MEASURING COMPLIANCE WITH THE ETSU-R-97 SIMPLIFIED LIMIT

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1 INTRODUCTION

This paper reports on a number of factors that influence whether a wind turbine project is measured to comply or not with the simplified ETSU-R-97 35dB(A) $L_{A90,10min}$ condition[1] in the light of the IoA Good Practice Guide (IoA GPG)[2], particularly the Supplementary Planning Note 5: Post Completion measurements (SPN5)[3], and based on experience of compliance measurements in the field.

2 BACKGROUND

A large number of wind turbine projects in the UK have been consented with the simplified ETSU-R-97 noise condition. This condition is still being widely used either for projects which can demonstrate that no sensitive receptors would be present within a 35dB(A) 'noise contour' or for properties not specified by background noise related planning conditions. In practice, it has been found that assessing compliance with this 'simplified' condition is particularly challenging, post completion.

Consider the example of a single turbine project which received a noise complaint from a receptor approximately 750m away for which the maximum ISO9613:2[4] prediction was 28.2dB(A) at standardised 10m wind speeds of 8 – 10ms^{-1}. The first stage of the complaint investigation requested by the local Environmental Health Officer (EHO) was to demonstrate or refute that the 35dB(A) condition was being met at the property. If compliance with the simplified condition was demonstrated, the second stage was then to investigate other potential factors that could have given rise to the complaint.

For this receptor location, considering downwind directions only, the finally agreed maximum level of turbine noise derived from an extended measurement campaign was 33.8dB(A) at standardised 10m wind speed (v_{10}) of 8ms^{-1} with a similar value obtained for 9ms^{-1}. This was an unexpectedly high noise level relative to the propagation prediction, despite using noise recording in this case to assist in filtering extraneous measurement data. Meanwhile, the complainant's noise diary recorded instances of annoyance best correlated with v_{10} wind speeds below 8ms^{-1}, and it was clear from aural observation at the site that the complaint was most likely to relate to an amplitude modulation effect.

Figure 1 provides a general illustration of the issues raised by the above example: the wind speeds at which turbine audibility, and any adverse amplitude modulation effects, might occur are not those typically most critical for demonstrating planning compliance with a simplified 35dB(A) condition.

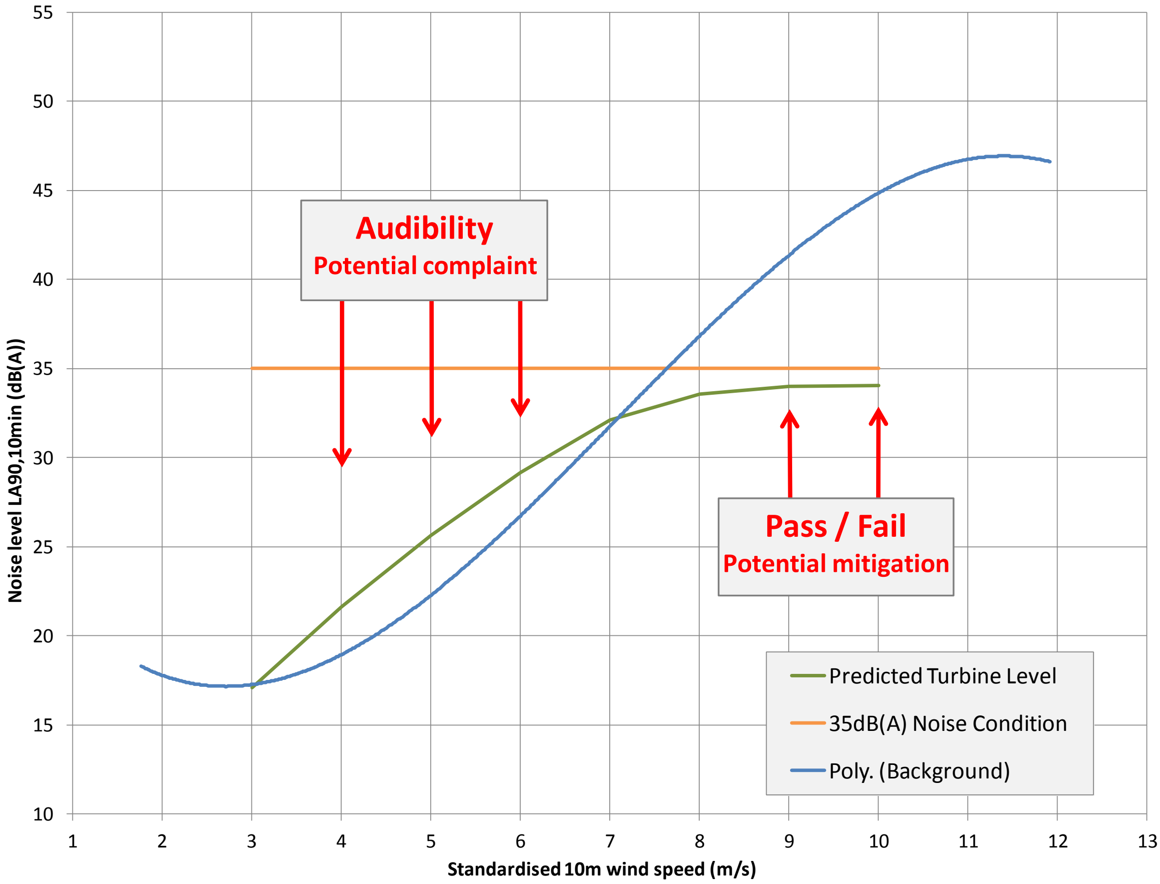

Figure 1 – Noise Level v Standardised 10m Wind Speed showing Predicted Turbine Noise, the 35dB(A) Noise Condition and a typical Background Noise Profile

The post completion assessment method tends to produce values for turbine noise level that lose coherence with predicted levels as wind speeds increase above ~8ms^{-1} implying an increase in measurement uncertainty. Yet, these uncertain results would form the basis for noise mitigation if an apparent breach of condition is shown. The mitigation would then be activated for wind speeds above 8ms^{-1} when the turbine is less likely to be audible at nearby properties due to masking from background noise. Therefore, the mitigation is unlikely to satisfy any complainant and will reduce financial viability of the project for the developer.
These considerations motivated an investigation of some of the key factors that have potential to limit the effective use of the 35dB(A) condition in the light of the IoA GPG.

3 FACTORS INFLUENCING COMPLIANCE

The factors influencing compliance considered were: sensitivity of calculations to measured level difference between background including turbine noise and background noise only; measurement distance from turbine(s); standardisation of wind speed; and wind shear, including time of day of measurement.

For each of these, an illustrative example of real data has been provided, followed by a discussion of that factor in relation to assessment outcomes.

3.1 Sensitivity of Calculations to Measured Level Differences

3.1.1 IoA Good Practice Guidance

The IoA GPG anticipates the problem of proving turbine noise levels where background levels and level differences are low. SGN5 paragraph 2.4.8 states:

"...where the shut-down noise approaches the operational noise, the level of shut-down noise has an increasing effect on the calculated turbine noise such than ***when the difference between the two is 3 dB or less****, it may no longer be appropriate to use this correction with any degree of accuracy and* ***some other method*** *of determining turbine noise in the presence of high levels of background noise may need to be agreed with the planning authority.* ***In the event that the typical background noise is greater than the turbine noise limit, and if the additional contribution of the turbine noise to the prevailing background is difficult to discern with confidence from the data, then it is likely that compliance with the ETSU-R-97 limits would be demonstrated.*** *In such cases where noise limits are less than ETSU-R-97 limits (e.g. apportionment of noise impacts due to cumulative impacts) compliance measurements may need to be undertaken in closer proximity to the wind farm to ensure background noise levels do not unduly influence the readings.* ***This may also be significant when determining compliance with planning limits such as the ETSU-R-97 simplified limit of 35 dB*** L_{A90} *since background noise is likely to be around this level or higher when the turbine reaches rated power, except under exceptional conditions."*[5]

3.1.2 Typical Example of Low Level Difference

Figure 2 illustrates a typical site where the 35dB(A) condition has been assessed at a suitable, representative location within the dwelling's curtilage. The site in question was found to exhibit low wind shear characteristics. *The data marked by a red cross and fitted with a red polynomial function are those measured with the turbine operating (turbine plus background) and the data marked with blue triangles and fitted with a blue trendline are background levels in the absence of turbine noise.*

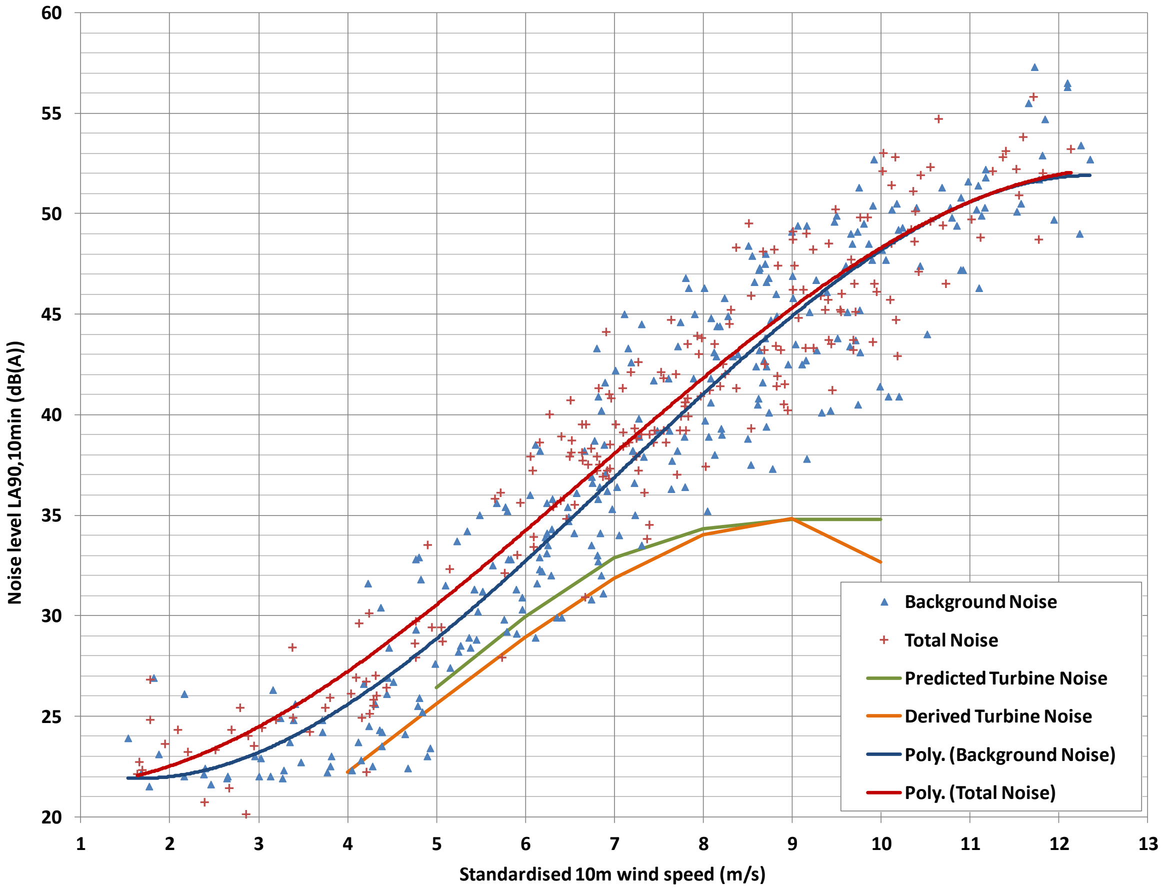

Figure 2 – Noise Level Variation with Wind Speed for a Wind Turbine Site

One consequence of low wind shear is that the noise data to wind speed gradient is steeper than for standard conditions, typically resulting in a higher spread of noise data within each wind speed bin and a lower level of confidence in the trendline fitted through the data.

In the situation illustrated by **figure 2,** the level difference (between the trendlines) remained less than 2dB throughout the wind speed range. In addition, background noise levels exceeded predicted turbine noise levels throughout.

In this case, the calculated turbine noise ended up lower than 35dB(A) at wind speeds where the background noise was above 40dB(A) (8, 9 and 10ms^{-1}) even though the level difference between trendlines was <1dB(A).

However, at lower wind speeds where the level difference was at least 1dB(A) and background noise levels were below 40dB(A), the derived turbine noise levels were credible, at around 1dB(A) below a prediction inclusive of manufacturer's uncertainty.

3.1.3 Evaluation of Measurement Sensitivity to Level Difference

To evaluate how sensitive a calculation is to the measured level difference it was instructive to consider what happens if the measured turbine plus background noise level is just 0.1dB(A) lower, reducing the level difference by 0.1dB(A). The effect is plotted in **figure 3**.

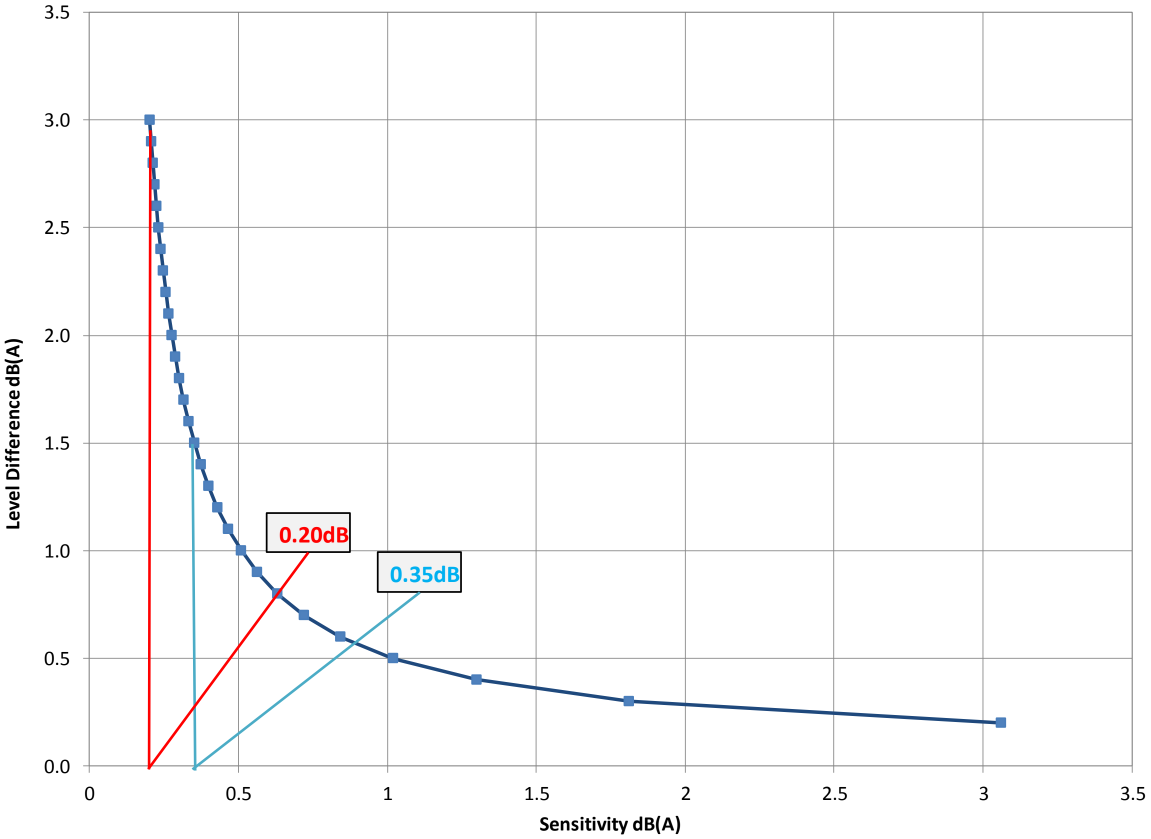

Figure 3 – Graph of Level Difference vs Calculation Sensitivity highlighting the effect of a 0.1dB decrease in total noise on derived turbine noise

The graph highlights that less confidence can be taken from measurement results where the level difference is low – an increase from 0.4 to 0.5dB(A) results in an approximately 1dB(A) greater estimate of turbine noise. For example, if the background noise levels were 45dB(A) $L_{A90,10min}$ at standardised wind speed of 10ms^{-1} (a fairly typical value) the turbine noise calculated for level differences of 0.4dB and 0.5dB would be 34.8dB(A) and 35.9dB(A), the latter implying a breach of condition.

Meanwhile, to achieve the 3dB(A) level difference desired by the SPN5 para 2.4.7 across the full wind speed range would normally require a measurement of an 800kW turbine to be approximately 240m away, while nearby properties would typically be a minimum of 400m distant.

Figure 3 suggests that it may be pragmatic to accept level differences of around 1.5dB(A) as these do not significantly increase the variation in the turbine noise levels derived. However, level differences of 1dB(A) or less are subject to much more significant error.

3.2 Measurement Distance from Turbines

Figure 4 highlights the potential benefit of using an intermediate measurement location much closer than the property to the turbine(s). The proxy location in this case was chosen to lie on the 40dB(A) worst case prediction contour.

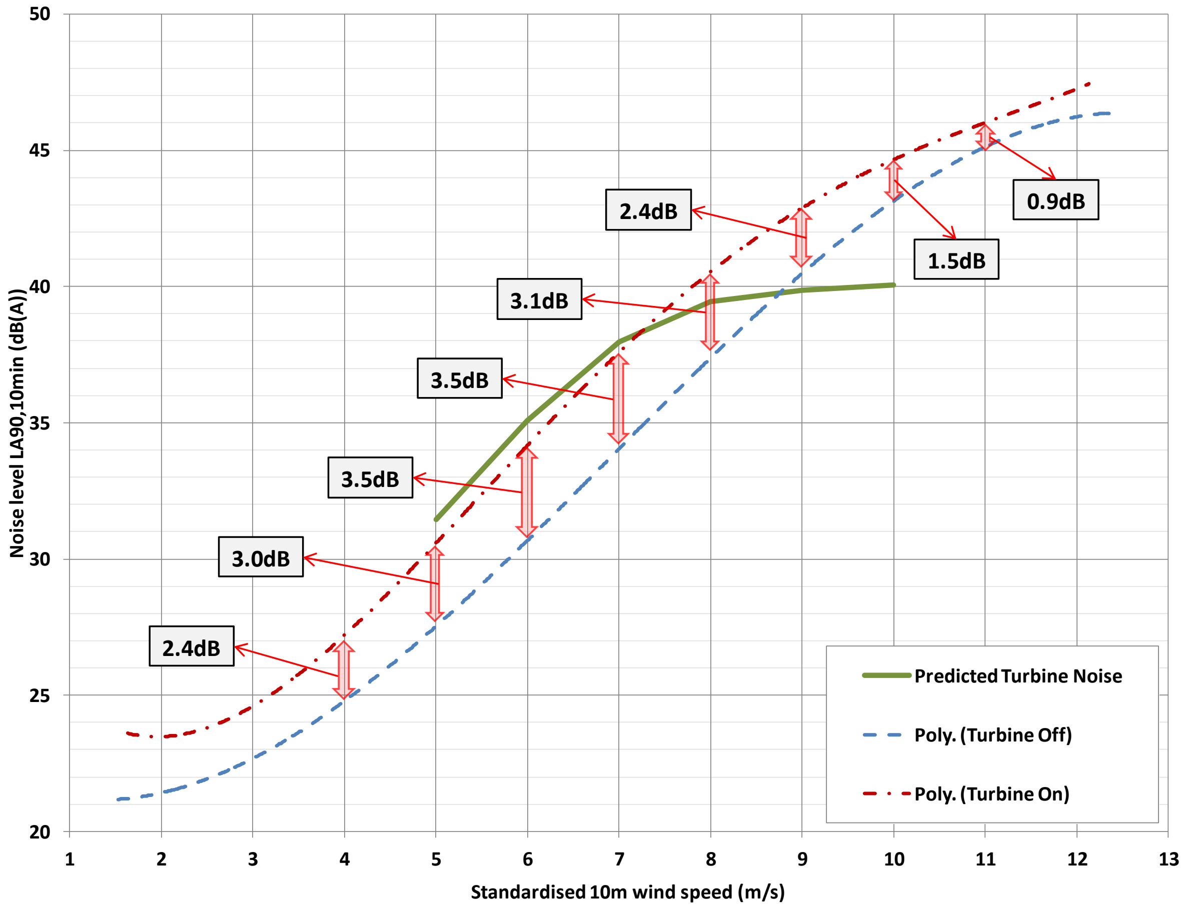

Figure 4 – Variation of Noise with Wind Speed at an Intermediate Proxy Location

In the example, a level difference of 1.5dB(A) or greater was achieved at all wind speeds of interest (up to $10ms^{-1}$). Meanwhile, at the mid range of wind speeds, background noise levels were largely below 40dB(A) and the level difference was sufficient to give a high level of confidence in the computed turbine noise levels.

However, proxy locations must be chosen with care to avoid measurement in a very different noise environment. Moreover, if the measurement is required as the result of a complaint, it should be carried out at the property from which the complaint originated, suggesting that such a measurement would be required at a proxy location in parallel with a location at the property, adding to the cost of monitoring.

3.3 Standardisation of Wind Speeds

A practical difficulty for small commercial wind turbine projects with the 35dB(A) constraint is wind speed measurement. There are two aspects to this: firstly, obtaining a reliable v_{10} with and without the turbine operating that one can reasonably compare; and, secondly, dealing with turbines which reach rated power before $10ms^{-1}$ v_{10}.

The first part of the problem may not be entirely obvious since wind turbines have anemometry located at hub height. However, these wind speed readings are adversely affected by the blades rotating in front of them. While wind turbine manufacturers make corrections for this, these corrections are in place when the blades are stationary, and so the wind speed readings when the turbine is switched off (as required during compliance measurements) are unlikely to be comparable with those made with the turbine switched on.

A more effective way of obtaining the hub height 'wind speed' for the operating turbine below rated power is to consider the average power output. Any method that uses the power curve to derive the v_{10} with the turbine switched on is likely to suffer from the problem of power curve saturation prior to reaching $10ms^{-1}$.

This still leaves the problem of obtaining equivalent data with the turbine switched off. While most large wind farm projects would have an onsite hub height anemometry mast installed from which a consistent hub height wind speed measurement could be obtained both with and without turbines operating, this is highly unlikely with the smaller projects subject to the simplified 35dB(A) planning condition. Moreover, small projects will often have much more limited scope for quickly installing a hub height wind speed measurement due to such factors as restricted land ownership and/or planning application boundaries, temporary planning permission being required for a mast and the costs associated with hiring wind masts, SoDAR or LiDAR equipment.

3.3.1 A Method for Obtaining Comparable v_{10} Wind Speeds

As a result of the above considerations and practical experience in the field, the following approach has been adopted to attempt to obtain credible and comparable v_{10}s:

- Install a control wind speed measurement ideally upwind of the turbine and property under investigation (a 10m mast can still be used effectively for this at low cost);
- Adopt the IEC61400-11[6] approach to deriving the relationship between power output and hub height wind speed with the turbine switched on. Temperature and pressure measurements are used, where available, to correct for air density.

With this approach, only a proportion of the power curve is used to avoid high scatter at cut-in wind speed or power curve saturation at rated power. For an Enercon E48 with 55m hub height, for example, the 'allowed range' translates to v_{10}s of $3.8ms^{-1}$ – $8.3ms^{-1}$. For higher wind speeds, a correlation between the power curve derived wind speeds and the hub anemometer must be used.

- In contrast to the IEC61400-11 approach, the power curve derived wind speed data is correlated to the parallel set of 10m measured data. This then allows a 'true' hub height wind speed data set to be produced for the periods where the turbine is switched off. These can be checked against the hub anemometer readings for consistency.

Calculations are carried out for each wind direction (30° wide bins are commonly used) so that directional wind shear differences are accounted for.

These two sets of derived hub height wind speed data can now be 'standardised' to 10m height using a roughness height of 0.05m. In terms of compliance measurement, the key benefit is that two directly comparable wind speed data sets are produced.

This contrasts with the general method outlined by the IoA GPG[7] and the IEC61400-11[8] method – in effect these approaches use different wind speed measurements for turbine on and off conditions.

3.4 Wind Shear

Much time has been devoted in recent years to the treatment of wind shear in relation to noise assessment for wind turbines. It should be noted that the above method treats two of the three main areas of wind shear variation: wind direction and wind speed. Directional shear must be treated if a control wind speed measurement below hub height is used. Wind shear variation with wind speed is accounted for by the correlation of power curve derived wind speed and the control wind speed measurement.

The third main area of wind shear variation is time of day. In the context of the simplified 35dB(A) noise condition, it is significant that wind shear is highest at night, as illustrated in **figure 5**, showing a typical winter time diurnal wind shear profile:

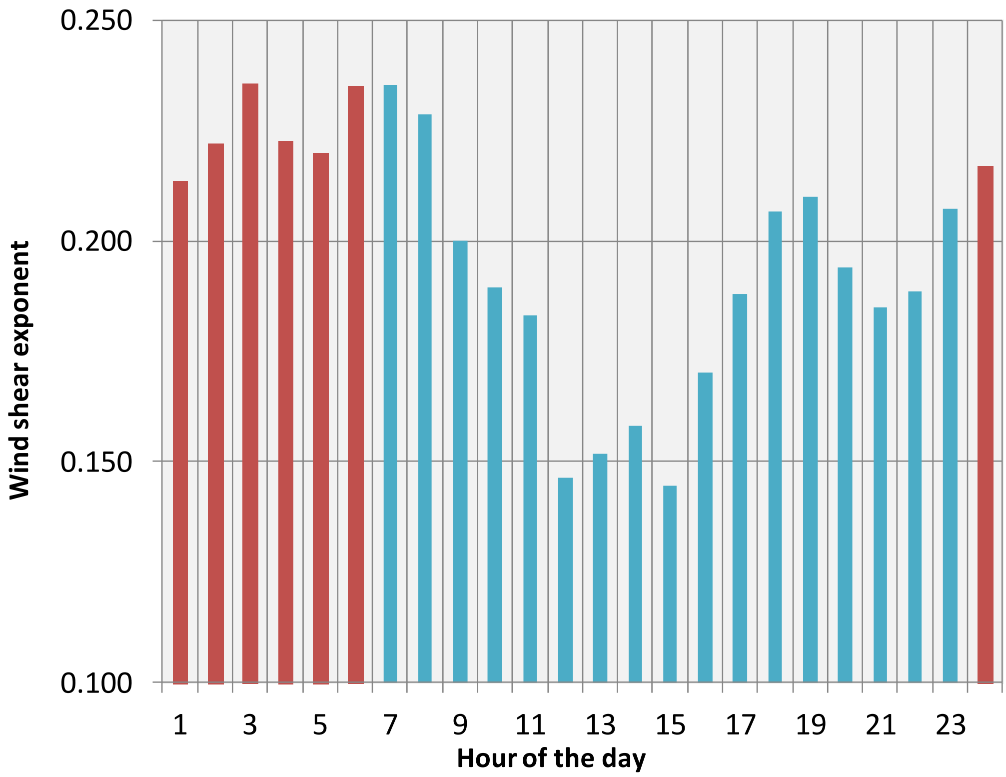

Figure 5 – Typical Winter Diurnal Wind Shear Variation (with Night-time highlighted in Red)

A helpful suggestion of SPN5 (para 2.4.4)[9] has been to direct 35dB(A) condition measurements to focus on 23:00 – 04:00 GMT, where wind shear tends to be highest and where the majority of extraneous noise sources are not present. In practice, measurements during summer periods may be ended at 02:00 or 03:00 GMT because of the dawn chorus.

4 CONCLUSIONS AND RECOMMENDATIONS

In conclusion then, experience to date with small-scale commercial wind turbine projects in Scotland is that establishing compliance or non-compliance with the simplified 35dB(A) planning condition is challenging when noise levels are measured at the property itself, because of the distances and relatively low levels of turbine noise involved.

A potential solution to this problem is to increase the use and acceptability of intermediate proxy locations for noise monitoring. However, as mentioned, ensuring a robust proxy measurement can still prove problematic and may not eliminate the need to monitor at the property itself.

It has been found that the IoA GPG SPN5 (para 2.4.7) has made little difference to the attitude of EHO's because they still require demonstration of compliance with the planning condition for all wind speeds even if level differences do not justify any confidence in the results obtained, and even if the background noise levels measured far exceed 35dB(A). It is recommended that, at wind speeds where level differences are below 1.5dB(A), EHO's extrapolate turbine noise levels from results obtained with level differences greater than 1.5dB(A), using predicted turbine noise levels to evaluate the likelihood of compliance.

Meanwhile, the IoA GPG's suggestion to monitor the 35dB(A) condition between 23:00 and 04:00 has tended to maximise level differences and has generally been accepted by EHO's.

It has generally been found that the IoA GPG has helped to reduce the amount of time spent with EHO's discussing data exclusions and methods of establishing trendlines through data. It was also essential from a practical point of view that 10m masts could still be used for post-completion measurement, particularly in relation to cost and the need for measurement consistency when comparing turbines switched on and off. For sites where an independent hub height wind speed measurement is not possible, it is recommended that the method outlined for computation of wind speed with the turbine(s) switched on and off is adopted to ensure consistency, given the unreliability of turbine anemometry.

In practical terms, it would be of great benefit if requests to vary background noise conditions from a fixed 35dB(A) to background + 5dB(A), or some other suitable background noise related condition, were considered positively by EHO's simply because with such conditions it is less critical to correctly establish the actual turbine noise level.

5 FURTHER WORK

The IoA GPG hasn't considered how treatment of measurement uncertainty could inform the EHO's view on compliance in marginal cases and reduce the scope for disagreement about whether sufficient data has been captured. This has become important in relation to measurement of downwind conditions. In addition to consideration of typical measurement uncertainty factors, the uncertainties in the plotting of trendlines through measurement data should be evaluated – a more robust way of doing this than simply considering r^2 correlation coefficients would be useful.

6 REFERENCES

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2. Institute of Acoustics, *'A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise'*, IoA, (2013)
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4. The International Organization for Standardization, *'ISO9613:2 - Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation'*, ISO, (1996)
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6. International Electrochemical Commission, *'IEC 61400-11: Acoustic Noise Measurement Techniques'*, 3rd Ed., (2013)
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