10th International Conference on

Wind Turbine Noise

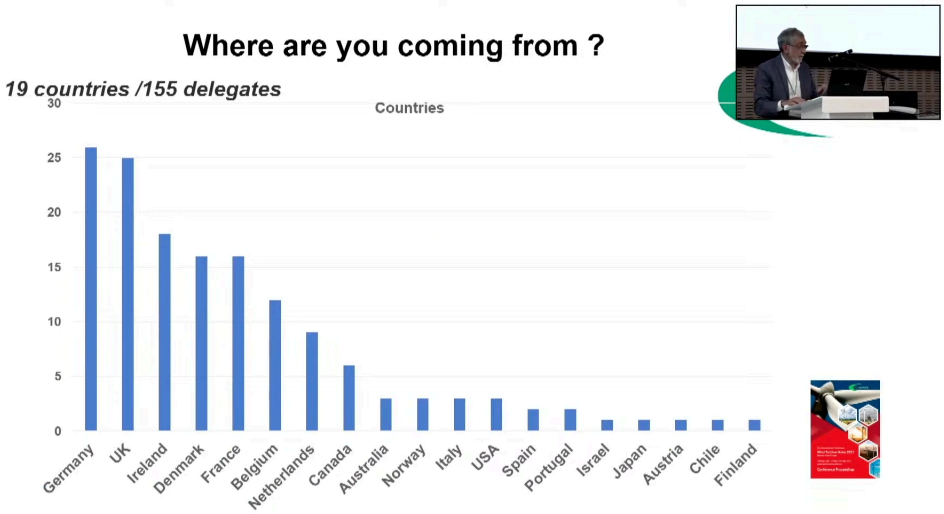
Dublin, Ireland + Remote

June 21-23, 2023

The 10th International Conference on Wind Turbine Noise (WTN 2023) was held as a "hybrid" local and remote conference. 125 delegates attended locally at Trinity Business School, Trinity College, Dublin, Ireland and 30 additional delegates attended remotely (watching on-line) with some 12-15 routinely connected by "chat" to share ideas and comments with each other.

I may have been the only conference attendee in the "Objector" category, as I noted no others.

The 155 delegates represented 19 (or 20 said on closing) countries, including 6 from Canada.



The 6 from Canada included 3 developer representatives, there as listeners who were not heard from; 2 as Session Sub-Chairs, David Michaud from Health Canada who also was a lead-off speaker at a forum titled "Impact on People," and David Colby, former Medical Officer of Health from Chatham Kent; and finally myself as the only paper presenter from Canada.

44 – 20 minute papers were presented (including 3 remotely) grouped in the following sessions, with each group followed by a discussion / question and answer period:

- Propagation (mostly about model development for sound travelling from the wind turbine to receptors) – 7 papers in a split session
- Mode Management (methods and the impact of reduction of turbine speed and output to reduce noise, when necessary to meet regulatory limits) – 3 papers
- Guidelines and Regulations – 5 papers
- Source Noise (mostly about models to predict the noise at the source, - the wind turbine) – 7 papers in a split session
- Impact on People – 8 papers in a split session (Including mine, presented remotely)
- Compliance (mostly about monitoring campaigns) – 4 papers
- Miscellany – Including Amplitude Modulation – 5 papers
- Tonal Noise – 5 papers

The paper presenters might be categorized roughly as follows (some authors represented several fields, so this list is only approximate):

- University wind departments – 18 papers (some doctoral candidates, or post-doc fellowships)
- Wind industry consultants – 14 papers
- Industries providing wind components – 6 papers
- National regulators – 2 papers
- Operators of wind developments – 2 papers
- Independent researchers – 2 papers (I've put myself into this category)

Additionally, the conference included 3 "Forums" of 40 minutes or so, usually opened by an address from one or two speakers, followed by a panel discussion, on these topics:

- Are we moving towards a consensus on Wind Turbine Noise Regulation?
- Wind Turbine Noise Reduction: Beyond Serration (blade trailing edge modification)
- Impact on People

This was the 8th WTN Conference that I attended. I anticipated that attending "remotely" would mean missing out on the person-to-person contact that formed a big part of the WTN conferences previously attended. As it turned out, the majority of those who I looked forward to meeting again after past conferences were not there in person this time, in some cases because of personal or family health challenges, or perhaps because their work programs may have changed to no longer give them time (or perhaps interest) to attend the conference this time. In fact, more of the group who I would have hoped to speak to were also attending remotely than in person. A core group of 12 to 15 took an active part in the "chat" session daily that ran concurrently with the streamed presentations. These were active conversations.

Sharing of ideas during those sessions actually seemed to be more than occur in normal break-time at face to face conferences. Also, the organizers arranged a "Zoom" face to face chat each day, and a group of 6 to 8 gathered around a "Zoom Lunch Table" for an hour or so daily. I'd like to acknowledge the following group and thank them for their openness and sharing with an international flavor in those conversations. I learned a lot, thanks.

- Dick Bowdler UK / Scotland
- Alex McKenzie UK / England
- Geoff Leventhall UK / England
- Malcolm Hayes UK / Wales
- Thomas Sorensen Denmark
- Oscar Breugelmans Netherlands
- Mark Jiggins UK
- Kris Aper Belgium
- Robin Woodward UK / Wales
- Matthew Cand UK
- Cormack Staunton Ireland (who did a wonderful job of meeting the AV needs)
- Corneel Delesie Belgium
- Brice Geoffroy France
- Sophie Nyborg Denmark
- Sebastien Wschiansky Switzerland
- Pierre Fillion France

To those who were there in person or on line to whom I missed saying "hello" to renew past acquaintances, I apologize. Maybe next time? (Grouped alphabetically by country).

- David Colby Canada
- David Michaud Canada
- Bo Sondergaard Denmark
- Lars Sommer Sondergaard Denmark
- Jean Tourret France
- Fritz van den Berg Netherlands
- Cathy MacKenzie UK
- Sabine Hunerbein UK
- Bruce Walker USA
- Mark Bastasch USA
- And others who I've missed, sorry!

While there were things to learn from each of the 43 presentations other than mine, and the 3 forums, this is the list of key learnings that jump to the top for me. No doubt as I go back over the videos of each day's presentations, my notes, and the book of all presentation papers, more will come to mind. In my following comments, please note that my recollection of what was said by others is based on my notes of what I thought I heard people say. They are not based on a "transcription" of comments. Some might feel I misquoted what they thought they had said, and if so I apologize. There was certainly no intent to offend anyone by misquoting them.

1. Forum – Wind Turbine Noise Reduction – Beyond Serrations

This forum, moderated by Franck Bertagnolio (Danish Technical University) was comprised of these panelists from industry:

- Erik Sloth (Vestas Wind Systems)
- Roger Drobietz (GE Wind Energy)
- Cordula Hornung (Enercon)
- Jeremy Herault (LM Wind Power - blade manufacturer)

In the panel discussion about future options to reduce the blade noise, the opening position of Roger Drobietz was that 80-metre long blades are:

- very complex,
- undergo extreme loads and forces,
- need to last 25 years,
- have a shape that needs to be optimized for performance, to carry the loads
- mass too needs to be optimized, to avoid overloading the machine
- also, need to be optimized for stability, flexibility, aero-elasticity,
- and finally, (perhaps in that order?) need to be optimized for noise

For this reason, he noted that a pure noise optimization was never going to work. To add a slot in the blade to carry an active component to change the suction characteristic that might be adjusted to reduce noise would be very difficult, and he did not foresee it happening. It would need additional drivers to move the components. It would increase complexity, and would impact the blade structural integrity. It might positively impact noise, but would have many adverse effects. He did not see any new active systems in the next 10 years, and felt the need was to stay with passive methods, not active. There had already been discussion following the prior session that actively pitching the blades to accommodate varying wind speed from the bottom to the top on each rotation (due to wind shear), thus reducing the amplitude modulation (swoosh) would require many, many, back and forth cycles of the very large blades over their lifetime, and would risk failure. It too was not seen as likely. On a personal note, the representative of Siemens present during an Armow pre-construction public meeting in 2007 had assured me that their blades already did this, something I doubted at the time, but could not counter as the operational details were not provided. Now the experts from GE, Enercon, and Vestas, as well as the main blade manufacturer assure us that it is indeed not happening now, has not happened in the past, and is not likely to happen in the next decade.

Erik Sloth continued that any additional complexity of the blade would result in maintenance difficulties (such as dirt or ice getting into any openings on the blade for retractable components). Any control systems for an active system (wiring, actuators, etc.) in the blade would result in additional lightning strikes. He continued that while they are trying to reduce sound power in the outer 15% of the blades by serrations, brushes, or other modifications, perhaps they needed to stop adding “add-ons” to the outer parts of the blades and to focus instead to the inner part of the blades (closer to the blade root or hub), to reduce the noise

actually getting to the neighbours. To paraphrase his words, perhaps they are not dealing with the right part of the problem – but they are dealing with what the regulators are requiring. I find it concerning that those who know the issues best, are not standing up to the regulators and legislators, to advise them what the best path forward is.

Cordula Hornung added that the need was to reduce the low frequency range of sound emission. Serrations impact the mid frequency range, not low frequency. Control of low frequency noise would require dealing with inflow noise for which there is currently no solution. There is research into things like leading edge serrations, but they would be very hard to implement. They also need to consider the fact that the propagation models are based on a monopole source, and thus are not fully accurate.

Jeremy Herault added that it is difficult to predict what might be next after serrations to reduce noise, and something new would only be added to the blade construction if it adds value. He too doubted that any active system will be implemented, although there may be some progress on other passive modifications.

In summary, the panelists concluded that any complex system in the blades with active drivers is unlikely in the next 10 years. Perhaps changing the shape of the serrations might be a path forward to improve the situation. The panelists suggested that they should not be focusing so intently on sound emission, but they must comply with the regulations. Erik Sloth concluded, "But are the regulations protecting the neighbours? I see they are not."

Eric Sloth also noted that, the angle of attack (the angle at which impingement of incoming air hits the blade) changes with wind speed across the rotation. The angle of attack "is massively important – for both performance and noise." While cyclical blade pitching might be possible, it is unlikely to happen. The wear on the blade tilt bearings could also be an issue.

I could not help thinking back to 2009 at WTN 3 in Aalborg, when my paper titled, "A New Explanation for Wind Turbine Whoosh – Wind Shear," had suggested that the variation of the angle of attack caused by the change in wind speed due to wind shear across the blade resulted in the "whoosh." However, my suggestion had been discounted by all present. Now after 12 years the importance of "angle of attack" on "amplitude modulation" – aka the rising and falling swoosh, seems to be recognized as important. Things just take time.

David Colby queried if anyone had done study of biological systems. He noted that owls fly silently, so modeling owls might make a silent turbine. Eric Sloth replied that serrations are indeed modeled on the shape of a bird's feathers, but noted that an owl flies very slowly compared to the speed of a wind turbine blade tip. He noted that if they could reduce a wind turbine tip speed from the current value of about 60 m/sec, to the speed at which an owl can fly silently (less than 1 or 2 metres per second) they could make wind turbines very quiet, but they would also be very expensive. As an example, a Vestas V82 with a rotational speed of 14.4 rpm, and a 41-metre long blade has a tip speed of $(2 \bullet \pi \bullet 41\text{m} \bullet 14.4 \text{ rpm}) / 60 \text{ min/sec} = 62 \text{ m/s}$. (> 220 km/hr) They only look to be slowly moving through the air because of their size.

Erik Sloth concluded, “At conferences like this we can recognize that we can do better. We can decrease annoyance and get more energy if we do it right. The challenge is to get politicians to realize that we are telling them a good idea.”

2. Tonality Reduction Through “Adaptive Tuned Mass Dampers”

An interesting paper by Alexander Busch of ESM-GmbH of Germany showed how vibration in wind turbine drive systems can result in tonality that can be radiated from the turbine, resulting in annoyance. Some of the charts he presented looked remarkably familiar to ones seen from processing recordings of K2 sound samples. They have a number of vibration solution systems, including a tuned mass damper that can be tuned to frequencies between 50 to 600 Hz, as well as a system they describe as an adaptive tuned mass damper that can be tuned to vibration that changes as machine speed changes.

https://www.esm-gmbh.de/en/products/noise-tuned-mass-dampers/ - adaptive-TMD

I plan to select several appropriate examples showing tonality experienced from the Siemens SWT 101 wind turbines in the K2 array from recordings we have, to send to the company. It is worth asking if this is the sort of issue they have experience with, before sending the information to the Ministry and K2, identifying that the annoyance issue from tonality with the K2 turbines might be addressed.

3. To Find the Source of Problems Follow the Money

While this was not the subject of a presented paper, I could not help thinking that it was just below the surface in many. The most obvious and troubling one, to me, was another remote presentation by Mr. Nicholás Bastián-Monarca, Director of Engineering of Acústica Austral in Chile. His presentation went through the steps required to license a wind power development in Chile. What bothered me most was that for citizens, who would be living in rural areas, 24/7, 365 days a year, the requirement for wind turbines was to meet either background plus 10 dBA, or 65 dBA in the daytime and 50 dBA at night. (Ontario requires a limit of 40 dBA day or night in rural areas.) However, in contrast, in areas that tourists might visit, the Chilean recommendation will be to not exceed the background noise level (that is, at least 10 dBA less than for people living in the area, 24/7, 365 days a year.) Yes, I thought, (although it was NOT said in the presentation) money talks, and we mustn’t make tourists go away.

4. Softening of Standards to Enable More Wind Developments

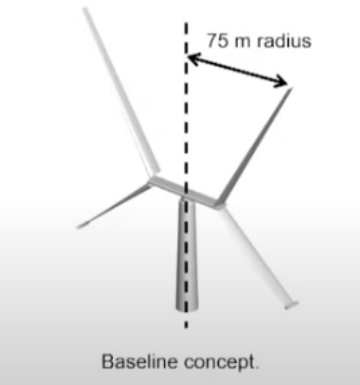
I lost count of how many times I heard that the International Energy Agency was requiring more wind power developments to be built in order to meet the zero carbon limits set by the Paris 2015 Climate Change Conference. A good overview of the issue was given by Madelon Ekelschot-Smink on behalf of herself and Erik Koppen, in a presentation titled, “Standards for regulating environmental impact of wind turbines.” Both authors represent “Arcadis” noted on their website as an engineering company headquartered in the Netherlands, but with offices in over 70 countries globally, who note themselves as “the world’s leading company delivering sustainable design, engineering, and consultancy solutions for

natural and built assets." The presentation discussed how as a result of a court decision, the Netherlands has dropped all national regulation for wind turbines, and are reconsidering setback limits. They noted, for example, Poland has reduced limits from 10x height setback for wind turbines (perhaps 2400 metres for some), to 700 metres (actually up from a 500 metre proposal), regardless of size. This was required of Poland by the European Union, "to receive European funds under the national recovery plan." The state of Bavaria in Germany will reduce from a 10X height setback to 800 metres "for wind priority areas" to "catch up in the production of wind energy." Other nations were noted as having limits of 4x height. The main criteria for setback was noted to be "to prevent visual nuisance", and "visually overwhelming effects." Standards are dropping like flies was my thought.

Neeraj Paul Manelil spoke on a paper titled, "Influence of atmospheric boundary layer characteristics and source height on sound propagation from a 5 MW wind turbine." The interesting part though, was his opening noting his motivation as "the harmful effects of noise pollution" that highly annoyed 10% with effects of stress and sleep deprivation. The paper includes the line, "*This has led to an increase in the number of onshore wind turbines, but with it come concerns surrounding the environmental and safety impacts of this technology. In particular, noise has become an increasingly significant health problem in recent years, as exposure to excess noise can lead to stress, sleep deprivation, cognitive impairment, hypertension, and cardiovascular disease…"* In the discussion following, Dr. Gundula Hübner, a professor of social psychology at the MSU Medical School, Hamburg, who was the first session chair on "Impact on People", and later presented on "Analysis of Mitigation Measures for Wind Turbine Noise Annoyance," was quick to point out, (I paraphrase only) "you cannot say there are health problems from wind turbines. There may be annoyance but there is no confirmation of health effects." Annoyance and sleep deprivation appear to be reduced in emphasis to being minor irritants, and not important enough to hold back further development.

5. Session on Source Noise

Seven papers discussed research into ways that might be applied to reduce the noise from wind turbine blades. They mostly represented work ongoing at Universities and tended to be quite heavy with equations and calculations. The comment was made by one chat participant about not being able to follow the presentations, but being glad that someone was doing the in-depth work. Some of the researcher's comments on the ease of implementing additional components to reduce noise had admittedly left me wondering if practicality was considered. One speaker had commented that the need was just to send someone up to stick "Vortex generators" on the blade surface, to result in a potential improvement. Just "sending someone up on the blades" to stick on components (that might be thrown off, and become airborne) struck me as perhaps not fully thought through.



There was one notable exception in this series of talks, which was a presentation on development work for an "X Rotor" hybrid turbine for offshore application.

The X-Rotor turbine, as described would have two 100-metre long upper blades, with the top tips separated by 150 metres, and two 65-metre long lower blades, each with a secondary 6.5-metre rotor on the lower blade tips.

A simulation of the expected acoustic output of the turbine was played. It was very loud. I could only think, "Oh my!"

6. Population Effect versus Individual Effect

The seemingly un-reconcilable conflict between population effect versus individual effect with respect to wind turbines continued to be seen in the conference. To my mind, there should be no conflict between these two areas of focus. Both need to apply. I can remember making the point in my testimony at the first Ontario Environmental Review Tribunal for the Kent Breezes wind power development. I had discussed that wind turbines should mirror the nuclear safety area which addressed BOTH the population safety effect and the individual safety effect for:

- the entire population living in the environment of the plant,
- as well as the individual living at the plant fence.

If the plant was surrounded by a large population density, then the population impact was predominant. In contrast, if the population in the vicinity was low, then the individual impact was predominant, but both limits had to be met. I had noted that for wind turbines, the predominant safety effect would not be a population effect, but an individual effect for the person living nearby. In cross examination, the counsel for the developer had posed the statement, "But surely you must agree, Mr. Palmer, that the consequences of being harmed by a nuclear accident are far more serious than the consequences of being harmed by a wind turbine." My response was simple. "Actually, sir, the consequences of being harmed (or killed) by either are exactly the same, you are dead."

One of the first demonstrations of the conflict between these two mutually required areas of protection was seen following the discussion session after the three presentations on "Mode Management." The presenters had noted work being done to optimize production output while enabling meeting sound limits, by maneuvering turbine output through the use of "modes" to reduce turbine speed, and hence noise when necessary. David Michaud identified

himself as representing Health Canada, and posed the statement, “It seems very strange to me that you’d want to use modes to reduce the power output in the first place. Because, presumably you want to offset fossil fuels burned with clean energy, and by reducing the mode … you increase the percent required from fossil fuel required by the electrical grid … so the net health effect on the population could be worse when you are reducing power output … You are using modes to reduce exposure … presumably because that annoys people that might interfere with sleep … but by reducing sound level you have get power from somewhere else.”

One presenter replied, you are speaking about the population effect, but the developer or wind farm operator has to comply with the regulations.

David Michaud continued … “I wonder if the community realizes … why not just … for every minute or hour above the limit, if we distribute some benefit to the community, and leave the turbines alone … it must cost a lot of money to reduce power output … just distribute the money to the community … what happens is they actually want the turbines to be audible then … you are really protecting health by not over relying on other sources.”

The interpretation I felt I had heard, was that the position of Health Canada being represented was that the population was best served by high wind turbine output, and the individual concerns were of less importance. It seemed that for Health Canada both population and individual effects did not need to be met, only the population effect, as more important.

The session chair Bo Sondergaard closed the session with a chuckle, suggesting, “David you will have to make a presentation at some time later and argue for the fact that more noise is better for the surroundings. It will be very interesting to hear the response to that.”

In a later session, after the Forum discussion on “Wind turbine noise reduction: beyond serration,” the population versus individual position of Health Canada seemed to be reinforced. David Michaud posed the question, “Would a community prefer an invisible turbine or a silent turbine?” He then responded to his own question, saying, “They would prefer an invisible one, I suspect.” This effectively represents the population position, rather than the individual position. The general population is little impacted by sound from the turbines, but have to look at them as they travel through the countryside. Hence, the population position is biased towards visual impact not sound. In contrast, for the individual who lives next to a turbine, the prime concern is usually the sound. That is what individuals mention as what keeps them from sleeping, not what the turbine looks like.

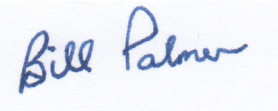
One might argue that in Ontario, and possibly some other jurisdictions, the main population

effect of wind turbines is their impact on the price of electricity and it's knock on impacts on the economy. However, in Ontario, one reads on the IESO (electrical system operator) website, that, "since Jan. 1, 2021, approximately 85% of non-hydro renewable energy contract costs are being shifted from the rate base to the tax base." Those renewable energy costs formerly increased the price of electricity in a "global adjustment term" but the shift effectively moves those costs into the provincial debt, to be paid for in the future. Hence the main population impact has become invisible, as it became a "pay-me-later" cost instead of "pay-me-now." The debate as to which eventually costs more, "pay-me-now" or "pay-me-later" is a subject for another day, but I suspect the population impact will not be negligible.

While I mean no offence to anyone, I suspect the "population vs. individual" concern is what drives those in positions of power (e.g. government leaders and regulators) to favour population emphasis. They believe they are most effective by focusing on "the big picture." Yes, it impacts the most voters. Individual needs come a distant second. This has the effect of putting those leaders in conflict with individuals. My personal model has to be the one put forward by Jesus, who although the highest possible leader, was not above stopping to deal with the needs of the individual, such as the woman spoken of in Luke chapter 8. Even though crowds pressed around Jesus, the woman thought "If I just touch his garment, I will be healed." Jesus stopped, even with the crowd demanding his attention, and focused on the needs of the one, as he did many times. I cannot but believe that we are called in the same way, to deal with the individual, at times. "Love God, and love one another," is the commandment, not, "Love the crowd." Both the population effect and the individual effect matter for a just society.

As promised, this initial summary only highlights the top issues (for me) from this conference. No doubt more will continue to come to mind as I go back over my notes, and carefully read all the presentation papers, but this will give an overview for interested folks of what I learned. I thank the conference organizers for their work, and for permitting me to present my paper as a "remote" one to a "hybrid" conference, since that was not the initial intent.

Sincerely, thank you.



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