Recent Developments In Environmental Assessment Methods For Wind Turbine Noise

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Background

The mechanism of noise generation by large wind turbine generators (WTGs), and the sound level impact can vary dramatically over time at a given receptor location, and to a degree greater than many other types of industrial noise. It is widely known that WTGs tend to emit greater sound power as wind speed increases, but it is perhaps less predictable how other environmental factors influence the radiated sound power for a given reference-height wind speed and the propagation of sound to a receptor.

To ensure acceptable noise impacts at residential neighbors, it is appropriate for regulators to require that the acoustic impact of proposed WTGs be assessed using standardized methods and against standardized criteria. Yet, because of the range in actual impact at a receptor from one observation period to another, selecting a condition covering all possible situations is difficult.

In 2007, HGC Engineering prepared for the Canadian Wind Energy Association (CanWEA) a document outlining best practices for the developers of wind farm projects, and summarizing the assessment methodologies in the different jurisdictions in Canada[1]. The various guides in use at that time all provided general limits for sound levels, but less guidance on the prediction methods, leading assessors to rely on general purpose methods, and to develop their own assumptions. For these reasons, the acoustic assessment of wind farms in many jurisdictions tended to have a somewhat arbitrary nature; different assessors would produce somewhat different results.

To deal with this issue, the Ontario Ministry of Environment (MOE) published a guideline document which required the use of ISO 9613 for calculations related to the propagation of sound, and IEC 61400-11 to establish sound power. However, there remained variability between assumptions used in the analysis by different assessors, and therefore variability in the results and recommended setback distances from residential receptors. Accordingly, the MOE published a new draft document [2] which makes changes aimed at reducing the variability amongst assessors by specifying certain assumptions to be used in the analysis

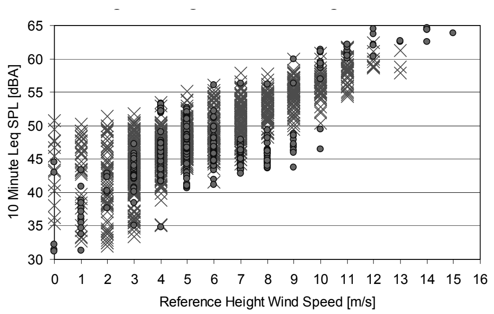

Fig. 1. Sound levels versus reference height wind speeds measured at wind farms in Nova Scotia (circles) and Ontario (crosses).

and mandates the consideration of wind profile effects.

Correctly applying the MOE procedures will generate for each reference height wind speed a predicted sound level at any given receptor. The recent changes will reduce the variability of results amongst assessors, but the question remains as to how well the predicted results will mirror the real-world sound level impact. A discussion of the actual extent of this latter variability is important, as there is a perception amongst some in the public that a sound level measurement made under any arbitrary atmospheric condition should reflect the prediction.

Factors considered

Some factors governing the observed sound levels affect the sound power emitted by a turbine, some affect the propagation from a WTG to a receptor, and some do both. This paper focuses on factors which change with time; factors like distance and site topography also influence sound propagation but are not discussed here.

Air absorption

The effect of variations in air temperature and humidity are considered by noise propagation models. Using ISO 9613 it is generally possible to see a change of 1 to 2 dB over typical source to receiver distances by modifying air properties. The draft MOE document mandates that air absorption be considered at 10°C and 70% relative humidity. The practical result of this change is unlikely to reduce the variability in predicted results by more than 1 dB.

In practice, changes in air density or humidity with elevation may also cause some other interesting effects. Fog has been subjectively identified as a factor increasing the apparent sound by some residents near wind farms. In addition to the influence on propagation, low-lying fog layers may result in high wind shear coefficients effectively resulting in little or no background sound concurrent with high sound power emissions from the WTGs.

Ground absorption

The propagation of sound varies with ground type, or, for a given receptor, with seasonal variations in the ground condition (snow covered ground, hard ice, grasses, etc). In the case of WTGs, where the sound source is very high, it is less clear what effect seasonal variation may have. In typical modeling methods implementing ISO 9613, the difference between fully absorptive ground and fully reflective ground is generally about 3 dB for second-storey receptors, although somewhat larger at lower elevations. The draft MOE interpretation document suggests that a global value of G=0.7 be used. The practical difference in modeling between this value and fully absorptive ground appears to be about 1 dB. An alternate method described by the MOE makes use of specific G values for the source, middle and receiver regions.

Wind profile

Wind profile relates to the variation in wind speed with height above grade. The term "wind shear" is used to describe the same thing, generally assuming a logarithmic profile. The wind shear exponent quantifies the wind shear. IEC 61400-11 deals with wind profile through consideration of "roughness length". It attempts to normalize actual wind profiles encountered during the measurements by defining a fixed reference "roughness length", and transforming measured sound levels to theoretical sound levels under the standard condition. A standard roughness length of 0.05 is equivalent to a wind shear exponent of about 0.16. From projects assessed by HGC Engineering, wind shear exponents approaching 0.5 are common under nighttime conditions. To put this in terms of wind speeds, a 10 m wind speed of 7 m/s with a wind shear coefficient of 0.16 results in an 80 m wind speed of 9.8 m/s, whereas the same 10 m wind speed with a coefficient of 0.5 results in an 80 m wind speed of 19.5 m/s. As required by IEC 61400-11, most manufacturers list the sound power output of their turbines as a range, correlated with 10 m wind speeds under the reference wind profile condition. In practice, then, where the wind shear exponent might vary from 0.05 to 0.45 through a given day, the sound power output from the turbine might vary over the entire range (which could be 5 to 10 dBA), even while the speed at the reference height remains constant. The MOE document mandates that wind profiles be considered by adjusting the manufacturer's stated sound emissions in consideration of the site specific wind profile. While this is clearly important, the document does not provide assistance as to how the site specific wind profile is to be developed. Such practical considerations as to how many site-specific wind measurements are to be made, at what elevations, for what duration, and – perhaps most importantly – what value amongst the tremendous range that will be calculated over the monitoring period should be selected as the governing wind profile, are not discussed.

Wind direction

For many wind farms, typical setback distances are currently in the range of 400 to 500 metres for the closest residences. This is larger than in many industrial noise impact situations making the influence of wind direction much more significant. This is particularly true in the case where many WTGs are located on only one side of a residence. At the distances in question, it is not unreasonable to expect that there would be times when the WTGs can barely be heard, and others when they are the dominant source of sound. Wind turbines are also directional in their acoustic radiation; as changes in wind direction change the orientation of a WTG with respect to a receptor, further changes in observed sound can occur.

The MOE document does not address wind direction, and assessors will continue to assume the "moderate downwind condition" or long term average described by ISO 9613. This minimizes variation between assessors, but is a major factor in the variability of actual measured sound levels and their deviation from predictions.

Summary

Of the four factors discussed above, the most important in governing the variability in actual measured sound levels are considered to be wind profile and wind direction. The MOE interpretation document now requires the consideration of wind profile, buts lacks specific details as to how this is to be done. Wind profile will continue to be an important factor leading to variability of predictions amongst assessors in Ontario. Ground and air absorption will now be handled in the same way by all assessors, but these factors are considered less important in practice. It is useful to recognize that ISO 9613 does not purport to predict sound pressure levels under all conditions, and limits the applicability of the stated accuracy of +/- 3 dB to relatively low source heights and modest distances, both of which tend to be exceeded in the case of WTGs.

Audit Results

To demonstrate the typical variability of sound levels over time, Figure 1 show the range of average (LEQ) sound pressure levels measured by HGC Engineering at wind farms - one over 7 days in Nova Scotia, and one over 9 days in Ontario. In both instances the measurement locations are about 350 metres from the nearest WTG. In the chart, data for intervals during which there was negligible electrical power produced by the WTGs have been removed, and the data has been plotted against the wind speed. The above results show a wide range of sound levels for each reference wind speed. The variability is typically +/- 5 dB or more, and is greater at low reference-height wind speeds where the influence of wind profile is greatest.

Conclusions

Assessing the environmental noise impact from WTGs is necessary to ensure compatibility with nearby residential properties. Standardized methods for doing so have been evolving and the MOE for example, recently revised their guidelines to minimize the variability of results between assessors by prescribing certain assumptions. The importance of wind profile has been acknowledged in the guideline, but this alone is unlikely to reduce variability between assessors until a standard definition of worst-case site specific wind shear has been agreed upon.

Acoustic audits show temporal variability of sound levels of at least +/- 5 dB for a given reference height wind speed. This degree of variability exceeds any likely differences expected between assessors, and highlights that actual sound levels will potentially exceed those predicted by ISO 9613 at times. Thus, it is important to realize that while standardized assessment methods provide a useful and consistent basis for assessing WTGs, they do not necessarily reflect the range of actual sound levels expected at receptors.

References

[1] HGC Engineering, (2007). Wind turbines and sound: Review and best practice guidelines. Available at: http://www.canwea.ca/municipalities/municipalities_bestpractices_e.php

[2] Ontario Ministry of Environment, (2008). Noise guidelines for wind turbines. Interpretation for applying MOE NPC publications to wind power generation facilities. Draft May 2008.❑