INADEQUACY OF WIND TURBINE NOISE REGULATIONS AND THEIR APPLICATION

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1. INTRODUCTION

As this is being written, the regulations for future wind-energy development in Ontario are being discussed and revised. The reason for new regulation is that in May 2009 Ontario adopted a Green Energy Act which removes municipalities from the approval process and puts the final decision on projects with the Ontario government. The draft regulations for noise at a receptor issued by the Ontario Ministry of the Environment (MOE) are not so different from those established by MOE in October 2008 and, Germany aside, not so different from those in other jurisdictions.

Typically, noise regulations require an L_{eq} = 40 dBA limit at a receptor (home, school, institution) as determined by the ISO prediction code 9613, the manufacturer's noise specification for the turbine, a suitable ground effect parameter and an atmospheric absorption coefficient of 0.005 dBA/m. In practice this translates into setbacks from receptors of about 500 m for an isolated modern turbine and about 800 m for a group of three similarly spaced turbines. Two jurisdictions, Ontario and New Zealand, still allow an increase in the limit with increase in wind speed. The new draft regulations in Ontario have dropped this allowance but as yet they are just draft regulations.

There are several recommendations from health and other authorities that these setbacks are far too small (see Harrison 2008). The recommendations are for setbacks in the range of 1.5 to 2 km. An on-going health-impact study in Ontario (McMurtry, 2009) has so far turned up more than 70 victims with health problems, severe enough to require medical attention, caused by the proximity, pre-approved by the MOE, of one or more turbines to their homes. Two field studies, one in Sweden (Pedersen and Perrson Waye 2007) and one in Wisconsin (Bittner-Mackin 2003), have found annoyance with wind turbine noise at the 40 dBA level among 50% of respondents; this compares with 3 to 4% for traffic noise at 40 dBA. It is clear that the turbine noise limits are too lenient to the wind industry and that changes are needed if wind-energy development is to continue to expand. This paper discusses the basis for the inadequacy.

2. INADEQUACIES

The myth of masking from ground level wind noise seems to have been laid to rest thanks to the pioneering work of van den Berg (2004) and the myriad measurements that have demonstrated the large wind speed gradient in the atmosphere at night. This will not be discussed further here. However, for those people living with the reduced setbacks that resulted from earlier regulations with the masking noise allowance, the problem remains until the offending turbines are shut down. The remaining problems are concerned with the large intrusion of turbine noise above ambient, the characteristic swooshing sound of an operating turbine, the excess low frequency noise due to turbulent inflow and the neglect of uncertainty in noise prediction.

2.1 Intrusion

Rural regions are very quiet, probably below 25 dBA at night. This means that typical guidelines are allowing a 15 dBA intrusion above background and, given the annoying characteristic of turbine noise, this is too much. There is no need to allow this large an intrusion. Germany, which has a population density 20 times larger than that of Ontario and has a well-developed wind energy generation system supplying 6.4% of its electrical energy, has a night-time noise limit of 35 dBA. In another instance, New Zealand, in section 5.3.1 of its draft regulations, is introducing a secondary noise limit of 35 dBA for evening and night-time in low background environments.

2.2 Amplitude Modulation

Wind turbine noise is periodic in the blade passage frequency. It is clear from the work of van den Berg (2005). It is clear from the Salford report (Moorhouse et al 2007) published by the British Wind Energy Authority. It is acknowledged by MOE in its turbine noise regulations published in October 2008. The consensus is that it amounts to about 5 dBA of amplitude modulation. This amplitude modulation is averaged away by regulations based upon an L_{eq}. However, the ear does not average and this swooshing sound adds significantly to the annoyance associated with turbine noise. A 5 dBA penalty is needed to account for the amplitude modulation.

2.3 Turbulence

Many noise complaints draw attention to a component that sounds like a rumble (a dryer or a passing train that never passes!). This is probably excess low frequency noise associated with turbulent inflow of air into the blades. The turbulence has two sources, turbulence in the atmosphere and the turbulent wake from neighbouring turbines. SODAR measurements (Barthelmie 2003) have shown that for $x/D \sim 5$, the turbulent intensity (TI) behind a turbine is comparable to the atmospheric TI (x is the distance behind the blade and D is the blade diameter). They were 5% and

7% respectively. Turbulent intensity is defined as σ/v where σ is the standard deviation of the wind speed v (Wagner et al 1996). The SODAR measurements were made every minute and the averaging time for σ and v was 10 minutes. Low frequency noise requires a faster time scale for the calculation of σ and hence of the appropriate TI. However, the important point is that turbulence about 5 blade diameters behind a turbine is significant. I note that for the Wolfe Island wind farm in Ontario about half of the turbines are within 6 blade diameters of an upwind turbine for the prevailing south-west winds. As an aside, the velocity deficit for the same half of the turbines due to the wake of the upwind neighbours will be 20% (Barthelmie 2003), so lowering the power output efficiency by 50% (0.8^3) from that of the upwind turbines!

Moriarty and Migliore (2003) and Moriarty (2004) working at the National Renewable Energy Laboratory in Golden CO, made a study of inflow turbulence noise from turbines, with both measurements and predictions. Below 1 kHz, the turbulent inflow noise can dominate the total turbine noise. For instance, with a TI of I = 10.6%, at 100 Hz this noise is 30 dBA larger than the combined noise from all other aerodynamic sources. Doubling the frequency decreases the turbulence noise by 5 dBA. The noise power is proportional to I^2, so that the sound pressure level falls by only 6 dBA as the TI is halved. The noise measurements bear out the predictions apart from the need for an adjustment for the averaging time for the determination of σ.

It is quite clear from measurements of the turbulent wake downwind of a turbine, the close proximity of turbines to each other at wind developments around the shores of the Great Lakes, the predictions of turbulent inflow noise calculations and the agreement with measured noise that it is vital that this noise source be a part of noise regulation. This noise will not go away at night when the day-time atmospheric turbulence gives way to the stable night-time atmosphere. Turbulent inflow noise is predominantly in the low frequency range below 1 kHz, particularly near the lower range of hearing, and where the absorption by the atmosphere is minimal. Enough is known that prediction of turbulence noise can be made both from prior wind speed test tower measurements and from the proposed layout of the turbines. To date, no jurisdiction is requiring turbulence noise in their approval process. This must change.

2.4 Uncertainty

No prediction is going to be 100% correct. The turbine manufacturer quotes an uncertainty of ±1 or 2 dBA. One of the frequently used prediction codes, ISO-9613, specifically states an uncertainty of ±3%. These are independent uncertainties and so will add in quadrature. Therefore the prediction for noise at a receptor will carry an uncertainty of ±3 to 4 dBA. No self-respecting and responsible engineer would ignore the uncertainty in a design calculation; yet noise consultants do ignore this uncertainty and, in Ontario, the engineers at MOE allow this neglect.

4. CONCLUSION

Regulations for wind turbine noise presently in force are inadequate to protect rural residents from annoyance and, in many cases, health problems resulting from operating wind turbines. The typical noise limit of 40 dBA needs to be reduced to 35 dBA. There needs to be a 5 dBA penalty for amplitude modulation. There needs to be an analysis of turbulent inflow noise, for both atmospheric and wake turbulence. The uncertainty of noise prediction codes must be included. Together, these essential up-grades to regulation will push setbacks to the 1.5 km range where they should be.

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