ First, investigate the use of aeroelastic models without loads data validation ➢ Collect detailed measurement data on wind turbines above 200 m^2 RSA of different topologies ➢ Develop an aeroelastic model of the same turbines and compare results for each load case to determine how accurately the models predict measured loads without the need for code verification through the collection of loads data ➢ Publish research findings, which may be used to recommend a revision to the IEC 61400-2 ➢ Document recommended text for consideration as part of a future IEC 61400-2.	Spain—Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas? U.S. - National Renewable Energy Laboratory	
		Modify design classes, turbulence parameters to better reflect consumer sites and provide inflow information into design tools.			
3	6.2	Preliminary research conducted under IEA Task 27 indicates that reducing the current standard design classes with a varied turbulence parameter will more accurately reflect consumer sites. Validation of a new,	Validate and document a new, high-turbulence design class for distributed wind turbines (potential with V_{ave} = 10 m/s, I_{10} = 0.36), which would require:	Task 27 Small Wind Technical Report Task 41 partners:	Low Lead: Belgium

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		high-turbulence class that was proposed under Task 27 would provide a more solid technical backbone for future standards-making experts.	➢ Develop one design class for micro wind ➢ Document test and modeling results in technical journals ➢ Validate preliminary results with more datasets ➢ Document recommended text for consideration of future IEC 61400-2 ➢ NREL review research results in support of Task 41.	Belgium—Vrije Universiteit Brussel Poland? Spain—Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas? Australia - Murdoch university?	
4	6.3.2.3	The power spectrum of turbulence tends to be modified by the landscape. If the surface roughness of the landscape is high (i.e., urban terrain; peri-urban terrain; or open terrain with ridges, hills, groups of high trees), the turbulence intensity of air flow increases. Such land topography typically generates turbulent structures of the same length scale as that of the landscape "obstacle" itself, increasing energy (in the sense) at the corresponding frequency range. This shift in power to a higher frequency band (bin) has a detrimental effect on rotor fatigue loads. The more frequent the loads are, typically the shorter the life cycle of a wind turbine. Another important aspect to consider is the atmospheric stratification. Neutral conditions are not so common, but the near-neutral	More reference information is needed about this condition to allow assessment regarding the need for improved standards in this area. This would include the following research: ➢ Validate the Normal Turbulence Model by analyzing other 3-d measurement data sets ➢ Refine the Normal Turbulence Model based on comparison of past data and present data results ➢ Evaluate select wind turbines using TurbSim, FAST, HAWC2, etc. on fatigue damage calculations	Task 27 Small Wind Technical Report Task 41 partners: Belgium—Vrije Universiteit Brussel? Poland? Spain—Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas? USA – Subcontract	Medium Lead: Belgium

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		conditions are typical for medium and high wind speeds. These are the most important for fatigue damage calculation because they translate to an increased thermal convection from the ground up and vice versa depending on seasons and the time of a day (diurnal cycle). Based on measurements from numerous country sites in an effort led by Belgium and Poland, a basis for a new wind class and new Normal Turbulence Model were presented. NREL retired researcher Neil Kelley performed analyses that showed the need to focus future efforts on understanding vertical flow in weak, unstable atmosphere around rated power. (Currently the IEC 61400-2 has no limited information on vertical inflow, thermal stability, etc.)	➢ Focus research efforts on better understanding vertical inflow ➢ NREL review research results in support of Task 41.	Denmark – Denmark Technical University?	
STRUCTURAL DESIGN					
		Minimize overbuilding of small wind turbines by streamlining Simplified Loads Model (SLM) requirements, which will reduce machine costs.			
5	7.4, 7.8, and 13.2.3	<u>Simplified Loads Models</u> The SLM was developed in the second revision of the IEC 61400-2. This method replaced the expensive requirement of simulation models and replaced it with simper equations and high factors of safety. There is no fatigue case that addresses the	If most small turbine manufacturers are moving to aeroelastic models, the SLM could be revised to focus only on micro turbines. Additionally, different modeling load cases and safety factor recommendations should be developed and documented. This will include the following efforts:	Task 41 partner: Taiwan—Taiwan Institute of Energy Research (VAWT)? Denmark – DTU (Peggy)	Low / Medium Lead: Taiwan

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		common occurrence of high vertical winds at times of atmospheric instabilities. The method was based on a comparison of turbine measurements and aeroelastic models, identifying areas that needed high factors of safety to be conservative. The current safety factors are quite high, which increases turbine cost and leads many manufacturers of small to medium turbines to return to using aeroelastic models, which they see as being valuable for other reasons. Since past international standards committees have had limited engagement from vertical-axis wind turbine experts, there is no SLM for vertical-axis wind turbines. There is some overlap of this effort with item 1 above around what is the higher size limit to apply SLM to this work? <u>Factors of safety</u> As standards evolve, more knowledge can be applied to standards. An understanding of necessary factors of safety has changed over time, yet there has been no focused effort to gather data and refine the factors of safety.	➢ Conduct a parametric study on the use of the 300 N.m method (method used in Denmark for easy assessment of structural strength) ➢ Develop a fatigue load case with turbulence intensity as an input that addresses gyroscopic loads, including yaw bearing (passive yaw), yaw error (active yaw), power production and fault, normal shutdown, parked (low cycle/high fatigue), different fatigue for on and off-grid turbines ➢ Develop a downwind specific set of SLM parameters ➢ Reduce some SLM load cases if they do not impact design ➢ Develop new assumptions for yaw rate, etc. based on measurement data ➢ Document recommended text for consideration of future IEC 61400-2.	Japan?	

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		Enable manufacturers to use aeroelastic simulation tools that reflect their current design and more likely inflow conditions, further reducing certification costs.			
6	7.5	<u>Aeroelastic model</u> Aeroelastic simulation modeling capabilities have helped wind turbine designers for all size turbines. The U.S. distributed wind industry has clearly indicated that all major manufacturers are using and will continue to use aeroelastic models in turbine design if they remain available at a low cost. A major challenge for U.S. industry is the lack of refinement in aeroelastic models (i.e., FAST) to reflect the needs of modern distributed wind turbine designs. (Danish Technical University has HAWC2, the latest in simulation models for wind turbines.)	DOE has reduced investment in the FAST code. The current version of the tool does not incorporate many of the critical functions focused on small and medium wind turbines, and there are no plans to improve the code to reflect distributed wind turbine priorities. Revising the FAST code will involve the following: ➢ Update the current version of the FAST code to incorporate distributed wind-focused features that were omitted from current versions of the software ➢ Expand the FAST code to include new features relevant to distributed wind, such as turbine tower (guyed or lattice) dynamics, including validation ➢ Expand training around the use of the FAST code to allow modelers to improve their distributed wind turbine models.	Task 41 partners: Denmark—Denmark Technical University? U.S. – National Renewable Energy Laboratory?	High Lead:
7	7.5	While FAST needs to be updated, some aspects are key to distributed turbine design.	To address this issue, the following is recommended: ➢ Modify FAST modeling tools and provide information on	Task 41 partners:	High (timeline dependent on FAST

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		For example, in a review of data conducted by Neil Kelley from the California Micon 65 and National Wind Technology Center ART, probability distributions of root flapwise blade damage equivalent loads and peak loads were compared to all wind components but specifically vertical winds. These results demonstrated the criticality of including coherent eddy structures in any inflow simulations used with simulations of small wind turbines.	tool capabilities for distributed wind turbine design and consumer site inflow ➢ Provide technical advice to modelers on new FAST options and TurbSim load case inputs that reflect a highly turbulent site most commonly found by consumers, such as the General Dynamic Wake option with FAST v.8 ➢ Document recommended text for consideration of future IEC 61400-2.	Denmark—Denmark Technical University? U.S. – National Renewable Energy Laboratory?	revision timelines) Lead:
8	IEC 61400-13	Turbine specific models need validation from wind turbine measurements under operation. IEC 61400-2 requires compliance with IEC 61400-13, the loads testing standard. This is a very detailed standard, which has been difficult to meet. It's possible that parts of IEC 61400-13 may be appropriate for small and medium wind turbines but other parts may not.	A clear and documented methodology is needed that will allow aeroelastic models to be validated and meet IEC 61400-13 requirements. ➢ Identify and document measurement needs for general key aeroelastic model inputs and specific inputs needed for different turbine configurations ➢ Document technical guidance on how to set up a methodology for validating aeroelastic models and comply with IEC 61400-13		Links with aeroelastic model development for distributed wind turbines and technical justification for increasing the size limit.

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			➢ Pilot test the method, share with Task 41 partners, and publish.		
		Increasing the understanding of tower dynamics and methods to increase structural damping will reduce fatigue failures.			
9	10.2	<u>Tower dynamics and interactions</u> Preliminary results from Task 27 work led by Austria must be validated. The researchers concluded that in order to reduce the risk of fatigue failure, the following approaches were recommended: ➢ Small wind turbine tower systems should be designed in a way that guarantees an overcritical mode of operation within the range of 70% PN to full rated power when stimulating forces are relatively high. ➢ Small wind turbine tower systems should be designed to have as high a structural damping factor as possible. Damping factors between 10% and 20% are desirable. To increase the structural damping and reduce natural frequencies, damping or decoupling elements may be used. ➢ Small wind turbines have resonances that are likely to occur within the tower-rotor system as the natural frequency of these structures (several-meter-high tower with high	To address the concerns raised, the following actions will be needed: ➢ Validate the research to reduce likely fatigue failure ➢ Perform a modal test to identify the structural damping factor ➢ Develop a method to model tower dynamics accurately for free yaw turbines with tower resonance ➢ Document recommended text for consideration of future IEC 61400-2.	Task 41 partners: Austria—University of Applied Sciences Technikum Wien	Medium Lead: Austria?

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		rotor mass on top) often fall in the critical frequency range matched by the rotor at high wind speeds.			
TYPE TESTING					
		Refining duration test requirements will help launch technical innovation and streamline test costs.			
10	13.4	<u>Duration</u> Duration testing has been identified as a key challenge for many manufacturers, typically due to the length of time that is required to obtain enough high-wind data to meet requirements. A key consideration is re-thinking the duration test, identifying other ways to answer the important questions on turbine operation and durability. Which elements of the duration test gives us the "best" and "most important" information? Three efforts are needed: ➢ Quickly develop new duration test requirements for expedited implementation within an updated AWEA standard. ➢ Conduct the review of existing data sets to determine the value of different aspects of the duration test.	The following actions will address the challenges associated with the current duration test methodology: ➢ Develop a screening analysis tool to gather data on duration test time, operational time fraction, high-wind-speed time periods, etc. ➢ Obtain data on turbine failure as a function of existing duration test data—consider reducing high-wind-speed requirements ➢ Develop a draft update of the duration test ➢ Assess whether duration test requirements can be reduced, phased, and conducted at a different site (micro, small) ➢ Develop a draft update of the duration test requirements	Task 41 partners: Denmark—Denmark Technical University? and Nordic Folkecenter? Spain—Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas? U.S. National Renewable Energy Laboratory IEC TC88 Test Laboratory Group—provide data	High Lead: U.S.

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		➢ Develop a new duration test methodology that better pinpoints likely areas of failure while lowering costs and the timeline to fulfill standards requirements, validate the new methodology, and document results for use in the fourth revision of IEC6100-2. It is estimated that data exist on more than 20 duration tests collected among a group of stakeholders including NREL, the Small Wind Certification Council, Windward Engineering, and other test laboratories. These data can form the basis of needed comparison and the technical backbone needed to identify changes. This approach allows for the U.S. market to quickly and nimbly remove a barrier to innovation of technology, then take this new duration test into the global market through the IEC standard.	➢ Hold duration test process discussion in conjunction with the Distributed Wind Energy Association (DWEA) annual conference ➢ Document results for a near-term future AWEA/DWEA small wind turbine standard ➢ Validate with pilot testing of new duration test requirements ➢ Work to implement new duration test requirements within the fourth revision of IEC 61400-2.		
		Reporting power performance as a range will reduce consumer expectations of energy production.			
11	IEC 61400-12-1 Annex H	<u>Power performance</u> Power performance test methods are well understood, and the IEC 61400-12-1 has an Annex H that documents special requirements for small wind turbines.	To assess the methodology and develop an understanding of the potential challenges of this approach, the following would be required: ➢ Develop comparisons of power performance test	Task 41 partners: Austria—University of Applied Sciences Technikum Wien?	Medium Lead:

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		The industry practice is to plot one power curve and its estimated annual energy production based on uncluttered or valid sectors of wind direction. Most distributed wind sites are in areas of high turbulence with nearby clutter, and the annual energy production estimates provided for certified small wind turbines are rarely accurate. Most sites produce dramatically less energy than predicted. One approach would be to have two power curves, one representing high turbulence (invalid sectors of data) and one representing low turbulence (valid sector data) to present a range that more accurately bounds production estimates. Another testing question is, “Can a power curve be used to reduce loads test requirements?”	results for valid and invalid sectors ➢ Document methodology for a dual power curve plot ➢ Document results for future IEC 61400-2 ➢ Work to implement new power performance reporting requirements within IEC 61400-12-1 and IEC Renewable Energy (IECRE) requirements.	China—Inner Mongolia University of Technology? Denmark—Denmark Technical University? and Nordic Folkecenter? Korea—Korea Institute of Energy Research? Spain—Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas?	
		Loads testing is complex, especially for smaller wind turbines, but identifying measurements to validate aeroelastic models will improve model quality and turbine design.			
12	IEC 61400-13	<u>Loads testing</u> The main value of loads testing is in validating aeroelastic models. Those models, when validated, can be used as a tool to not only enable certification but also to be used as a tool for consideration of design changes.	To simplify the process of being able to use aeroelastic models, the following is recommended: ➢ Develop methodology to streamline the IEC 61400-13	U.S. – National Renewable Energy Laboratory?	High Lead: U.S.

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		The dominant issue with mechanical loads testing is the costs. The costs are a combination of the required instrumentation, data acquisition system, the required skillset (often needs to be hired externally), and the fact that it takes a while to collect sufficient data. For small turbines, in many ways the costs increase as they are harder to instrument and the size of the instrumentation starts to matter, thus requiring a smaller form factor.	measurement requirements specifically to small wind. ➢ Identify method to validate aeroelastic models (Can yaw and pitch control have reduced testing requirements?) ➢ Document results for future IEC 61400-2 and/or 61400-13 ➢ Consider developing/adding a small wind annex to 61400-13 to address specific requirements for small wind.		
		Reducing acoustic testing requirements, when appropriate, will reduce testing costs.			
13	IEC 61400-11 Annex	Acoustics testing Small wind turbines produce audible sound, which can impact the market. An IEC 61400-11 annex addresses unique requirements for small wind turbines, but the standard requires tonality testing that may not be informative for distributed wind turbine consumers. The issues with the tonality portion of the assessment are that the processing of the data is somewhat laborious and the added value is questionable. Most often a qualitative description of the presence of a	The following actions should be undertaken: ➢ Document technical rationale on why “tonality testing” is not value added ➢ Document results for future IEC 61400-2.		Low Lead:

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		tone is just as good to determine a tone near the turbine.			
		Understanding the functionality of the safety systems is key for developing safe machines.			
14	13.6	<u>Safety and function testing</u> Safety and function testing aligns and supports the duration test, and it is tailored for different turbine configurations. Now there are multiple datasets of safety and function testing conducted for dozens of small wind turbines. If these data were combined, the requirements may change.	To better understand if current safety and function tests can be refined, the following actions are required: ➢ Document technical rationale based on measurements as to why only RPM and power control are needed for micro wind turbines ➢ Review multiple datasets to find patterns and trends, later identifying any needed changes to the safety and function test ➢ Document results for future IEC 61400-2.	Task 41 partners: Denmark—Denmark Technical University? and Nordic Folkecenter? Spain—Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas? U.S. – National Renewable Energy Laboratory? IEC TC88 Test Laboratory Group—provide data	Low Lead:
		Expanding blade testing can help reduce fatigue failures at consumer sites.			
15	13.5.2	<u>Blade testing</u> Historically, duration testing was devised to reduce structural strength analysis and blade testing, particularly for fatigue.	To address this identified challenge through the development of a new testing regime for smaller wind	Spain—Centro de Investigaciones Energéticas,	Medium/Low Lead:

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	IEC 61400-23	Anecdotally, industry members have seen blade failures that could have been identified during the design cycle and component testing. Small and micro turbines typically have higher RPM than large wind turbines, which leads to centrifugal stiffening. Yet no blade tests have been developed to test this phenomenon. Further, if the factor of safety for blades could be reduced by blade fatigue testing, the result should be a technically viable, lighter weight turbine.	turbines, the following steps are required: ➢ Develop full rotor testing method for micro wind ➢ Develop strategy to reduce factors of safety based on blade fatigue testing ➢ Gather existing fatigue blade test results ➢ Analyze why some blades fail in the field but not in testing compared to blades that fail in testing but not in the field ➢ Develop an approach to centrifugal testing ➢ Document results for future IEC 61400-2.	Medioambientales y Tecnológicas? U.S. – National Renewable Energy Laboratory ?	
CONFORMITY ASSESSMENT					
		Having a common approach to certifying wind turbines helps stabilize the global market.			
16	IECRE SSG54	Conformity assessment sets up methods, procedures, and protocols for certifying, reporting certification results, and identifying what is needed to update existing turbine certifications based on design changes.	To complete this effort, the following will be needed: ➢ Help to refine conformity assessment guidelines for small wind turbines ➢ Build the technical basis for recommending that both power curves are presented in certification reports.	IECRE SSG54	High Lead: