COMMENT ON: "OFF-SHORE WIND FACILITIES: RENEWABLE ENERGY APPROVAL REQUIREMENTS"

John Harrison - Sept. 5th, 2010

SUMMARY

Sound propagates readily across water. This common knowledge and experience is supported by sound propagation modelling. It is demonstrated that for a typical wind-energy generating system that may include a hundred or so turbines the sound pressure level could be as high as about 50 dBA on shore with an exclusion zone of 5 km. This is far in excess of typical rural night-time background noise levels of 25 to 30 dBA, of the present Ontario 40 dBA noise limit for on-shore wind-energy generating systems and the German night-time limit of 35 dBA. This estimate does not include the effect of turbulence in the atmosphere and its impact on the generation of excess low frequency noise.

INTRODUCTION

I will address only the question of setback for turbine noise mitigation because that is where I have expertise.

SOUND PROPAGATION OVER WATER – GENERAL COMMENTS

First and foremost it is our common experience that sound propagates readily over water, particularly at night when background sounds die down and when the atmosphere becomes stable. I well remember a comment by Mr. Phil Brennan, Manager of EAAB at MOE, at the first focus group meeting that I attended: *A neighbour's generator, 2 km across the lake from my cottage, drives me crazy in a way that no noise does at home in Toronto*. (This is not an exact quotation but does represent the point that he was making.) Two things are important here: the ease of sound propagation over water and the low background noise in rural Ontario, particularly at night. The propagation of sound over water is discussed in the next section. The low background noise at night is what allows the intrusion of turbine noise. Let us be clear here: there is no difference in the average wind speed at hub height (80 to 100 metres) between day-time and night-time and hence no difference in the turbine noise between day-time and night-time. This is demonstrated by the wind energy output of the Ontario wind generating systems. The following table summarizes data from the Ontario Independent Energy System Operator (IESO). The months chosen represent the four seasons. The capacity factor is the monthly average power output (MW) divided by the nameplate power output (1085 MW for the period July 2009 to April 2010). The averages were taken for day-time (6:00 am to 6:00 pm) and night-time (6:00 pm to 6:00 am). The ratios demonstrate that there is no significant difference in power output and hence noise output between day and night.

Month	July 2009	Oct. 2009	Jan. 2010	April 2010
Day-Time Capacity Factor	15.4%	31.4%	32.8%	31.9%
Night-Time Capacity Factor	14.1%	30.9%	33.1%	34.8%
Ratio: Day/Night	1.09	1.02	0.99	0.92

By contrast, there is a significant difference in wind speed at ground level between day and night. To those of us who have any experience of rural areas and particularly of Ontario lakes large and small, this is demonstrated by the calming of the wind and the consequent calming of the lakes at night. For those without that experience, data from meteorological towers offer the proof. A comprehensive survey of such data was given in the paper that I presented at the 2008 World Wind Energy Conference. The summary of data from 28 sites, world-wide, was that the average (day and night) ratio of wind speed at a height of 10 metres to that at 80 metres was 0.7 ± 0.1 whereas the night-time average was 0.5 ± 0.1. During the summer months the difference is magnified.

SOUND PROPAGATION OVER WATER – LITERATURE REVIEW

The science of noise from off-shore wind turbines has been reviewed by Sondergaard and Plovsing (SP) in a report to the Danish Ministry of the Environment:
http://www2.mst.dk/udgiv/publications/2005/87-7614-687-1/pdf/87-7614-689-8.pdf
This report will be the basis for my comments. The report consists of two parts: (a) measurement of emission of offshore turbine noise and (b) calculation of sound propagation from offshore turbines. Part (a) is not relevant here. The difficulty of measuring sound emission is that the measurement must be made at sea and hence with a sound meter on a boat. The background noise from the boat was 55 to 58 dBA. Nevertheless at the required range of 85 to 125 metres from the turbine the methodology was shown to work. Part (b) was a combination of literature review and calculation using Swedish and Danish propagation models.

SP summarized the earlier work of Hubbard and Shepherd who measured turbine noise propagation over desert sand, like water an acoustically hard surface. Hubbard and Shepherd showed good correlation with spherical spreading and air absorption of sound for "high" frequency sound (630 Hz). However, in the infrasound region the results were better described by cylindrical spreading. Note that at low and infrasound frequencies absorption by the air is negligible. Where the crossover occurs is not known. However, the cylindrical spreading over an acoustically hard surface is very important because it means that the sound pressure level decreases by only 3 dB for each doubling of distance from the turbine rather than 6 dB for spherical spreading.

SP go on to discus propagation models formulated in Europe. The so-called Danish method is very simplistic with spherical spreading, a single parameter for air absorption (0.005 dB/metre) and a +3 dB correction for incoherent reflection from acoustically hard ground. In 1998, further work under the auspices of the European Union was presented for propagation over ground and water. This new model took account of the frequency dependence of the air absorption coefficient and so was viable for larger propagation distances. However, the model for propagation over water was tested for distance only up to 350 metres. In 2001, a Swedish report specifically addressed larger distances both over ground and over water. The model assumed a transition from spherical spreading to cylindrical spreading at a distance of 200 metres. This Swedish propagation model is written as:

$$L = L_s - 20\log(r) - 11 + 3 - \Delta L_a + 10\log\left(\frac{r}{200}\right)$$

L is the sound at the observer, L_s is the turbine sound power (e.g. 105 dBA), 11 is 10 log (4π), 3 is 3 dBA of ground reflection, ΔL_a is the frequency dependent absorption coefficient and r is the distance from turbine hub to the observer. The second term on the right gives the spherical spreading and the final term corrects for cylindrical spreading beyond 200 metres. Given that the transition distance for cylindrical spreading is uncertain, the authors of the model specify that the model gives an upper limit to the sound pressure level at the observer.

It is instructive to consider a numerical example. Consider 32 large turbines placed 5 km from shore, each generating 107 dBA of sound power. The total sound power is then 122 dBA (107 + 10 log 32). Ignoring for now the absorption term, the sound pressure level at the shoreline is 54 dBA. This is an upper limit because of the uncertainty in the model and because high frequency sound will have been absorbed. Figure 17 of SP gives a correction for air absorption based upon the frequency dependence of the absorption coefficient. At 5 km it is -8 dBA. Therefore the above estimate becomes 46 dBA.

I would like to add to this discussion and enlarge on an aspect of the Swedish model. At large distances, such as 5 km, the path difference between the direct and reflected pathways from turbine to receptor become small. For instance, at a distance of 5 km, the path difference is equal to or less than a quarter-wavelength for frequencies at and below 1700 Hz. That is, for the spectrum of sound that reaches a receptor the direct and reflected sound waves add coherently. This adds 3 dB to the sound pressure level. This takes the estimate for the upper limit of sound at the on-shore receptor up to 49 dBA. As an aside, if the average distance of the 32 turbines from the receptor is 6 km, this reduces the sound power level by only 1 dBA. Note that the Windstream proposal for the Wolfe Island Shoals has 24 turbines placed between 5 and 7 km from the Amherst Island south shore and another 100 or so placed between 9 and 12 km from the same shoreline.

This review of the work of SP and the above analysis makes clear that a 5 km setback of wind turbines from rural shorelines is inadequate from an acoustic perspective. This upper limit of about 50 dBA is far in excess of the typical night-time background sound pressure level, the present Ontario wind turbine noise limit of 40 dBA and the more realistic 35 dBA German night-time limit. There are other concerns that to date have been ignored by the Ministry of the Environment.

All measurements and calculations are subject to uncertainty. Specifications for turbine noise quote uncertainty of 1 or 2 dBA. ISO 9613, the standard model for calculating noise at a receptor from an on-shore wind turbine, includes an uncertainty of 3 dBA. SP made a measurement of turbine sound power level for an off-shore turbine and found a difference from the sound power level of a same type on-shore turbine of between 1 and 3 dBA, depending upon the wind speed. They write: *"The difference is within what could be expected when comparing two different turbines of the same type on land".*

There is turbulence in the atmosphere over water just as there is over land. In a published paper Barthelmie has measured a turbulent intensity at a Danish off-shore turbine site to be 7%. The author was more interested in the turbulence of the downwind wake from the turbines and so was not looking for the range of turbulence out at sea. Turbulence adds significantly to turbine noise, particularly to the low frequency component of the turbine noise. It is the low frequency noise which propagates with little absorption by the atmosphere, which is most subject to cylindrical spreading and coherent reflection and which causes the most annoyance. Part of any renewable energy approval process should be the measurement of the turbulent intensity over the range of height traversed by the blades.

It is now clear that the MOE noise regulations for on-shore wind turbines were and are woefully inadequate. They allow noise intrusion of more than 15 dBA in rural areas at night; neglect MOE's own general penalty of 5 dBA for noise of a periodic or cyclic character (amplitude modulation); included an allowance for masking noise for several years beyond the time that research in Europe had shown that masking noise is generally just not present at night; ignore the contribution of turbulent air to low frequency turbine noise; ignore the uncertainty in the sound power of turbines and in the propagation models; and finally, ignore the recommendations of medical and other authorities that setbacks from modern large up-wind turbines should be 1.5 to 2 km. The failure of MOE to correct these inadequacies (masking noise apart) could be the embarrassment of admitting its initial lack of judgement, knowledge or spine.

Now that we are seeing the advent of off-shore turbines in Ontario it is vital to get things right at the beginning. The proposals coming forward involve hundreds of turbines in the Great Lakes. A 5 km exclusion zone is far from adequate. I would like to support a point made by Bill Palmer in his EBR commentary. In Europe, as they have gained experience with off-shore wind turbines, regulators have been increasing the setbacks from shore, to far beyond the meagre 5 km proposal for the Great Lakes. Rather than go through the same learning curve, Ontario needs to make use of the European experience.

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