Summary to:

The effect of a common wind shear adjustment methodology on the assessment of wind farms when applying ETSU-R-97

MAS Environmental - 27th October 2011

Introduction. MAS Environmental have undertaken a detailed study of methods used to account for wind shear in UK assessment of wind turbine noise impact. The full study can be downloaded from the MAS Environmental website[1]. This paper summarises the main issues in a simplified form to try to explain the consequences of the findings of the study.

In the UK planning policy supports the use of ETSU-R-97 to rate and assess noise from wind farms. At the time of publication in 1997, wind turbines were of a height of about 30m to the hub. Modern day turbines are often 80m to the hub and hence the swept area of the blades is much greater. With the increase in hub height of the turbines also came problems with wind shear affects and turbine noise impact.

Wind shear. Wind shear can be described as the change in wind speed with height. Wind speed differs with height and usually wind speed increases with increasing height. High wind shear is when there is a much faster wind speed at upper heights than at lower heights. Low wind shear is when the wind speeds at upper and lower heights are similar. Wind shear can have an adverse affect on turbine noise impact under high wind shear conditions.

In high wind shear conditions there is a faster wind speed at upper heights where tall wind turbine hub heights and blades are likely to be. High wind speed results in high turbine energy generation and hence high noise output.

[1] http://www.masenv.co.uk/uploads/STUDYREPORTComparison%20of%20thearticleandETSUW111004FINAL_sec.pdf

Meanwhile, due to high wind shear conditions, there is a much lower wind speed near the ground. This means that there is little wind generated background noise at dwellings to mask turbine noise. Thus, under high wind shear the situation arises where there is maximum turbine noise output (due to high wind speeds at turbine hub height) but very low background noise levels near ground level (due to much lower wind speeds and little wind generated background noise).

Accounting for wind shear. When ETSU-R-97 was written turbines were smaller and hence the effects of wind shear were not observed. The noise impact assessment methodology and rating of turbine noise impact in ETSU-R-97 does not account for wind shear effects. In 2009 a group of acousticians published an alternative method to that set out in ETSU-R-97 for assessing noise impact from wind turbines in the Institute of Acoustics magazine 'Acoustics Bulletin', referred to hereon as "the article method"[2]. It was argued that this revised assessment methodology would address noise impact from wind turbines and the affect of wind shear.

The article method differs in the way it approaches assessment of wind turbine noise compared to that set out in ETSU-R-97. ETSU-R-97 states that background noise levels should be referenced to 10m high measured wind speed. Although ETSU-R-97 does not factor for the affects of wind shear, wind shear can still be accounted for in keeping with ETSU-R-97 by adjusting predicted turbine noise levels to reflect differing levels of wind shear.

In contrast, the article method adjusts background noise levels for wind shear even though the affect of wind shear is on turbine noise. Under high wind shear conditions, the article method assumes that predicted turbine noise is the same as under lower wind shear conditions, but that the background noise level measured at a specific wind speed now occurs at a higher wind speed. It was argued by the authors of the article method that this would have the effect of accounting for wind shear in turbine noise impact assessment, suggesting a lower turbine noise limit at higher wind speeds compared to ETSU-R-97.

[2] Bowdler, D. et al (2009) "Prediction and assessment of wind turbine noise", *Acoustics Bulletin*, March/April 2009: p.35

MAS study. Research was conducted by MAS to test the assumptions of the article method and its suitability as an alternative assessment methodology to ETSU-R-97 as written.

Using data gathered from a number of proposed wind farm sites across the country, MAS were able to compare predicted turbine noise impact using both the article method and using the assessment procedures identified in ETSU-R-97 and adjusting predicted turbine noise for wind shear.

The suitability of the article method was judged by comparing the margin provided by each method between the predicted turbine noise and the turbine noise limit. With regard to protecting the local community from adverse noise impact, it is better for an assessment methodology to suggest that predicted turbine noise will exceed the limit than for it not to. Similarly, it is better, if turbine noise does not exceed the limit, for the assessment methodology to suggest that predicted turbine noise will be closer to the limit than it is for it to suggest that it will be well below the limit. This is simply so that communities can be better informed as to the likelihood of adverse noise impact; it provides a better prediction of the safety margin[3].

The two methods were therefore assessed by comparing how likely each method was to suggest a breach of turbine noise limits or to show turbine noise levels closer to turbine noise limits. Positive values in the results indicate that the ETSU-R-97 compliant methodology provides greater protection for communities as it predicts less headroom or margin between turbine levels and limits. Negative values indicate that the article method is more likely to predict that turbine noise levels will exceed limits (or be closer to turbine noise limits) and hence negative values indicate that the article method provides better protection for communities. The values in the results identify the extent of the difference in protection between the two methods with a higher value denoting a greater level of protection of one method over the other.

[3] This can be alluded to driving and speed cameras - would a driver prefer the car speedometer to calculate speed using a method that generally showed compliance with a speed limit, even when that was not the case, or one that was more likely to show that the speed limit was broken?

Results. The overall results of the analysis are presented in table 1 below. The data was assessed for all wind speeds between 3-12m/s and also for the critical range of 5-7m/s. The wind speed range of 5-7m/s is critical for two reasons. Firstly, it is between these medium wind speeds that predicted turbine noise is most often seen to exceed the limit. Secondly, it was suggested that the article method would provide best protection for communities in the range 5-7m/s. The data was also assessed for two different commonly occurring wind shear conditions, ɑ=0.25 and ɑ=0.4.

Table 1: Summary of results from all sites assessed

	All wind speeds (3-12m/s)		Critical wind speeds (5-7m/s)	
	α=0.25	α=0.4	α=0.25	α=0.4
% no gain from adopting article method	77	80	91	96
% gain from adopting article method	23	21	9	5
% no difference between methods	6	5	1	1
% loss of protection adopting article method	72	75	91	95

No gain. Where there is no gain from using the article method this is the combination of '0' values (no difference) and positive values (loss of protection using the article method, advantage to using the ETSU method).

Gain to using the article method. Negative values are cases where the article method provides greater control over noise levels, i.e. where there is an advantage to using the article method.

No difference. Where there is no difference between the two methods the value is 0 hence neither positive or negative.

Loss of protection using the article method. Positive values are cases where the ETSU method provides greater protection; the greater the value the greater the protection. This is where the ETSU method is more advantageous and there is a loss of protection from using the article method.

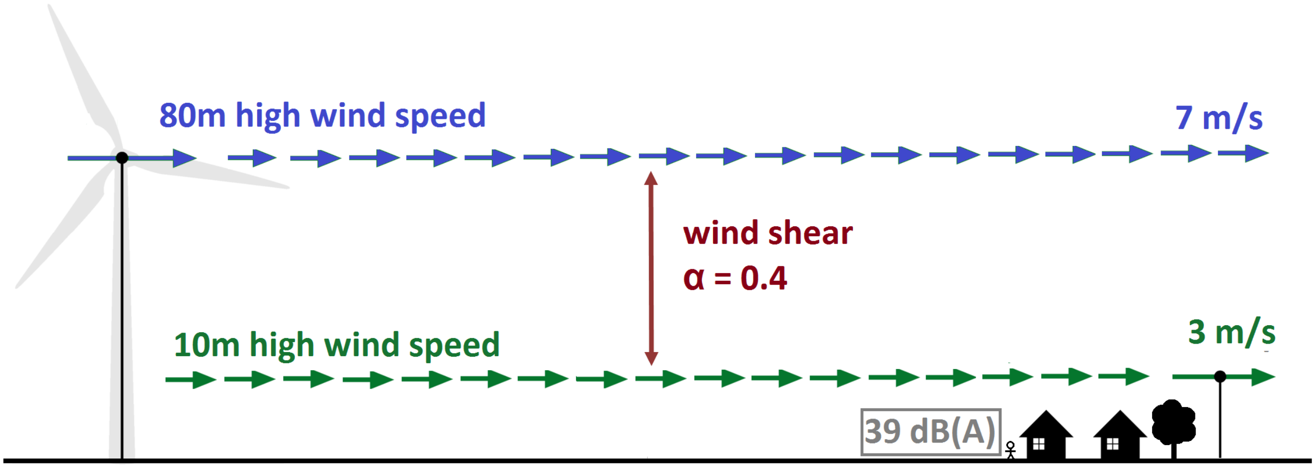
Table 1 above clearly shows that across all wind speeds for both wind shear exponents assessed that there is no gain in adopting the article method. In 72-75% of cases analysed the article method actually resulted in a loss of protection to communities. Looking only at the critical wind speeds of 5-7m/s nearly all cases (91-95%) resulted in a loss of protection to communities by using the article method. The implication of the above results is that by using the article method to assess wind turbine noise, adverse noise impact will rarely be predicted. This is beneficial for developers as it increases the likelihood that the turbine development will be approved for planning permission. Use of the article method provides a worse situation for local communities as it is more likely to result in adverse noise impact once the turbine development is built despite there being no indication of it at the planning stage and little means for reducing or resolving noise impact post development.

Postscript. Not only is the article method unlikely to indicate adverse noise impact at the planning stage, but once the development is operational the article method virtually removes the ability for local communities to enforce controls over reasonable turbine noise impact. This is explained step by step below.

Compliance testing - ETSU-R-97 vs Article method

1. This is the typical situation occurring:

Figure 1: typically occurring situation (medium-high wind shear)



Facts from the above situation:

→ Wind speed at hub height (80m) = 7m/s
(wind turbine(s) near maximum noise output)

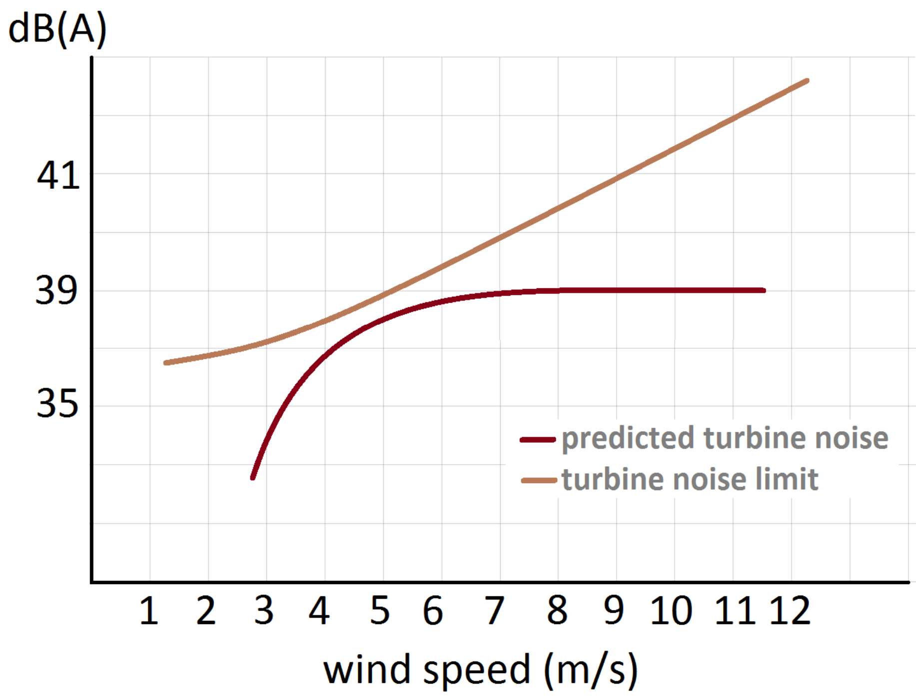
→ Wind speed at nearby housing (10m) = 3m/s
(low background noise levels)

→ Actual wind shear conditions between 10m and 80m height α=0.4

→ Measured turbine noise at nearby housing = 39dB(A)

2. Assume the graph below showing predicted turbine noise and turbine noise limits is applicable for both compliance testing according to ETSU-R-97 and the article method. The MAS study found that commonly the turbine noise limit line was similar whichever method was used, especially at the critical wind speeds (5-7m/s) where exceedace is likely.

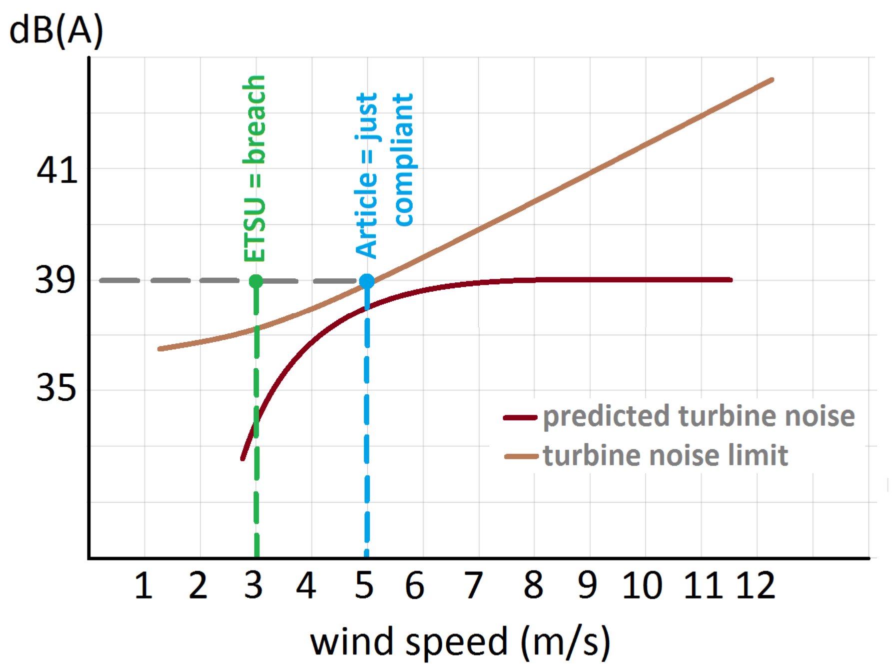
Figure 2: graph showing predicted turbine noise and turbine noise limit



3. Compliance test:

	ETSU compliance testing methodology	**Article method compliance testing methodology**
1. Determine turbine noise level	Measure turbine noise at dwelling = **39 dB(A)**	Measure turbine noise at dwelling = **39 dB(A)**
2. Determine wind speed	Measure 10m high wind speed = **3m/s.**	**a.** Measure or calculate hub height wind speed =**7m/s.** **b.** Derive 10m height wind speed using the following formula and assuming a standard ground roughness of z_0=0.05: $V_1/V_2 = \ln(h_1 / z_0) / \ln(h_2 / z_0)$ Where: V_1 is the wind speed (m/s) at a height of h_1 metres above the ground, V_2 is the wind speed (m/s) at a height of h_2 metres above the ground. Derived 10m height wind speed: $V_{10}/V_{80} = \ln(10 / 0.05) / \ln(80 / 0.05)$ $V_{10}/7 = \ln(10 / 0.05) / \ln(80 / 0.05)$ $\mathbf{V_{10} = 5m/s}$
3. Check compliance	See graph below (**green** line)	See graph below (**blue** line)

Figure 3: Compliance with turbine noise limit (ETSU versus article)



In the event of a complaint, analysis would follow either of the two paths depending whether assessed under ETSU-R-97 or using 'standardised' wind speeds as adopted by the article method.

As shown in figure 3 above ETSU-R-97 compliance testing methodology shows a breach of permitted turbine noise levels, and hence unreasonable noise impact as reflected by the presence of complaints. The article method suggests that turbine noise levels are compliant.

ETSU-R-97 automatically accounts for wind shear conditions as it measures turbine noise levels and 10m high wind speed under conditions representative of those that cause the complaint. In the above example the wind shear conditions causing complaint are equal to ɑ=0.4. The article method fails to account for the actual conditions causing the complaint because of the common assumptions used in the formulae used to derive 10m wind speed height. It does not measure the actual 10m wind speed but derives it from hub height. By doing this it only ever assumes wind shear conditions of ɑ=0.16. As demonstrated above, this lower wind shear value assumes that the wind speed at 10m is higher that it is likely to be when complaints occur. In the example above it assumes that the 10m height wind speed is 5m/s rather than the 3m/s that is actually occurring. This means that using the article method turbine noise will very rarely be shown to breach the permitted limit and hence even when turbine noise is unreasonable, compliance is indicated. This removes the ability for local communities to enforce reasonable turbine noise limits. It effectively renders any wind farm, where the article method has been used, incapable of enforcement as ETSU-R-97 intended and subject to higher turbine noise levels than should be permitted.