AN INVESTIGATION OF THE WIND INDUCED BACKGROUND SOUND LEVELS IN RURAL AREAS FOR EXISTING AND PROPOSED WIND FARMS

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1. BACKGROUND

The increasing prevalence of wind power across the globe has led to a growth in the number of wind turbines in proximity to human settlement. As a result, the sound level impact from wind turbines has become a fairly contentious issue in some areas. The audibility of wind turbine generators is often a factor of low background sound levels, which in rural environments are dominated by natural sounds. Thus, HGC Engineering has considered ambient sound levels as part of a number of acoustic audits and assessments for existing and proposed wind farms.

This paper investigates the variability of wind induced background sound levels in various rural areas by comparing sound level measurements conducted by HGC Engineering in Canada, the United States, and Central America with the reference background sound levels presented by the Ontario Ministry of the Environment (MOE). Specific consideration will be given to the effects of topography and the relationship between hub height wind speeds and ground level wind speeds. This analysis of actual wind induced background sound levels provides a better understanding of the sound level impact from wind turbines in varying rural environments.

2. STUDIES

HGC Engineering's experience has shown that the measurement of background sound levels in conjunction with wind speeds at various heights and locations is an important part of the planning process. A previous study prepared for the Canadian Wind Energy Association (CanWEA) recommended that ambient sound levels be monitored to assist in defining the criteria and to provide a benchmark for any sound measurements conducted after the wind farm is operational [1].

The MOE has recognized wind turbines as unique among other industrial sources because they produce more sound as wind speeds increase and because increasing wind speeds generally result in increasing levels of background sound. The current MOE guidelines, "*Interpretation for Applying MOE NPC Technical Publications to Wind Turbine Generators*", for the assessment of sound from wind power projects presents sound level limits for wind turbines that are based on reference wind induced background sound levels measured at a particularly quiet site, correlated with wind speeds at a height of 10 m [2]. The reference sound levels are presented in terms of the L_{90}, the sound level which is exceeded 90% of the time during a measurement. The L_{90} sound level eliminates the contribution of short duration local noises.

2.1 An Existing Wind Farm in Ontario

There are a number of challenges associated with auditing the sound level impact from an existing wind farm and comparing the results to appropriate guidelines and the sound level predictions made as part of the initial acoustic assessment. In general, the sound level limits established by the local jurisdiction will typically apply only to the sound level contribution of the source under assessment (In this case, the wind turbines). Thus, where the sound level measured at a receptor includes significant sound due both to the relevant sound source and to unrelated background sound sources (road traffic, local noises, and wind, for example), some form of evaluation must be made to determine the sound level contribution of the source under assessment in the absence of background sounds.

Several sound level monitors were deployed at representative receptor locations throughout an Ontario wind plant to record the sound levels over a period of approximately one week. A sound level monitor was also deployed at a 'remote location' to record background sounds unaffected by any noise from the wind plant. The monitor was located approximately 3 km north of the closest wind turbine in a relatively exposed area with some tall grass nearby. One of several factors considered in the data analysis was the influence of ambient sound levels. Where trends in the data measured at the remote location mimicked the data recorded at the receptors, it provided an indication that the wind turbine generator(s) were not appreciably affecting the sound levels at the receptors, particularly during periods of high winds and correspondingly high background sounds.

Figure 1 presents the measured L_{90} sound levels and the corresponding 10 m wind speed measured near the monitoring location and also presents the reference wind induced background sound levels (L_{90}) presented in the current MOE guidelines specific to wind turbine generators. The sound level data was considerably higher during the daytime hours due to local activity, therefore only the data recorded during the nighttime hours (19:00 until 7:00) is presented below. Periods of rain were also excluded from the dataset. The grey highlighted area indicates time periods where, at times, the sound level fell below the range of the sound level meter.

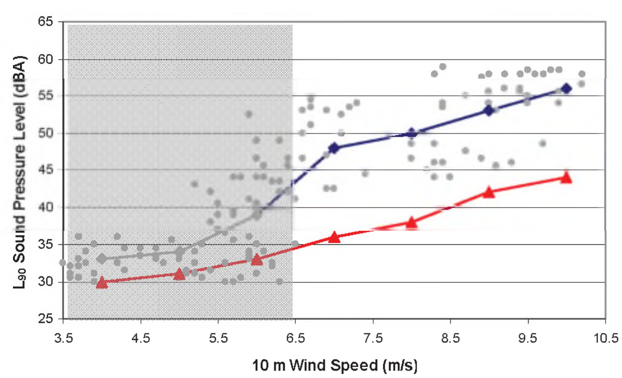

Fig. 1: L_{90} sound levels measured at a wind farm in Ontario during nighttime hours at a remote location (●), average L_{90} sound levels for each wind bin (◆) and the reference wind induced background sound levels defined by the MOE (▲).

Considering 10 meter wind speeds on the order of 7 m/s and higher, the measured background L_{90} sound levels were typically higher than the reference background sound levels defined by the MOE. This monitoring location was located in a relatively open field that had exposure to wind from all directions. This may not be typical of some residences, which would generally be somewhat shielded from the wind from some directions due to the residence itself and other nearby buildings. Nevertheless, the remote monitor was helpful in determining time periods that were dominated by wind induced background sound at the residences.

2.2 A Proposed Wind Farm in Central America

As part of an acoustic assessment completed for a proposed wind farm in Central America, background sound levels were measured at five representative receptor locations. Locations were selected to capture the sound levels from the major roadways, major topographical changes, and rural areas. Measurements were conducted for a period of approximately 72 hours to obtain a representative data sample. During this time period, wind speeds were also recorded at various locations and heights for correlation with the ambient sound levels.

The site layout was mountainous with elevations ranging from 1,250 to 1,830 meters above sea level. The proposed locations for the wind turbines were heavily influenced by wind resources, which are generally most significant at higher elevations. As a result, the placement of wind turbines was generally along the mountain ridges. This unique site layout and topography played an important role in determining the influence of background sound levels due to wind induced noise.

Analysis of the measurement data showed that the sound levels were not as affected by changes in wind speed, measured near the wind turbines, as the measurements conducted on relatively flat ground for the wind farm in Ontario or as expected based on the reference background sound levels defined by the MOE. The severe topographical variations have a significant impact on the wind speeds at the different receptor locations. As a result, many locations are somewhat protected from high wind speeds.

An evaluation of the background sound and wind speed measurements showed that under certain conditions, it would be possible to have the wind turbines producing full power with background L_{90} sound levels at neighbouring receptors being on the order of 35 dBA.

2.3 A Proposed Wind Farm in Pennsylvania

Background sound levels were measured at six representative receptor locations as part of an acoustic assessment for a proposed wind farm in Pennsylvania. Measurements were conducted for a period of approximately one week to obtain a representative data sample. During the measurement time period, wind speeds were also recorded at two locations and several heights for correlation with the ambient sound levels.

The proposed location for the wind turbines was along the top of a mountain ridge (320 – 400 meters above sea level), with residences located on both sides of the mountain ridge (130 – 260 meters above sea level) at various distances from the proposed turbine locations.

Figure 2 shows L_{90} sound levels measured at one of the monitoring locations and the corresponding 10 m wind speed calculated using the relationship between wind speeds recorded at various heights on the closest metrological tower using the wind shear relationship [3]. This figure also presents the reference wind induced background sound levels (L_{90}) presented in the current MOE guidelines specific to wind turbine generators. Sound levels at this location did not vary significantly between daytime and nighttime periods. Thus, all measured data, except periods of rain, have been shown in the figure below.

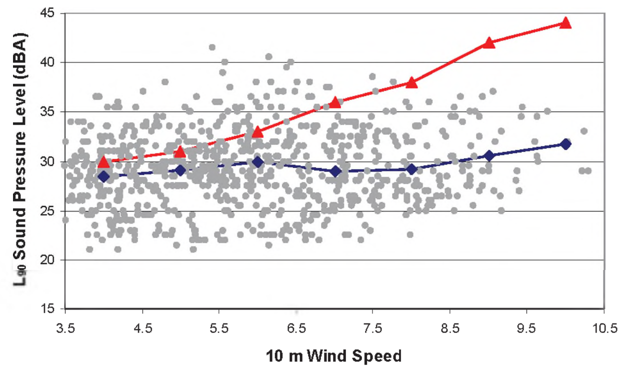

Fig. 2: L_{90} sound levels measured at a wind farm in Pennsylvania (●), average L_{90} sound levels for each wind bin (◆) and the reference wind induced background sound levels defined by the MOE (▲).

As shown in Figure 2, the sound levels recorded at this residence were not significantly influenced by changes in wind speed at the top of the mountain. The ambient sound levels remained fairly consistent throughout the measurement period and were consistently less than the reference sound levels defined by the MOE. An analysis of the data indicates that the wind turbines can be operating at maximum power and the ambient sound levels can be on the order of 30 dBA at very quiet residential receptors.

3. CONCLUSION

HGC Engineering monitored background sound levels as part of a number of acoustic assessments and audits for existing and proposed wind farms. The results showed significant variability in both the magnitude of the measured sound levels and the influence of wind speed, depending on the site layout, orientation, and local topography, shielding effects, and vegetation. Depending on the site, ambient sound levels may be greater than or less than the reference background sound levels defined by the MOE. Elevated ambient sound levels increase the difficulty associated with auditing the sound level impact from the wind turbines. However, they do provide a benefit to the residents in that they tend to mask the sounds from neighbouring wind turbines. The opposite is true for sites with low ambient sound levels.

The results confirm the importance of monitoring ambient sounds at a variety of representative receptors. It is particularly important when the sound level limits are based on ambient sound levels and for sites with significant elevation changes.

REFERENCES

[1] HGC Engineering, Canadian Wind Energy Association, "Wind Turbines and Sound: Review and Best Practice Guidelines", 2007.

[2] Ontario Ministry of the Environment (MOE), "Interpretation for Applying MOE NPC Publications to Wind power Generation Facilities", 2008.

[3] IEC 61400-11 International Electrotechnical Commission, "Wind Turbines", 2009.