north american
WINDPOWER®

Reprinted with permission from the May 2008 issue

Understanding Turbine Sound Impact Studies

Noise impact studies can help developers predict the amount of noise that will be generated by a wind farm before project construction begins.

BY KENNETH H. KALINSKI

Wind turbines make noise, or, more accurately, sound. Whether this sound as it reaches its neighbors is inaudible or unbearable depends on a number of factors, including the level and pitch of the sound generated by the turbine, the distance to its neighbors, meteorology and the intervening terrain. Given this information, the amount of noise generated by a wind farm can be predicted fairly well before the first shovel of a wind energy project hits the ground.

Noise standards

Noise standards are not common in the U.S. Although a few states and local governments have established quantitative limits to the level of allowable noise from a wind farm, these limits, if they do exist, are primarily qualitative in most states. Having noise standards makes the analysis somewhat easier to perform. However, the developer should still review the standard to make sure that it reflects a reasonable level, or whether a lower limit should be achieved.

If no quantitative standards exist, other noise guidelines can be consulted; for example, many noise studies have referred to the 1974 U.S. Environmental Protection Agency's so-called "Levels" document, U.S. Bureau of Land Management's "Programmatic Environmental Impact Statement on Wind Energy Development" and the World Health Organization's "Guidelines on Community Noise."

Characterizing the environment

Prior to conducting sound propagation modeling, it is useful to carry out preconstruction noise measurements. Preconstruction monitoring may be required under the area's noise ordinance, or the noise standard may be relative to the background sound level in a particular locale. Even if preconstruction monitoring is not required, it can be used to:

- understand how much wind turbine noise will be masked by background noise,
- establish a baseline as a comparison with post-construction noise levels in case complaints are lodged, or
- help decision-makers understand the noise impacts of the turbines relative to existing sound levels.

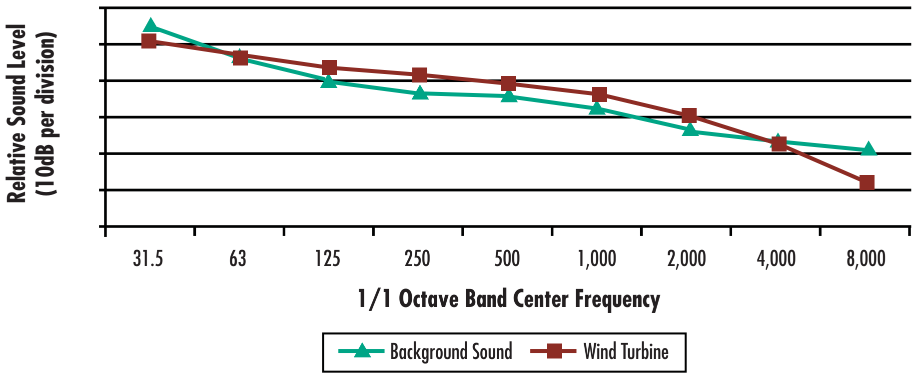
Background sound levels should generally be monitored in areas that represent "sensitive receivers," such as homes, schools, places of worship, hospitals and public campgrounds. Other areas may include businesses, cemeteries and parks. Because highways tend to contribute the most to anthropogenic noise, sound monitors generally need to be placed only in unique areas with respect to traffic volume and speed. For example, if a home is situated next to a school, there would be no need to place a monitor at both locations because the same highway affects both receivers similarly.

However, if the school fronted a highway with an average daily traffic volume (ADT) of 15,000 and a speed limit of 30 miles per hour (mph), and the home fronted another highway with an ADT of 5,000 and a speed limit of 50 mph, a sound level meter at each location could be used to characterize their respective unique background sounds.

Equipment

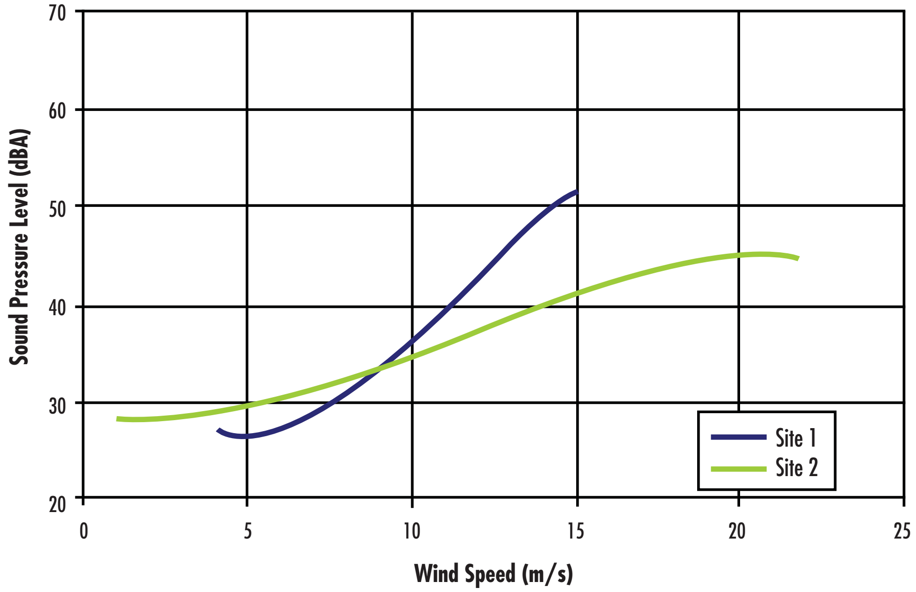
Background sound level monitoring is performed, typically, for a few days and can last as long as a couple of weeks, depending on the goals of the monitoring, local requirements and the variability of metrological events during the monitoring period. Sound level meters must have sufficient battery life and be able to withstand the various temperature and weather extremes that they will be exposed to for a given length of time. The sound level meter often is enclosed in a waterproof case and at-

Figure 1



Comparison Of Frequency Spectra From Wind-Induced Background Sound And A Commercial Wind Turbine

Figure 2



Correlation Of Background Sound Levels By Ridgeline Wind Speed

tached to its preamp and microphone via a cable. The microphone is fitted with a waterproof windscreen and may often include bird spikes.

Noise control engineers and consultants use sound level meters that meet the accuracy standards of International Electrotechnical Commission/American National Standards Institute (IEC/ANSI) Type 1, which is accurate to within +/-0.7 decibel (dB), or IEC/ANSI Type 2, with an approximate +/-1 dB error range. Sound level meters are calibrated with handheld calibrators both before and after the measurement to ensure that the meter calibration has not drifted during the monitoring period. In addition, handheld calibrators should be lab-calibrated every year; sound level meters should be lab-calibrated every two years.

Sound level meters used for environmental monitoring vary considerably. Some simply log average overall sound levels, others log statistical sound levels – averages and percentiles – over a specified logging interval and time period. Some of these have recording features that allow sound files to be recorded at defined intervals or when levels exceed a specified threshold. This is useful for identifying sources of sound. Another category of sound level meters, sometimes referred to as “real-time analyzers,” records the spectral content of the sound at specified intervals. For example, the Cesva SC310 can record two weeks of one-second, one-third-octave band sound levels.

Turbine sound levels

The two most important parameters related to noise impacts from wind turbines are sound power and tonality. Sound power, which has units of watts, is a measure of the acoustical energy emitted by a source. Sound power is distinct from sound pressure. Sound pressure is the perceived level of fluctuation of air pressure at a point in space. Sound pressure is measured in Pascals. Because of the large range of sound power and pressure, both are usually reported in decibels, and therefore, are often confused. And although sound power cannot be directly measured, it can be calculated using several methods, including the measurement of the sound pressure at a given distance.

For wind turbines, the standard method for measuring and reporting the sound power and tonality is given in IEC 61400-11 and IEC 61400-14, respectively. Another method for calculating tonality in general is found in ANSI S1-13. Most wind turbine manufacturers provide consulting services with standardized reports of sound emissions that follow the IEC standards, which can then be used when modeling the impacts of the turbines.

Special issues

Wind turbines are special sound generators in that their sound emissions often are masked by noise from the wind moving through trees and other vegetation, and their sound level is highly dependent on meteorological conditions. In addition, wind turbines generate some low-frequency sound, which tends to propagate better than higher-frequency sound.

Masking

Sound levels from both wind-induced background sound and wind turbines are a function of wind speed – that is, the stronger the wind, the louder the resulting sound. In areas that are covered by trees and bushes, the effect is amplified. Combined with the fact that the frequency spectrum from wind is very similar to the frequency spectra from a wind turbine, the sound from a wind turbine is easily masked by wind noise at downwind receivers. Figure 1 compares the sound spectrum during a 20 mph to 26 mph wind event at hub height with that of a commercial wind turbine. As shown, the shapes of the spectra are similar.

Note that although winds may be blowing where turbines are located, there may be little or no wind at ground level near the project neighbors. This is because the "roughness" of ground cover slows surface winds. This effect is amplified in more mountainous areas, where hills further reduce valley winds.

Figure 2 shows a correlation of wind speed along a ridge with the sound level at a ground-level receiver. For site one on Figure 2, the sound level meter is closer to the top of the ridge where wind turbines are located, whereas site two is located in the valley about 2,500 meters away. As shown, the sound level nearer to the ridge site rises fairly rapidly with wind speed, but at site two, the sound levels do not rise until the wind speeds on the ridge reach about 5 to 7 meters per second. In this case, the turbines would be most audible when winds are blowing with relatively moderate speeds on the ridge but with light winds in the valley.

Meteorology

Meteorological conditions can significantly affect sound propagation. The two most important conditions are wind shear and temperature lapse. Wind shear is the difference in wind speeds by elevation, and temperature lapse rate is the temperature gradient by elevation. Under conditions with high wind shear (large gradient), sound levels upwind from the source tend to decrease and sound levels downwind tend to increase. With temperature lapse, when ground surface temperatures are higher than those aloft, sound levels on the ground will decrease. The opposite is true when ground temperatures are lower than those aloft – an inversion condition.

Often used as a substitute for these conditions is "stability class." Stability classes range from A to G, where A is a highly unstable condition – high solar radiation and high winds – and G is very stable – clear night, no wind and strong temperature inversion.

In general, sound propagates best under stable conditions with a strong inversion, such as during a clear night with low winds. In those situations, sound levels from wind turbines would be at their lowest. Wind speeds under very stable conditions – Stability Class G – generally are too low to generate electricity, and thus, the wind turbines would produce little or no noise. As a result, worst-case conditions for wind turbines tend to be under more moderate nighttime inversions.

Infrasound is sound pressure fluctuations at frequencies below about 20 Hz – sound below this frequency is generally not audible. At very high sound levels, infrasound can cause health effects and rattle lightweight building partitions. However, because modern wind turbines, with the hub upwind of the tower, do not create this level of infrasound, analysis of infrasound at most sites is not necessary.

Low-frequency sound is in the audible range of human hearing – that is, above 20 Hz but below 100 Hz to 200 Hz, depending on the definition. As with infrasound, high levels of low-frequency sound (e.g., above 70 dB at 31.5 Hz) can rattle lightweight partitions in buildings. In addition, low-frequency sound that is well above background sound levels at higher volumes can be annoying.

Wind turbines generate low-frequency sound, primarily from the generator and mechanical components. Improved sound insulation at the hub has reduced much of the mechanical noise in modern wind turbines. Low-frequency sound can also be generated at higher wind speeds when the inflow air is very turbulent. At these wind speeds, however, low-frequency sound from the wind turbine blades is often masked by wind noise at the downwind receivers.

Low-frequency sound propagates better than higher-frequency sound and tends to diffract more in the atmosphere under inversion conditions. Sound propagation modeling should take into account the differential atmospheric absorption of low- and high-frequency sound.

Sound propagation modeling

In sound propagation modeling, the sound pressure level at a distant receiver is estimated. There are several different modeling protocols used around the world. In North America, the most common is ISO 9613-2, "Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation." This standard methodology takes into account the sound power of the source and attenuation from geometric spreading, atmospheric absorption, ground effects and intervening objects. Propagation is assumed under moderate temperature inversion where the receiver is downwind from the source.

There are several good computer programs that implement the ISO 9613-2 methodology. These programs also can make adjustments for different stability classes, wind speeds and wind directions. Another advantage is that they are compatible with different types of computer assisted design and geographic information system software.

Modeling turbine noise can be a challenge. The results depend on what choices are made with respect to ground attenuation and meteorology. Tests conducted by experts in the field have shown that modeled sound levels can vary considerably depending on what choices are made. As a result, sound propagation modeling for regulatory purposes should be conducted only by a qualified noise control engineer or consultant.

A noise impact study can address other sources of noise from a wind energy project. For example, construction noise impacts can include drilling, blasting and other site work. Electric power substation noise should also be considered, especially if transformers are located near residences.

Conducting a noise study

Noise studies are an integral part of the planning for turbine layout. As a result, the study should be started as soon as preliminary turbine locations are identified. Noise impact studies typically take about six weeks to complete – even longer when iterations of turbine siting must be conducted. Sound propagation modeling may show areas with high levels of noise, requiring changes to the locations of one or more turbines.

There are several consulting firms in the U.S. that are experienced in wind turbine analyses. The Web sites of the Institute of Noise Control Engineering, National Council of Acoustical Consultants and Noise Pollution Clearinghouse all provide consultant directories.

Kenneth Kaliski is director of environmental services for White River Junction, Vt.-based Resource Systems Group Inc (RSG). He is a licensed professional engineer and is board certified with the Institute of Noise Control Engineering. RSG is a member firm of the National Council of Acoustical Consultants. Kaliski can be contacted at kkaliski@rsginc.com or (802) 295-4999.