inter·noise 96
25th Anniversary Congress – Liverpool

INCE: 14.5.4

THE MEASUREMENT OF NOISE FROM WIND FARMS AND BACKGROUND NOISE LEVELS

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INTRODUCTION

PPG 24 Planning and Noise [1] gives guidance in Annex 3 Paragraph 19 concerning the introduction of an industrial or commercial noise source into an existing noise environment. It states that;

"The likelihood of complaints about noise from industrial development can be assessed, where the Standard is appropriate, using guidance in BS 4142 : 1990." [3]

The Wind Annex of PPG 22 : Renewable Energy [2] states at Paragraph 44 that;

"Using BS 4142 to assess wind turbine noise may be inappropriate for several reasons:

(a) wind farms are likely to be developed in largely rural areas and not in the areas to which the standard is principally addressed, namely mixed residential and industrial areas;

(b) the scope of BS 4142 specifically precludes situations where the background noise levels are below 30 dB(A). This level is typical of the background noise level which might be found at some potential wind farm sites;

(c) BS 4142 recommends that noise measurements should not be taken in "extreme weather conditions such as high wind speeds greater than 5 m/s average". This restriction guards against unrepresentative measurements due to wind noise on the microphone. Wind farms are likely to be sited in windy areas where BS 4142 conditions may not be satisfied. Care should be taken when measuring noise levels in windy conditions."

The placement of most UK wind farms in remote rural areas where background noise levels are very low (< 30 dB L_{A90}) results in no clear

guidance for the assessment of wind turbine noise. A Working Group on Wind Turbine Noise (WGWTN) was sponsored by the DTI to provide informative information concerning the measurement and assessment of wind turbine noise. The preliminary recommendations of the WGWTN were issued in 1995 [4]. This paper considers the measurement and analysis of background noise data and the application of the data to form noise limits at neighbouring properties

WIND TURBINE NOISE

Wind turbines operate over a wind speed range of 3 to 25 m/s. At wind speeds above 25 m/s, turbines blades are feathered or tip brakes deployed, to stop power generation during high wind load conditions. The noise emitted by a wind turbine increases with wind speed by between 1 and 4 dB L_{Aeq} /m/s. Therefore, the noise level from the wind farm at a neighbouring dwelling will be dependent upon the wind speed.

Following the guidance within BS 4142 for assessment of the likelihood of complaints due to a noise source, the noise from the wind farm should be compared with the pre-existing background noise level.

Assessment of wind farm noise should take into account the change in noise emitted by a wind turbine and the change in background noise level that occurs with wind speed. The change in background noise level will be related to the shelter that is afforded by the local topography surrounding a dwelling, the level of ambient noise that is not associated with wind effects, i.e. traffic, streams, etc., and the direction from which the wind is blowing. Any noise survey undertaken to assess the background noise level at a proposed wind farm should try and include an assessment of these effects.

BACKGROUND NOISE SURVEY

To assess the noise impact at a neighbouring dwelling requires that background noise data is collected for different wind speeds. Wind direction can be important for dwellings that are positioned within hollows or deep valleys and which are sheltered from the wind. Dwellings that are sheltered when down wind of a wind farm are likely to experience their greatest noise impact for this wind condition. Therefore, these dwellings are important when assessing the noise environment near a wind farm.
Measurement of the background noise level should follow the guidance contained within BS 4142 with respect to equipment type and traceability. The measurement location selected for the assessment should reflect the usage of the dwelling and its environs. A dwelling with a patio facing

towards a wind farm is an indication that the location is used for quiet relaxation during the day.

To determine the background noise level at different wind speeds will require that noise measurements are made over an extended period, normally more than a single day, to allow sufficient data to be collected that covers most wind conditions. Simultaneously to the noise measurements, wind speed measurements should be made on-site. On-site wind speed measurements allow later prediction of the background noise levels for known operating wind conditions.

Wind speed measurements are normally undertaken as part of the site selection process by a wind farm developer. Site selection requires that the resource of the wind farm is estimated from wind speed measurements. The anemometers used for the assessment are normally between 10 and 40 metres in height. When assessing the effects of the wind farm it is important to ensure that the height at which the wind speed measurements have been performed is clearly indicated. Any future agreements with local Planning Authorities are likely to be based upon an allowable noise level for a set wind condition. The height at which the wind speed measurements are made can play an important part as to whether a wind farm meets these requirements.

Measurements of wind speed are normally undertaken over ten minute or hourly periods. To assess the change of background noise level with wind speed, background noise measurements should be undertaken using the same measurement period. The preferred time period is ten minutes as the wind can change significantly during an hour in both strength and direction.

The period of time that the noise survey is undertaken is dependent upon the weather conditions that are experienced during the survey. Surveys undertaken by The Hayes McKenzie Partnership normally require a minimum of one week of measurements at a location. During this time the wind will normally reach 12 to 14 m/s at the site. This wind speed is significant as the turbines are normally operating at rated power. It is also relatively rare for the wind speed to exceed this unless in a high wind speed location.

Figure 1 details the noise measurements for a dwelling close to a wind farm that experiences some sheltering from the wind. The Figure details all the collected data irrespective of time of the day or wind direction. The dwelling is positioned in a hollow to the east of a proposed wind farm. Trees surround the dwelling. A patio is to the south with a garden bench. Large patio doors lead from the living room onto the patio. The measurement position selected was outside the doors at the location of the garden bench. The facade facing the site had a pitched roof extension with windows at ground floor only. Barns and high trees provided further cover between the site boundary to the west and the dwelling. The

location of the barns, refuse bins, central heating oil storage tank and building materials storage area indicate that this area was not used for relaxation by the occupants.
The data presented in Figure 1 shows a degree of scatter around the derived prevailing background noise level. The standard deviation for the data is calculated as σ = 4.67 dB(A) for a fourth order least square polynomial regression fit. It may be seen that at low wind speeds, < 6 m/s measured at the site anemometer, background noise levels are below 30 dB L_{A90}. As wind speed increases, the background noise level also rises.

SETTING A NOISE LIMIT FOR A WIND FARM

The WGWTN preliminary recommendations provide informative guidance concerning the noise level by which a wind farm may exceed the prevailing background noise level. The WGWTN considered that an appropriate margin above the prevailing background for wind turbine noise was 5 dB(A) as this would "*...offer a reasonable degree of protection to both the internal and external environment without unduly restricting the development of wind energy which itself has other environmental benefits.*" The limit is set as an L_{A90} noise level.
It is assumed within the recommendations that the difference between a wind farm L_{A90} and L_{Aeq} is around 1.5 to 2.5 dB(A). Figure 2 details measured noise levels at a dwelling neighbouring an existing wind farm. The data analysis indicates that this assumption is not unreasonable. Therefore, turbine noise may be above the prevailing background L_{A90} noise level by + 6.5 to 7.5 dB L_{Aeq}. The guidance within BS 4142 indicates that this level of exceedence is of "*marginal significance*" when assessing the likelihood of complaints from a noise source.
It may be seen from Figure 1 that there is scatter around the polynomial regression line. The allowable turbine noise levels may therefore be greater than 5 dB(A) above the prevailing background noise level for some periods. These low background noise periods may lead to wind farm L_{Aeq} noise levels that are 10 dB(A) or higher above the background noise level. BS 4142 would indicate that during these conditions "*complaints are likely*". Conversely, there will also be periods when the background noise level is higher thereby masking the turbine noise.
The period of time that this condition may occur may be assessed by a cumulative distribution curve of the residuals for the derived prevailing background noise level. This will indicate the likely period that turbine noise of greater than 10 dB above background will occur. Figure 3 details the distribution of the data around the prevailing background noise level plotted in Figure 1. Figure 3 indicates that for 12% of the measurement period, the background noise will be 5 dB L_{A90} below the derived

prevailing background noise level. All data collected at this position has been analysed.
The dwelling is positioned to the east of the wind farm. Therefore, the maximum noise level from the wind turbines may be expected to occur when the wind is from the west, i.e. the dwelling is down wind of the turbines. Figure 4 details the regression analysis of the background data collected during the night-time period for a westerly wind direction. The scatter is reduced. This is due to the absence of noise sources such as animal activity (bird song, sheep dogs, sheep and other stock) and the reduced activity on farms and local traffic. The standard deviation is σ = 2.63 dB(A).
Figure 5 details the Cumulative Distribution for Figure 4. Figure 5 indicates that background noise levels may be below the prevailing background noise level by 5 dB L_{A90} or more for less than 6 % of the measurements.
The data presented in Figures 1 and 4 have a normal distribution around the derived prevailing background noise level. However, when noise measurements are performed close to a noise source that is independent of wind speed then the distribution may become skewed. Such a noise source may be a stream at the bottom of a valley.
Figures 6 & 7 detail the analysis at a measurement location close to a stream in a deep valley. It may be seen from the data that background noise levels are relatively unaffected by the wind at low speed. The data indicates that background noise levels may be 5 dB L_{A90} or below the prevailing background noise level for less than 1 % of the measurements.
Based upon the above analysis of the background noise data it is possible to predict the likely period of time during which wind farm noise may exceed the background noise level by more than 10 dB(A).

WIND FARM NOISE LIMIT

When negotiating Noise Conditions for a proposed wind farm, it is typical to use the measured background noise levels to set condition levels. The WGWTN Preliminary Recommendations propose that where very low background noise levels occur (< 30 dB L_{A90}) , that a fixed limit be applied that protects the amenity of a majority of average persons. These fixed limits are based upon guidance contained within PPG 24 and WHO Document 12 Noise Criterion [5], OECD Report [6], CEC Report EUR 9851e[7]. Discussion of these limits is contained within the WGWTN Preliminary Recommendations.
Wind farm noise emissions will increase within wind speed. PPG 22 indicates that the greatest noise impact from a wind farm may occur at low wind speeds but provides a warning with respect to deep valley locations. Deep valleys can result in significant sheltering to a dwelling. This will lead to no increase in background noise level with wind speed.

Therefore, the greatest noise impact from a development with sheltered properties may occur at a higher wind speed than cut-in.
The type of wind turbine installed at a site will also affect the wind speed of most critical operation. A two speed or variable speed turbine will have a greater rate of increase in noise level than a turbine with a single rate of rotation. Two speed wind turbines will have a step up wind speed where the will be a stepped increase in the noise emitted by the turbine(s). By prediction of the incident noise from the wind farm, it is possible to determine the wind speed at which the greatest noise impact may occur. This critical wind speed condition should be used when setting a Noise Condition. This will provide monitoring of the maximum noise impact that will occur from the wind farm but also allow collection of data when a good signal-to-noise ration will exist. Figure 8 details the regression line derived for Figure 6 with the permitted noise level plotted with respect to wind speed. For periods when background noise levels are below 30 dB L_{A90} it has been assumed that a fixed level of 38 dB L_{A90} has been agreed with the Local Authority. A wind farm noise level has been plotted. It may be seen that the most sensitive operating period for this example is at low wind speeds. It is recommended, based upon Figure 8, that a noise condition be set for a wind condition between cut-in and 6 m/s at the hub height of the wind turbines.

SUMMARY

This paper provides a method by which the background noise environment may be measured to allow assessment of the noise impact of a proposed wind farm. Guidance is provided concerning the setting of noise limits for adoption within Noise Conditions for a prospective wind farm.

Reference

1 Planning Policy Guidance Note 24 : Planning and Noise
2 Planning Policy Guidance Note 22 : Renewable Energy : Wind Annex
3 BS 4142 : 1990 Method for Rating industrial noise affecting mixed residential and industrial areas
4 Legerton M. , Preliminary Recommendations of the Noise Working Group, Proc. 17th BWEA Conf. 1995
5 WHO Environmental Health Criteria 12 - Noise : 1980
6 OECD Report : Reducing Noise in OECD Countries : 1978
7 CEC Report EUR 5398e : 1975

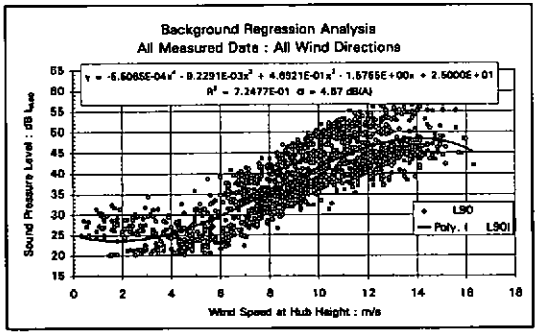

Figure 1 : All Background Data Regression Analysis

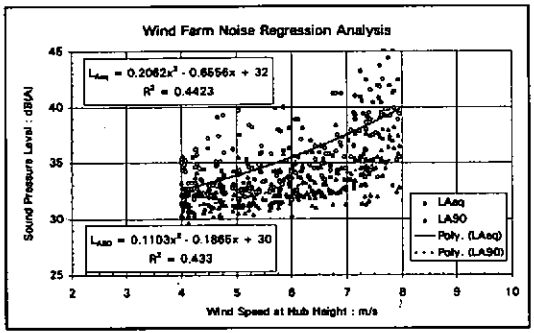

Figure 2 : Wind Farm Noise Levels Comparing L_{A90} and L_{Aeq}

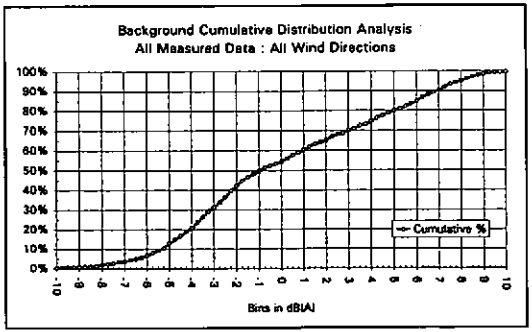

Figure 3 : Cumulative distribution of Figure 1

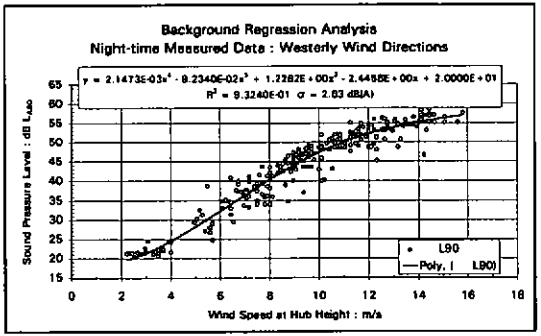

Figure 4 : Westerly Wind Night-time Background Regression Analysis

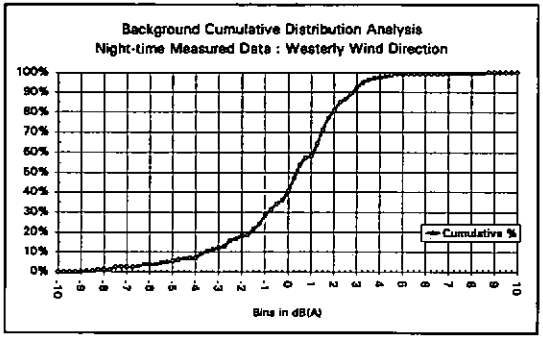

Figure 5 : Cumulative distribution of Figure 4

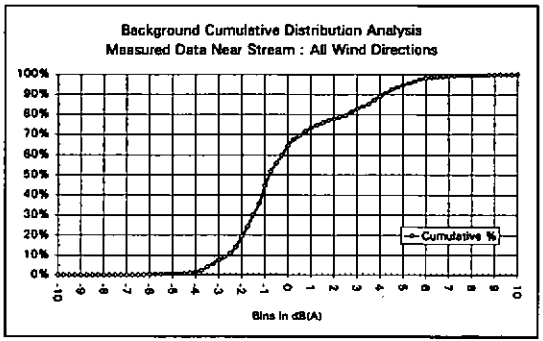

Figure 7 : Cumulative distribution of Figure 6

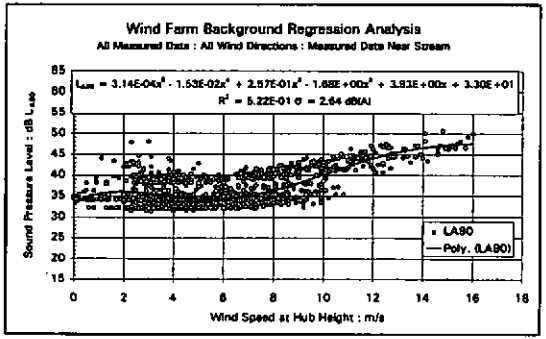

Figure 6 : Deep Valley with Stream Background Regression Analysis

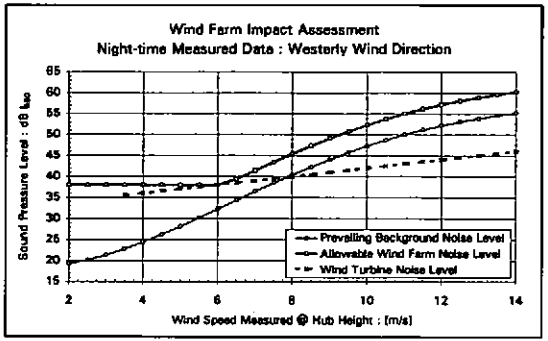

Figure 8 : Assessment of Wind Farm Noise