Why Noise Criteria Are Necessary for Proper Siting of Wind Turbines

Date: November 02, 2008

By:
George W. Kamperman, INCE Bd. Cert. Emeritus
Kamperman Associates, Inc.

And,

Richard R. James, INCE
E-Coustic Solutions

Introduction

Although industrial-scale wind turbines are now a familiar sight in many countries, they are only now becoming common in the USA and Canada. If the past few years are any guide, industrial "wind farms" will become very common indeed in North America, especially considering the robust government incentives for renewable energy.

Nina Pierpont's foregoing report injects an element of caution, perhaps even alarm, into this enterprise. Her research reveals significant health effects associated with living in the vicinity of industrial wind turbines. As a result of her research and that of others, we have reviewed sound studies conducted by consultants for governments, wind turbine owners, and local residents for a number of sites with known health or annoyance problems. (We included the homes of some of Pierpont's study subjects in our review.)

It is clear from Pierpont's report that turbine noise is a major issue for virtually all of her subjects. That wind turbine noise might be responsible for the majority of ailments identified by Pierpont as Wind Turbine Syndrome should not be a surprise. Sound levels of the type and level of those found on properties and inside homes of people living near operating turbines are often associated with sleep disturbance and the vast set of pathologies known to be caused by noise induced sleep problems. Dr. Pierpont's work builds upon a foundation of well accepted health risks documented by the World Health Organization (WHO) and other health standards organizations.

Building on Pierpont's work and that of other clinicians, we have developed a set of simple guidelines, using dBA and dBC sound levels, for communities to use in maintaining turbine

noise emissions within healthy limits. The following is a synopsis of a much longer report presenting measurement procedures and noise standards for use by towns in drafting responsible wind laws.[1]

Background

Wind farms using the newer 1.5 to 3 MW (megawatt) turbines have resulted in numerous complaints from people who find they no longer live in the quiet rural community they enjoyed before the turbines went online. Questions have been raised about whether the current siting guidelines used in the USA are sufficiently protective for people living closest to the developments. Research into the computer models used to determine the layout of industrial wind farms and the distances from residents nearest the turbines show that models are not accurate enough to be used as the sole basis for making siting decisions without corrections for known errors and unaccounted for weather conditions. The models fail to account for increased sound output from turbines, and the effects on sound propagation, under certain weather conditions. In addition, the models fail to disclose the known errors of the underlying algorithms that are given as ± 3 dB for ISO 9613-2 based computer models. Other tolerances for the input data and turbulence in the wind are also not disclosed, yet they can add another 8 dB to the wind turbine's sound levels at a receiving property under common weather conditions..

We also reviewed noise criteria from other countries used for siting wind turbines. Current standards for turbine siting rely either on not-to-exceed dBA sound levels, such as the 50 dBA limit promoted by the wind industry in the USA, or on not-to-exceed limits based on the pre-construction background sound level plus an add-on (e.g., L_{90A} + 5 dBA). Nearly all countries rely on A-weighted sound. Only Germany has an explicit limiter for C-weighted sound levels.

Discussion

Our study revealed that some people living as far as 3 km (1.9 miles) from a wind farm complain of sleep disturbance from turbine noise. Many people living one-tenth this distance

[1] See www.windturbinesyndrome.com.

(300 meters, or 984 feet) from turbines reported major sleep disruption and other serious medical problems from nighttime turbine noise. It is important to realize that the peculiar acoustic characteristics of wind turbine noise immissions cause the sounds heard at receiving properties to be far more annoying and troubling than the more familiar noise from traffic, industrial factories, and even aircraft.[2] Hence, the common community noise limits and "rules-of-thumb" used for the more common community noise sources are clearly not appropriate for siting industrial wind turbines.

It is worth noting, furthermore, that rural communities located at a distance from industry, highways, and airport-related noise emitters are much quieter than what is normally classified as "rural" in other community noise standards. Our studies show that the A-weighted L_{90} background sound level in rural communities is often between 20 and 30 dBA, sometimes lower. For communities a mile or more from major roadways, nighttime background sound levels of less than 20 dBA are not uncommon. This also results in much lower dBC values than for other suburban or rural communities nearer major roadways. Our research shows that low frequency sound is often in the range of 25 to 40 dBC for communities a mile or more from highways. Thus, a new noise source with strong low frequency content is more significant when in an isolated rural community than in a suburban or urban area with more traffic and other man-made noises.

In general, *the further away from major roadways, airports, or industry the lower the low frequency background sound levels*. Thus, C-weighted criteria are more necessary in these communities to avoid problems inside homes, especially during late evening and nighttime.

We pose, below, some frequently asked questions, together with our responses. (The complete list can be found in the fuller version of our report at www.windturbinesyndrome.com.

Do national, international, or state and local community noise standards for siting wind turbines near dwellings address the low frequency portion of the wind turbine's sound immissions? No, they do not. Although state and local governments are in the process of establishing wind farm noise limits or wind turbine setbacks from nearby residents, these

[2] Sound "immissions" refer to sounds as heard at the receiving location. "Emissions" refer to the sound from the perspective of the sound source.

standards incorrectly assume that limits based on dBA levels alone are sufficient to protect residents.

Do wind farm developers have noise limit criteria or wind turbine setback criteria that apply to nearby residents? Yes. However, the wind industry routinely recommends residential wind turbine noise level limits of 50-55 dBA at the nearest home. These levels are far too high for the quiet nature of rural communities and pose health risks for the nearest residents, according to research like Dr. Pierpont's. An additional concern is that some of the methods for implementing computer models to predict operational sound levels at locations in the community report sound levels that are lower than what will occur in real operation. These two factors in combination can lead to post-construction complaints and health risks from locating wind turbines too close to people.

How does wind turbine noise impact nearby residents? Initially, the most common problem is chronic nighttime sleep deprivation. According to the reviewed medical research, this may develop into far more serious physical, psychological, and cognitive problems.

What are the technical options for reducing (mitigating) wind turbine noise immission at residences? There are only three: 1) increase the distance between source and receiver, 2) prohibit nighttime operation, or 3) reduce the source sound power immission.

Is wind turbine noise at a residence more annoying than traffic noise? Absolutely. Studies show that wind turbine noise was perceived by roughly 85% of respondents even when the A-weighted sound level were as low as 35.0–37.5 dB. Traffic and other common community noises levels seldom cause similar responses for perception, annoyance or sleep disturbance at such low sound levels.

Why do wind turbine noise immissions of only 35 dBA disturb sleep? The assumptions about wall and window attenuation being 15 dBA, or more, that are commonly applied to outdoor noise sources may not be sufficiently protective, considering the relatively high amplitude of the wind turbine's low frequency immission spectra. When evaluating sound penetration through a modern wood frame home all frequencies, including the lower frequencies, must be considered, not just the A-weighted levels. The reduction may be 15 dBA or more, but that is

not the proper criteria for preventing sleep disturbance. When considered as C-weighted values the difference from outside to inside the home may be only 6 dB or less. It is the low frequency aspect of wind turbine immissions that creates the "rumble problem" indoors, plus building vibration, and this can be addressed solely with C-weighted criteria.

What are typical wind farm noise immission criteria or standards? Limits are not consistent and may vary even within a particular country. For example:

a) Australia: the greater of 35 dBA or L_{90A} + 5 dBA
b) Denmark: 40 dBA
c) France: L_{90A} + 3 (night), L_{90A} + 5 (day)
d) Germany: 40 dBA
e) Holland: 40 dBA
f) United Kingdom: 40 dBA (day), 43 dBA (night) or L_{90A} + 5 dBA
g) United States:
    a. Illinois: 55 dBA (day), 51 dBA (night)
    b. Wisconsin: 50 dBA
    c. Michigan: 55 dBA

What is a reasonable wind farm sound immission limit to protect the health of residents? We propose a maximum property line immission limit of 35 dBA (L_{Aeq}) and that the post construction L_{Aeq} with turbines operating not exceed the pre-existing background L_{90A} + 5 dBA. We also include C-weighted criteria to address people's complaints of low frequency noise. The dBC (L_{Ceq}) operating immission limit shall not be more than 20 dB above the measured dBA (L_{A90}) pre-construction nighttime background sound level plus 5 dB. A maximum not-to-exceed limit of 55 dBC (L_{Ceq}) is also proposed with adjustments if there are near-by heavily traveled major roads.

Why should the dBC immission limit not be more than 20 dB above the background dBA (L_{A90} +5)? The World Health Organization (WHO) and others have determined that a sound emitter's noise, which results in a difference between a dBC and dBA value greater than 20 dB, will be a troubling low frequency issue.

Is not L_{A90} the minimum dBA background noise level? L_{A90} is the statistical descriptor representing the quietest 10% of the time. It is <u>not</u> the minimum noise level. It may be understood as the sounds one hears when there are no nearby or short-term sounds from man-made or natural sources. It excludes sounds that are not part of the soundscape during all

seasons including wind generated noise. It is very important to establish the statistical average background noise environment outside for a potentially impacted residence during the quietest sleeping hours of the night (typically 10 PM to 4 AM). Nighttime sleep disturbance has generated the majority of wind farm noise complaints throughout the world. The basis for a community's wind turbine sound immission limits would be the minimum 10 minute nighttime L_{A90} plus 5 dB for the period of 10 pm to 7 am. This would become the Immission Limit for the proposed wind farm during the night. This can be accomplished with one or more ten (10) minute measurements during any night when the atmosphere is classified stable with a light wind from the area of the proposed wind farm. The Daytime Limits (7 am to 10 pm) could be set 10 dB above the minimum nighttime L_{A90} measured noise, but with 24 hour operation of the wind facility the nighttime criteria will always be the limiting sound levels.

Doesn't wind noise mask the sound of wind turbines? It is true that the sound level can increase over the L_{90} background sound level as surface wind speeds increase, but it is not true that wind masking is <u>always</u> present when wind speeds at the hub are sufficient to power the turbines. Nighttime weather conditions, especially in warm seasons, often result in wind velocities at the turbine hubs sufficient to power the turbines, while at ground level there is little or no wind. The result is the turbines can be operating at (or close to) full capacity while it is otherwise very quiet outside the nearby dwellings. These conditions exist frequently on clear nights when there is the vertical heat radiation from the surface of the earth decreases after sunset and the atmosphere becomes "stable." This condition is the focus of the "wind turbine noise problem" for many people. On nights like this, in the quiet of a remote rural community, turbine noise can be disturbing for miles (reports mention 3 km, nearly 2 miles).

Proposed Sound Limits

The simple fact that so many residents complain of low frequency noise from wind turbines is clear evidence that the single, A-weighted (dBA) noise descriptor used in most regions for siting turbines is not adequate. The only other simple audio frequency weighting which is standardized and available on all sound level meters is the C-weighting, or dBC. A standard sound level meter set to measure dBA is increasingly less sensitive to low frequency sound below 500 Hz. This is equivalent to one octave above middle-C on the piano. The same sound

level meter set to measure dBC is equally sensitive to all frequencies down to 32 Hz (lowest note on a grand piano). It is generally accepted that dBC readings are more predictive of perceptual loudness than dBA readings whenever low frequency sounds are significant.

Based on the above evidence, we recommend that wind turbine noise be measured using a) the commonly accepted criteria, which are based on pre-existing background sound levels in dBA and dBC, with b) a maximum 5 dB allowance for wind turbine immission – that is, 5 dB maximum for the audible sounds from wind turbines, over and above existing background sound levels. In other words, we recommend L_{A90} +5 and L_{C90} +5. To address excessive low frequency sound, we add criteria for low frequency noise out of balance with higher frequency sound.

We summarize the wind turbine sound limits as follows:

Wind Turbine Sound Limits to Protect Public Health

1. Establishing Long-Term Background Noise Level

a. Instrumentation: ANSI or IEC Type 1 Precision Integrating Sound Level Meter plus meteorological instruments to measure wind velocity, temperature and humidity near the sound measuring microphone. Measurement procedures must meet ANSI S12.9 Part 3.

b. Measurement location(s): Nearest property line(s) from proposed wind turbines representative of all non-participating residential property within 2.0 miles of project boundary.

c. Time of measurements and prevailing weather: The atmosphere must be classified as stable with no vertical heat flow to cause air mixing. Stable conditions occur in the evening and middle of the night with a clear sky and very little wind near the surface. Sound measurements are only valid when the measured wind speed at the microphone does not exceed 2 m/s (4.5 mph).

d. Long-Term Background sound measurements: All data recording shall be a series of contiguous ten (10) minute measurements. The measurement objective is to determine the quietest ten minute period at each location of interest. Nighttime test periods are preferred unless daytime conditions are quieter. The following data shall be recorded

simultaneously for each ten (10) minute measurement period: dBA data includes L_{A90}, L_{A10}, L_{Aeq} and dBC L_{C90}, L_{C10}, L_{Ceq}. Also record, maximum wind speed at the microphone during the ten minutes and a single measurement of temperature and humidity at the microphone for each new location or each hour whichever is more often. A ten-minute measurement contains valid data provided: Both L_{A10} minus L_{A90} and L_{C10} minus L_{C90} are not greater than 10 dB and the maximum wind speed at the microphone did not exceed 2 m/s during the same ten-minute period as the acoustic data.

2. Wind Turbine Sound Immission Limits

No wind turbine or group of turbines shall be located to cause wind turbine sound immission at any location on non-participating property containing a residence in excess of the limits in the following table:

Table of Not-to-Exceed Property Line Noise Immission Limits[1]

Criteria		dBA	dBC
A	Immission above pre-construction background:	$L_{Aeq} = L_{A90} + 5$	$L_{Ceq} = L_{C90} + 5$
B	Maximum immission:	35 L_{Aeq}	55 L_{Ceq} for quiet[2] rural environment 60 L_{Ceq} for rural-suburban environment
C	Immission spectra imbalance	L_{Ceq} (immission) minus (L_{A90} +5 (background)) ≤ 20 dB	
D	Prominent tone penalty:	5 dB	5 dB

Notes	
1	Each Test is independent and exceedances of any test establishes non-compliance Sound "immission" is the wind turbine noise emission as received at a property
2	A "Quiet rural environment" is a location 2 miles from a state road or other major transportation artery without high traffic volume during otherwise quiet periods of the day or night.
3	Prominent tone as defined in IEC 61400-11. This Standard is not to be used for any other purpose.

[1] The procedures amending ANSI S12.9, Part 3 provided in the most recent version (2.1 or later) of the "**THE "HOW TO" GUIDE TO SITING WIND TURBINES TO PREVENT HEALTH RISKS FROM SOUND**" by Kamperman and James apply for this table.

3. Wind Farm Noise Compliance Testing

All of the measurements outlined above in 1. Establishing Long-Term Background Noise Level must be repeated to determine compliance with 2. Wind Turbine Sound Immission Limits. The compliance test location is to be the pre-turbine background noise measurement location nearest to the home of the complainant in line with the wind farm and nearest the wind farm. The time of day for the testing and the wind farm operating conditions plus wind speed and direction must replicate the conditions that generated the complaint. Procedures of ANSI S12.9-Part 3 apply as amended and the effect of instrumentation limits for wind and other factors must be recognized and followed.

We have based our recommendations in this report on our present understanding of wind turbine sound emissions, land-use compatibility, and the effects of sound on health. Anyone choosing to follow these recommendations must assume all risks. Please seek professional assistance in applying these recommendations to any specific community or Wind Energy Conversion System (WECS) development.

For the most current version of the recommended criteria (2.1 or later), a sample noise ordinance and an explanation supporting the need for and basis of the criteria, please retrieve the full manuscript from: www.windturbinesyndrome.com.