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Putting into perspective the risks to public health and safety posed by wind turbine installations

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Abstract

Evaluation of the risks to public health and safety posed by wind turbine installations is presented based on the special relationship between engineers and public welfare. Also, the evaluation investigated concerns identified by residents. "Risk" was considered as the answer to the questions of what can go wrong, what is the likelihood of it happening, and what are the consequences? Response to what can go wrong, was found from two methods. First was examination of 13 acute events that have occurred to 2712 wind turbines in Ontario, Canada. The second was an investigation of chronic occurrence of special noise characteristics. The likelihood of acute events was found to be 0.5 E-03 failures per turbine year. Chronic conditions of special noise characteristics were found that correlated with resident concerns. Consequences of inadequate protective barriers were discussed. Conclusions identified will provide more effective public safety, and will reduce annoyance impacting health.

Keywords: wind turbine; public safety; risk; tonality; cyclical noise; annoyance

Introduction

1.1 The Preamble – "risk"

The book, "Risk Assessment, Theory, Methods, and Applications" by Marvin Rausand and Stein Haugen [1] introduces risk analysis by quoting from Stan Kaplan. Kaplan identified that failing a common definition of the word "risk," each author should clearly define how the word "risk" will be used. This paper will use the definition proposed in "Risk Assessment, Theory, Methods, and Applications." The authors proposed that "risk" is the combined answer to three questions:

- What can go wrong? (identifying the accident scenarios that may cause harm)
- What is the likelihood of that happening? (Which can be answered either qualitatively, or quantitatively as probabilities or frequencies, but needs to consider all the accident scenarios identified, and essential modifiers that can impact the likelihood.)

- What are the consequences? (This needs consideration of protective barriers in the event something goes wrong.)

Often the determination of "risk" is given by the simplified word equation, Risk = Frequency x Consequences.

Engineers have a special obligation related to risk. As an example, the Canadian Province of Ontario Engineering Act [2] identifies the legal obligation of Professional Engineers to protect public safety. The act notes this responsibility is paramount, even above duties to clients or employers. This paper identifies how risks that may have consequence to public health and safety posed by wind turbine installations interacts with this engineering legal responsibility.

Gathering the Data – The Experimental Procedure

2.1 What can go wrong?

Wind turbine scenarios that could do harm were identified by two methods.

- Acute scenarios were identified by tracking accidents in the Province of Ontario, Canada. Scenarios were limited to those when turbine components greater than 1 metre in size fell from wind turbines with a nominal tip height of 100 metres or higher onto the ground. The components had to fall at a location that was not protected by an effective barrier that would prevent hitting a citizen. 2712 turbines meeting this size criteria have operated in Ontario, from 8 different manufacturers. (2 have been shutdown and dismantled.) Known accidents of this nature from the pool of wind turbines are shown in Table 1. Falling ice events and falling blade flow straighteners were not specifically tracked. Typical failures are shown in Figures 1 and 2.

Table 1: Ontario wind turbine accidents

Date	Where / What Failure / Turbine Type	Age at Failure
2007-04	Port Burwell / blade fail / GE 1.5	0.9 years
2008-01	Prince Wind / blade fail / GE 1.5	2.1 years
2013-04	Kingsbridge 1 / fire / Vestas V80	7 years
2015-08	Goshen / blade fail / GE 1.62	0.5 years
2017-04	Bornish / blade fail / GE 1.62	3 years
2018-01	Raleigh / tower collapse / GE 1.62	7 years
2018-05	Huron Wind / blade fail / Vestas V80	15.4 years
2019-04	Sumac Ridge / blade fail / Senvion MM92	1.3 years
2021-06	Skyway 8 / blade fail / Vestas V100	6.9 years
2021-08	Bow Lake / tower collapse / GE 1.62	6 years
2024-06	Kingsbridge 1 / fire / Vestas V80	18.2 years
2024-06	Gestner / fire / Gamesa 2 MW	11.4 years
2025-03	Port Burwell / hub collapse / GE 1.5	18.8 years

Fig. 1 Typical wind turbine fire (Kingsbridge 1 2024-06)



Fig. 2 Typical tower collapse (Bow Lake 2021-08)

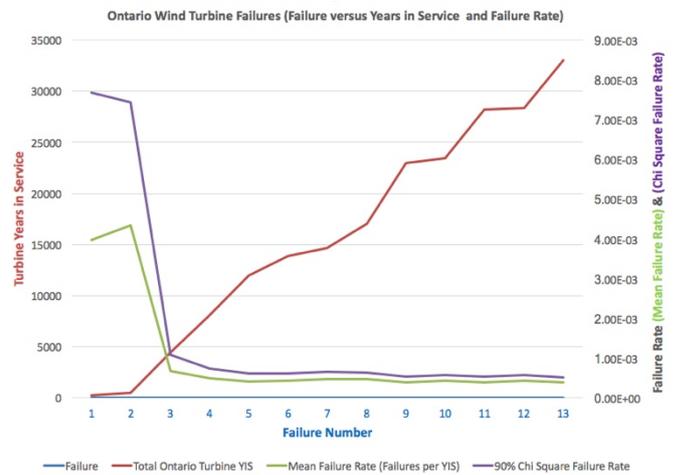


- A list of chronic scenarios associated with acoustic conditions was derived by investigating some of over 100 citizen reports of adverse impacts. Acoustic monitoring was conducted as described in sections 2.4.1 to .3 to determine if specific acoustic conditions could be correlated to the complaints.

2.2 What is the likelihood of acute scenarios happening?

The tabulated wind turbine acute accident scenarios, and the total Ontario turbine-years of operation when each accident occurred, was used to identify a failure rate. The progression of failure rates (both mean and Chi Square) and the total turbine years in service at each failure, was plotted in Figure 3. The figure shows a fairly constant failure rate of 0.5 E-03 failures per turbine years in service after the first few failures had occurred.

Fig. 3 Ontario wind turbine failure rate



2.3 What is the consequence of acute scenarios happening?

In a comparable situation of assessing public safety risk, Canadian nuclear regulators require that a deterministic safety analysis be conducted for every facility licence. The analysis must demonstrate that defence in depth exists to protect the public, in the event of failure of equipment, internal or external event, or operator error. [3] The deterministic safety analysis is used in the assessment of event consequences to show that effective barriers exist. Additionally, for licensing new facilities, or for existing facilities when the licensing basis includes it, there is a requirement for a probabilistic safety assessment. [4] The intent of the probabilistic safety assessment is to identify that no particular feature or initiating event makes a disproportionately large or significantly uncertain contribution to risk. The combined goal of the deterministic safety analysis and probabilistic safety assessment is protection for both the most impacted individual and the population impacted by a failure.

Assessment of public safety risk for a wind turbine installation should similarly show protection for both the most impacted individual and the overall population impacted. Deterministic safety analysis would show that for each known

wind turbine failure identified in Table 1, an effective barrier would have to exist. For example, for a blade failure, it would be necessary to demonstrate that a barrier such as an exclusion zone would protect any member of the public from being impacted. The consequence of the failure would then be low or negligible. A probabilistic safety assessment for wind turbine accidents identified in Table 1 would show the impact of features such as lack of fire suppression.

For wind turbine installations, the public safety impact on individuals is greater than impact on overall population. The public, or neighbours to wind turbines in Ontario, Canada, are “protected” by a regulatory exclusion zone equal to the turbine rotor radius (blade length) plus 10 metres. For the 2018-05 Huron Wind blade failure identified in Table 1, a 1.2 metre wire fence, located 52 metres from the turbine that failed bears a sign. The sign reads, “No Entry, High Voltage Hazard, Falling Ice Hazard (during cold weather), Trespassers will be prosecuted.” The day following the blade failure, the author visited the site, and photographed blade segments, including:

- 1.2 m x 3.6 m blade segment 150 m from tower
- 1.0 m x 3.6 m blade segment 170 m from tower
- 1.2 m x 3.0 m blade segment 210 m from tower
- 1.2 m x 3.0 m blade segment 280 m from tower
- 1.0 m x 0.15 m blade segment 560 m from tower

Other Ontario wind turbine failures have identified similar challenges to the “protective” exclusion zone. The 2021-08 Bow Lake tower collapse in Figure 2 shows the 50-ton turbine nacelle on the ground at a distance greater than blade length plus 10 metres from the tower. Wind facility staff reported to the municipality after the 2013-04 Kingsbridge 1 turbine fire consumed the nacelle, that burning debris landed 200 metres from the tower. A blade length plus 10 metre exclusion zone is demonstrably inadequate to protect the public for turbine collapse, blade failure, or turbine fire.

Ice falling from wind turbines, although not included in the table of acute failures, as hardly exceptional for Canadian installations, poses an additional challenge. Along Ontario provincial highway 21, a fence post with a 20 cm x 25 cm sign reads, “Caution, During Potential Icing Conditions Stay Back 305 metres from Turbines.” This would seem a reasonable suggestion, and is consistent with common recommendations for the turbine size. However, the sign poses several problems. First, the lettering is too small to be read from passing vehicles. Second, it is located at the boundary of the “right-of-way” of the provincial highway. The nearest wind turbine is set back 121 metres (the hub height plus blade length) from the highway “right-of-way.” Provincial monitoring shows an average daily count of 7050 motor vehicles pass by that location. [5] These vehicles cannot travel down the provincial highway and comply to stay 305 metres from the nearest wind turbine, located 121 metres from the right-of-way.

When considering consequences of known accidents with a frequency of 0.5×10^{-3} failures per turbine year, one might expect that the “protective” barrier would be effective. One would also expect that when a turbine operator posts a sign as a “protective” barrier, that it would be possible to comply.

Recognizing that neither expectation of “protective” barrier can be assured to make the consequence of known accident

scenarios to be low or negligible, it is necessary to proceed further to investigate the consequence of each accident. We will approach the investigation from the accident boundary conditions. We consider first tower collapse, demonstrated to have placed a 50-ton nacelle on the ground at a distance from the tower greater than blade length plus 10 metres. Even without medical expertise, it is apparent that the consequence at the point of impact, a location outside the protective zone, would be fatal to any human. We consider next the opposite boundary condition, ice fall from stationary wind turbine blades. Photographs and reports show ice greater than 30 cm x 30 cm x 2 cm, falling from stationary wind turbine blades. Landing at a distance of greater than blade length plus 10 metres from the tower. Lateral shift of where the ice lands, away from the tower occurs even with gentle breezes. Calculation shows this ice segment falling from the height of turbine blades is equivalent to dropping an 18-kg concrete block from an 8 storey window. Again, even without an expert assessment, the consequence can be seen to be fatal to a human. Heated turbine blades can result in even larger ice segments falling. [6]

We have considered bounding cases of the wind turbine tower collapse, or ice shed from stationary blades. Both demonstrated that a member of the public could suffer fatal consequences when located outside of the exclusion zones in locations purported to provide protection. It is logical that fatal consequences could occur from intermediary accidents, such as 1.2 m x 3.0 m blade segments 280 m from the turbine tower.

2.4 Gathering data for chronic noise issues

In addition to the acute wind turbine accident data collected, over 100 citizens reported adverse impacts to the author. A freedom of information request filed to the Ontario regulator showed 5832 complaints about wind turbine noise, vibration, and sound pressure filed from 2006-2018. This subsection identifies the data gathering to try to understand these issues.

2.4.1 Noise inside versus outside homes

Some reports were initially hard to comprehend. One family reported that when noise inside their home was untenable, they found some relief by sleeping in a tent, outside. This seemed odd, as it was expected that the home structure would attenuate the sound. Another resident reported that when unable to sleep due to noise, some relief was found by reversing sleeping position, with their head at the foot of the bed. Again, this was puzzling. Data was gathered by monitoring at different locations within the home, with windows open and closed. The results were reported at the 168th meeting of the Acoustical Society of America and subsequently documented in the Journal, Global Environment, Health and Safety [7]. The investigation showed that the phenomenon known as “room conditions” resulted in significantly different acoustic readings across a room. The centre of a room, near the foot of the bed, was lower in sound level than at the head of the bed in the room corner. Room shape, particularly if approaching cubic, impacts reverberation, and the variation across the room. Inside the home, where mid and higher frequency sound was attenuated, the cyclical variation of low frequency became predominant.

2.4.2 Tonal conditions reported from a particular turbine type

In another wind power development, residents reported they were troubled by tonal conditions from the wind turbines. An extended monitoring campaign was conducted. While “tonal-like” sound was apparent meeting the ECMA 74/418 code criterion for tonality, the current IEC or ISO/PAS codes for wind turbine tonality were too restrictive to note this as tonal, even though the annoyance was real. A similar acoustic profile was found at another site with the same wind turbine type. This work was documented in the Proceedings of Meetings on Acoustics of the Acoustical Society of America (ASA). [8]

2.4.3 Extended monitoring of conditions identified as annoying

Additional data was gathered at another site over a period of approximately 12 months to assess acoustic conditions identified by residents as annoying. This campaign monitored simultaneously at the residence in the vicinity of the wind turbines, and at a second nearby location of the same environmental profile, but without nearby wind turbines. Terrain, proximity to roads, trees, wind and weather conditions were very similar at both sites. This demonstrated the annoying sounds recorded were the result of the wind turbines, not the wind. This also was documented in the Proceedings of Meetings on Acoustics of the ASA. [8]

Results and Discussion

This work is an update and expansion of a 2018 study of public safety risk related to wind turbines. [9] Wind turbine failure rate has not fallen with the installation of newer wind turbines, but remains relatively constant at 0.5 E-03 failures per wind turbine year in operation.

Examination of the failures which have occurred demonstrate that the existing Ontario setback of blade length plus 10 metres does not provide an effective safety barrier to protect the public. Turbine collapses, fires, and blade failures have each resulted in impact that could have fatal consequences at distances greater than the required setback.

When considering the consequence of the failures which have occurred, the comparison was shown to other energy generating industries which have safety goals to ensure the protection of both the most impacted individual and the impacted population. While wind turbines tend to have little population effect, they do have a demonstrated impact on individuals. A person living near wind turbines might well look cautiously at their nearest turbine, and wonder, “Will this be the turbine to fail this year?” Their pleasure in their property can be limited by that consideration and noise from the turbines. The condition is different for an individual who lives continuously in the impacted area, compared to one who chooses to visit the area periodically, but can leave at will.

It is inappropriate for a wind turbine developer to encroach on the safety envelope of a neighbour, and inconsistent with individual safety goals of industry. The most impacted individuals are often those who moved to a quiet property as a sanctuary from a stressful past. Expropriation, the power of a government to transfer private property into public ownership,

even if for perceived public good, usually involves some form of agreed compensation. Taking away pleasure of property without formal expropriation might be considered theft.

While this paper will not discuss specific health issues arising from wind turbine noise, the work referenced has identified that there are characteristics in the wind turbine noise consistent with annoyance complaints. In particular, a significant variation in Z-weighted sound (LZ10-LZ90) ≥ 6 dBZ while A-weighted sound varied little (LA10-LA90) ≤ 3 dBA was found to correlate with resident annoyance complaints. [8]

Conclusions

Appropriate safety boundaries should be established around wind turbines, consistent with observed impact areas for known failures. Blade failure (impacting 280 metres for fatal consequences, or 560 metres for likely significant injury) would appear to be a bounding condition for physical impact for 120-150 metre turbines. Consistent with other generating means, the protection should apply to the most impacted individual. Noise from wind turbines needs to consider limiting the cumulative effect of all turbines impacting an individual. Avoidance of either tonal-like sound, or significant cyclical variation in Z-weighted sound while A-weighted sound varies little, needs to be controlled to limit annoyance.

Acknowledgements

The image in Fig. 1 of the wind turbine fire is from a CTV News broadcast by CTV reporter Scott Miller. It is used with permission.

The image in Fig. 2 of the turbine collapse is from SaultOnLine.com. It is used with permission. <https://www.youtube.com/watch?v=klzE1fOgLU>

The sound monitoring equipment used to perform acoustic monitoring at resident homes was purchased by residents and loaned to the author for data gathering.

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