Technical Note

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NOISE DOSE ASSESSMENT OF WIND FARM NOISE

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INTRODUCTION

Environmental Impact Assessment is the process by which decision makers evaluate whether larger projects should be allowed to proceed, either in the form which they are submitted, or incorporating mitigation identified as part of the EIA process. The method by which such assessments are carried out can be a contentious issue, whatever the impact which is being assessed (ie. landscape and visual, ecological, archaeological etc.) and whatever the source of such impact (new road scheme, power generation project, minerals extraction etc.). Wind turbine projects and noise are, of course, no exception to this.

Noise impact assessment tends to be carried out with reference to the particular assessment methodology which has been laid down in planning guidance for the particular country in question. It has been argued that noise assessment required for planning purposes may not always be indicative of the 'true' noise impact which may occur in practice. Noise impact is, of course, a purely subjective issue and it can be argued, on the other hand, that the noise impact can only be assessed by reference to the criteria laid down by the planning process and that the planning process should not, by its very nature, allow development to go ahead if significant impacts are predicted.

Notwithstanding the above, the prediction of noise impact has always been something of a holy grail for noise professionals, with a great deal of effort going into subjective studies of various environmental noise sources and the production of resulting dose response curves. One of the outcomes of these types of studies is the use of the L_{den} measurement index as a strategic assessment tool, and this has been adopted as such in Europe through the Environmental Noise Directive [1]. This index is, effectively, a long term L_{Aeq} corrected by the addition of 5 dB for noise occurring during the evening hours (1900-2300) and 10 dB for noise occurring at night (2300-0700) although the definitions of the time periods are flexible and may be adjusted to allow for local circumstances.

This study shows how the use of L_{den} could be applied to the assessment of wind farm proposals to provide an objective approach to wind turbine noise assessment, taking into account the range of wind speeds and wind directions, and hence noise levels at specific residential or other properties, occurring 'long term' for measured wind conditions at a specific site. It is not argued that this methodology would necessarily predict subjective impact any better than that which is being currently used in any particular country for either impact assessment or planning purposes. It is, however, a means for quantifying impact which takes account of the existing noise environment and the predicted noise environment due to the development which is being proposed, taking into account the variation in both existing and predicted noise due to wind conditions. It should be noted that this metric is unlikely to be suitable for practical noise control purposes which normally form part of the conditions or limits on wind farm planning consents. It may be that, nevertheless, it may constitute a useful control measure to be applied at the design stage, given the practical difficulties encountered in the measurement of noise from operational wind farms.

NOISE IMPACT ASSESSMENT

Noise limits for planning or assessment purposes can be expressed as absolute limits, relative limits, or as a hybrid of the two approaches. Absolute limits refer to a fixed decibel value which may, or may not, be dependent on time of day (ie. day, evening or night) or type of area (ie. mixed industrial, urban residential, sub-urban residential, rural etc.). Relative limits are limits which relate to a permitted level of noise change or a permitted level of noise increase above the existing background noise. Hybrid noise limits involve an element of both of these such as the UK limits commonly applied to wind turbine noise which relate to the existing background noise except for situations where background noise levels are very low, at which point absolute limits apply.

One of the unique factors of wind turbine noise assessment is that not only does the source noise level change with wind speed but the level of existing noise, in most cases, also changes with wind speed. As with most noise sources, the propagation of noise from source to receiver also changes with wind direction. The level of existing noise may also change with wind direction and the effect of wind direction may also depend on wind speed!

The most common approach for wind turbine noise assessment is either to compare the turbine noise with fixed noise limits under specific operational conditions (that is, at a fixed 'reference' wind speed or at the rated power[1] of the turbine as is commonly used in continental Europe), or with hybrid noise limits related to a derived background noise level, or a fixed limit if background level is low, as is commonly used in the UK, Australia and New Zealand.

In the Netherlands, the assessment methodology has recently been changed to the use of a 47 dB yearly L_{den} criterion [2]. This does not, however, make any reference to the existing L_{den} prior to the site becoming operational. Although

[1] The point at which the turbine is generating its specified power (eg. 2MW). Source noise level does not generally increase above the point at which it reaches rated power for pitch regulated turbines.

it is helpful, therefore, in terms of providing for an aggregate noise level once the variation in noise level with wind speed and direction is taken into account, it does not continue this approach to looking at the change in yearly L_{den} caused by the operation of the site. What is proposed here is a comparison of the L_{den} prior to, and subsequent to, the operation of the wind farm.

CALCULATION OF NOISE DOSE FROM A WIND FARM

In order to calculate noise dose with any degree of accuracy, access is required to a full year of wind speed and direction records, for consecutive intervals of maximum 1 hour duration, at the hub height of the proposed turbines. Where only sub-hub-height wind speeds are available, a reasonable approximation to hub height wind speed for each measurement interval may be calculated from two or more wind speeds at lower height. This can then be converted to 'standardised' 10 metre height wind speed[2] as used by wind turbine manufacturers for the specification of sound power level data[3]. In this way the noise output from the turbine can be defined for each hour of the whole year of records or for shorter intervals if the data is available.

The noise output can then be combined with wind direction information, together with other propagation factors including geometric, atmospheric, ground and barrier attenuation as specified in an appropriate prediction algorithm such as ISO9613, Part 2 [3]. In this way, the noise levels for every hour (or less) of the whole year of records can be predicted and used to calculate the L_{den} over the whole year by adding 5 dB to predicted levels for wind speed measurement intervals falling during the evening periods and 10 dB for those falling during the night-time periods.

In the absence of the incorporation of wind direction information in the prediction algorithm used[4], it may be helpful to refer to the work of Wyle Laboratories [4] which suggests an upwind attenuation increasing from 0 dB at the edge of the shadow zone, taken as 5.25 x hub height, increasing linearly to 20log(f) – 30 dB at the point at which the shadow zone is fully formed, taken as 15.75 x hub height. A reasonable approximation to cross-wind propagation may be to apply an attenuation of 2 dB which relates more to the change in source noise level for cross-wind propagation. For any given wind direction, each wind turbine may be categorised as falling into downwind, upwind or crosswind propagation directions relative to the receiver location which is being evaluated. Any number of different receiver locations can then be evaluated with the result that a receptor located in the same direction as the prevailing wind from the site[5] will receive a significantly higher L_{den} than one located in the opposite direction, not only due to the greater statistical prevalence of those wind directions but also due to the higher wind speeds, and hence higher noise levels, for such wind directions.

CALCULATION OF PRE-WIND FARM NOISE DOSE

Measurements of 'background noise level' are routinely carried out for wind farm noise assessment in the UK, Australia and New Zealand where appropriate noise limits are usually derived from such measurements by assessing the typical background noise for different wind speed conditions and adding an allowed exceedance at each wind speed[6]. This is, in effect, a legacy from industrial noise assessment standards which commonly allow a similar 5 dB exceedance. It is relatively unusual, certainly in wind farm noise assessment, for the existing noise to be quantified in terms of the L_{Aeq} or L_{den} measurement index where a measure of background noise such as L_{A90} or L_{A95} is normally used. It is, however, possible for existing noise level to be specified in terms of the L_{Aeq} index as it varies with wind speed based on best fit curves to plots of measured L_{Aeq} values against hub height wind speed. The best fit curves effectively represent an average L_{Aeq} value, as it varies with wind speed for the corresponding times of day. These can be used to define a reasonable approximation to the corresponding hourly L_{Aeq}, in the absence of noise from the proposed wind farm, for each wind speed value as used for the calculation of the wind farm noise dose. If sufficient data is available it may also be possible to subdivide this data into various wind direction sectors. This can then be used to predict a reasonable approximation to the whole year L_{den} in the absence of the proposed wind farm, with the appropriate corrections to noise levels occurring during the evening and night-time periods. It should be noted that this methodology does not allow the L_{Aeq}, as it varies through the day, evening and night periods to be taken into account. For situations where there is no variation in L_{Aeq} with wind speed, such as is likely to occur in more populated area where it would be expected to be more affected by non wind related sources, this could provide a variation to the approach proposed.

CALCULATED CHANGE IN NOISE DOSE

The above data can be used to provide the change in yearly L_{den} noise dose by comparing the dB addition of the post wind farm noise dose (ie. wind farm noise dose plus pre-windfarm noise dose) to the pre-wind farm noise dose. It could reasonably be expected that this would show a higher noise dose for properties subject to downwind propagation for more commonly occurring wind directions and higher wind speeds than those in other sectors, and a higher degree of noise dose change where a property is exposed to lower levels of existing noise, especially at night where higher levels of wind farm noise relative to background noise would be accentuated by the application of the 10 dB correction applicable to noise levels generated at night.

[2] 10 metre height wind speed converted from hub height assuming reference ground roughness conditions of z=0.05m.

[3] Where noise data is specified in terms of hub height wind speed this conversion is not required.

[4] ISO9613-2, for instance, only predicts short term noise levels for 'moderate downwind' conditions.

[5] ie. located to the north-east for a prevailing south-westerly wind direction.

[6] In the UK, for instance, noise limits are commonly set at 5 dB above this 'prevailing' background noise at each wind speed except at very low background noise levels where a fixed limit applies.

CONCLUSIONS

A method is proposed for strategic assessment of wind farm noise which takes into account the variation in wind speed and wind direction over a typical year of operation and the increased annoyance which may result from noise during the evening period and during the night. This is compared with noise from existing sources, quantified in a similar way. In this way an assessment of the existing noise dose, the proposed additional noise dose, and a comparison between the post and pre-development noise dose can be assessed for representative properties around a proposed wind farm scheme to provide a more comprehensive assessment than is provided by more traditional comparisons of worst case propagation conditions with absolute or relative noise limits.

REFERENCES

[1] *The Environmental Noise Directive* (2002/49/EC), European Commission, 2002

[2] M. Dijkstra and T. Kerkers, "Continuous noise monitoring of wind turbines", *Proceedings of the 4th International Conference on Wind Turbine Noise*, Rome, Italy, 11-14 April 2011

[3] International Organization for Standardization ISO 9613-2: 1996, *Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation*

[4] *Measurement and evaluation of environmental noise from wind energy conversion systems in Alameda and Riverside counties*, Research Report WR 88-19, Wyle Laboratories, October 1988

The 2012 conference of the Australian Acoustical Society will be held in Fremantle, Western Australia, from 21 to 23 November 2012. Acoustics 2012 Fremantle will be another great opportunity for Australian and International guests to get together to discuss all aspects of acoustics. Below are some updates on key presentations, workshops and dates.

Plenary and keynote presentations

The conference will include many interesting plenary and keynote presentations. Guest speakers include:

- Dr Irene van Kamp of the National Institute of Public Health and the Environment (Netherlands).
- Dr Ross Chapman of the School of Earth and Ocean Sciences, University of Victoria, Canada.

Pre-conference workshops

A variety of specialist workshops/short courses will take place prior to the event, including:

- *Active Noise Control*, University of Western Australia
- *Underwater Passive Acoustic Monitoring*
- *Advanced Machine Diagnostics and Condition Monitoring*, (2 day course), the course will be given by Em. Prof. Bob Randall from UNSW and will be held at Curtin University.

The key dates for the Acoustics 2012 Fremantle conference are:

Papers		**Registrations**	
Abstract acceptances	28 April	Registration begins	1 July
Full papers due	11 June	Late registration fees apply	1 September
Reviews released	27 August	Conference begins	21 November
Final papers due	19 September		

Please refer to the conference website for all the up-to-date information regarding the conference:
http://www.acoustics.asn.au/joomla/acoustics-2012.html

If the conference website does not answer any of your queries,
please contact the WA Division AAS secretary via e-mail (wa-secretary@acoustics.asn.au)