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Roof-top urban wind turbines in London

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With the Mayor of London's office decision to allow planning permission only if 10% of the building's energy consumption is from renewable sources, wind turbines are starting to be erected on roof-tops of residential blocks. A Proven 6 kW, 6m horizontal axis turbine was positioned on an 11 storey 1960's concrete construction block of flats in the summer of 2007. Noise and vibration measurements were taken on the roof-top and in the nearest flat. In addition, energy performance was monitored, wind speed and direction recorded and weather noted. Results confirm that traffic noise in central London is the dominant sound source. However, no one standard, piece of guidance or regulation can be used to investigate and analyse noise data produced by a roof-top wind turbine.

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Introduction

Planning consent for a roof top wind turbine at Elephant and Castle, Central London was conditional on noise and vibration monitoring over an initial 3 months, starting June 2007. A Proven 6kW wind turbine was installed on Ashenden House, an 11 storey concrete residential building on the Heygate Estate, see Fig 1. Monitoring was undertaken on the roof top and in an unused flat directly beneath the turbine. In addition, wind, weather and electricity produced were recorded. This paper reviews the initial results, taken over summer / winter 2008. For more information [1,2].

Fig1.The Heygate estate,Elephant & Castle, Central London

Fig 2.Proven 6 kW wind turbine on Ashenden House. Note the H-Frame mounting and the four concrete stubs

Fig 3. The roof-top monitoring equipment – noise, weather

Fig 4.Flat directly beneath the turbine -electricity metering

Methodology for Noise Measurements

The noise from the wind turbine was measured at the two worst case positions, one externally and one internally, see Figure 2 and 3. A CEL 593 sound level meter was positioned on the roof at 11m from the turbine, see Figure 2. Another CEL 593 was located in the empty flat directly beneath the turbine, window partially open, see Fig 3. The rooftop meter required an environmental measurement kit. A Nor121 weather station was used to monitor the rooftop conditions. All equipment took continuous 5 minute measurements for 1/3 octaves, L_{Aeq}, average wind velocity and peak wind velocity. Measurements were partially in accordance with BS61400:2003 [3]. Due to the roof-top nature of the installation, it was not possible to measure in accordance to BS 61400:2003, which requires measurements equally around the turbine at a distance equal to the height of the turbine. Hence, it was agreed to take the roof-top measurements at a distance of 11m in the prevailing wind direction, south-westerly. It should also be noted that ETSU 97 was used for part of the noise measurement procedures [4]. Background noise measurements were taken in Feb 2007 by 6 students from the MSc in Environmental and Architectural Acoustics at London South Bank University [1].

Wind Measurements

Wind velocity measurements were monitored for 20 days in July 2007, giving 5300 5 minute events. Cyclic behaviour of average wind speeds was observed, see Figure 5.

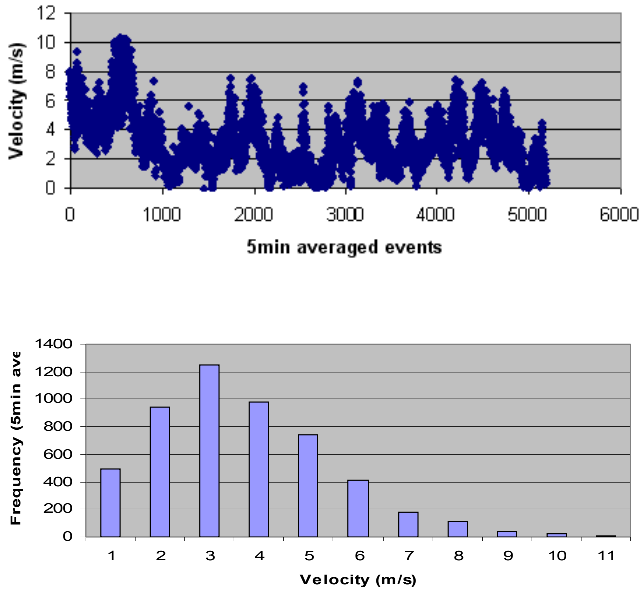

Fig 5. Roof top averaged wind velocities- July 2007

Analysing the data the median wind velocity was found to be 3 m/s. It should be noted that approximately 57% of the wind speeds recorded were 2,3,4 m/s. There is also a long tail of higher wind velocities with a maximum of 11 m/s.

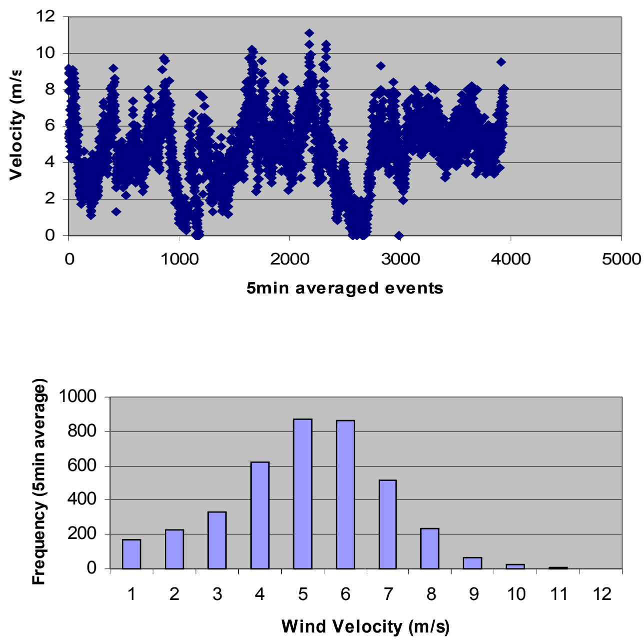

Fig 6. Roof top averaged wind velocities -January 2008

Analysing the data the median wind velocity was found to be 6 m/s in January 2008. It should be noted that approximately 60% of the wind speeds recorded were 4,5,6 m/s with an average of 4.7 m/s.

Electricity Production

The electricity generation was minimal for the first 5 months, 4.8% of the turbine's electrical potential, due to poor wind conditions, see Figure 5. The cut in speed of the turbine was 3.5 m/s. However, over 8 weeks, Dec 07 and Jan 08, the electrical production greatly increased due to increased wind speeds, see Figure 7. Under these conditions the potential efficiency varied between 4-30% and averaged 13.2%. Over 9 months the total electricity produced was 3.5 MWh, equal to an efficiency of 9% or approximately the electricity used y a typical household.

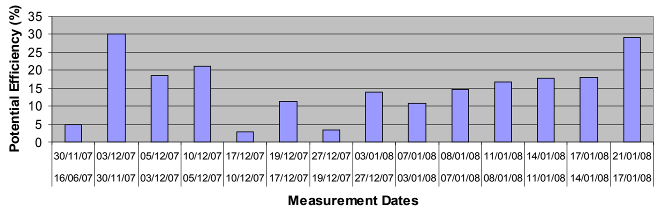

Fig 7.Electricity produced as a percentage of output potential

Noise Level vs Wind Velocity

Wind speeds and noise levels were compared; shown in Figure 8 is a typical result for a 3 day measurement sample, for more information[5]. It can be clearly seen that roof-top noise was uncorrelated with wind speeds. However, if the weekend data is extracted, based on analysis of reduced noise levels as measured inside the flat [1], a positive relationship was found, see Figure 9. Hence, for windy summer weekends the noise produced by the wind turbine may become audible. This relationship was not found during the weekend winter measurements when it was considerably windier, see Figure 10.

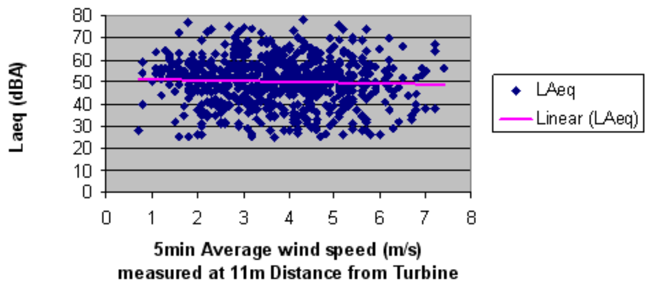

Fig 8. Relationship - wind speed & rooftop noise,August 07

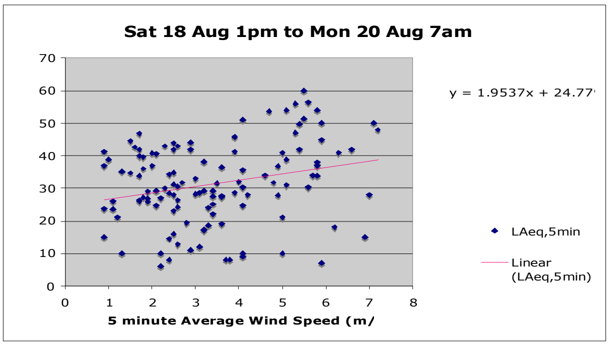

Fig 9. Reanalysed data for weekend noise levels - August

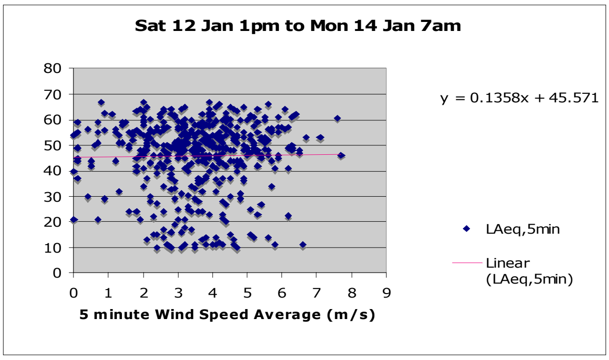

Fig 10. Wind speed & rooftop weekend noise, Jan 08

It should be noted that no tonality was found when 1/3 octave sound level measurements were analysed, for more details see [5].

Vibration Measurements

Vibration was measured inside the flat and on the H-frame of the wind turbine, sees Figure 11 Two vibration systems were used: a Rion VX54 meter with magnetically mounted tri-axial accelerometer for monitoring Vibration Dose Values [6], and a B&K 2143 real time analyser with an accelerometer for collecting 5 minute spot measurements in 1/3 octave bands. The forcing frequency of the turbine was found by taking 1/3 octave measurements on the H-Frame. It can be clearly seen from Figure 12 that 12.5 Hz is dominant. This equates to the 3 blades turning at 250 rev/minutes. For structural vibration, the highest results are shown in Figure 13, these were taken from measurements on 3 orthogonal surfaces in the flat directly beneath the wind turbine during above average wind conditions, 6m/s or more. The vibrations were found to be minimal, so adverse comment are unlikely in terms of RMS accelerations according to BS 6472 [6].

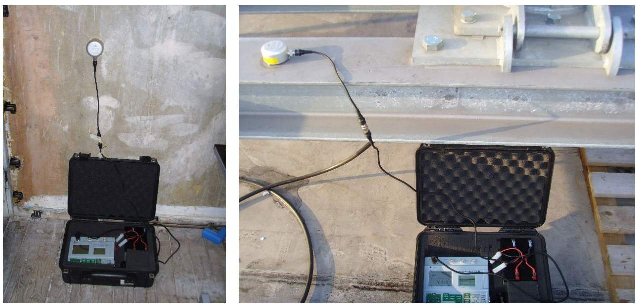

Fig 11 Vibration measurements in the flat & on the turbine

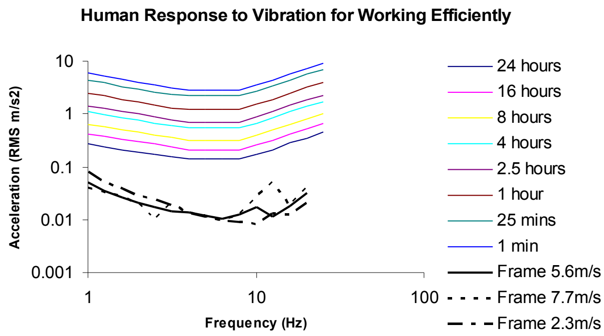

Fig 12 Shows the RMS Acceleration on the turbine (z axis)

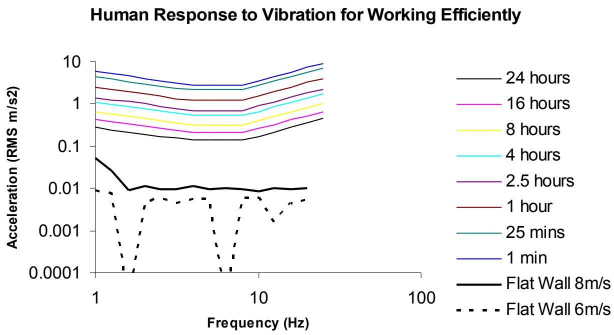

Figure 13 Shows the RMS Acceleration in the flat (z axis)

Alternatively Vibration Dose Value (VDV) can be measured in the flat, where adverse comment is unlikely below a VDV of 0.2 $m/s^{1.75}$. The measurements are given in Figure 14 and show values less than 0.01 $m/s^{1.75}$. A multiplication factor of up to 4 can be used for day time residential use, giving a VDV of less than 0.04 $m/s^{1.75}$. Note, this is in the worst case with high velocity winds and the most susceptible direction over the course of 68 hours, see Figure 15. A strong correlation between wind velocity and vibration dose was found r=0.72.

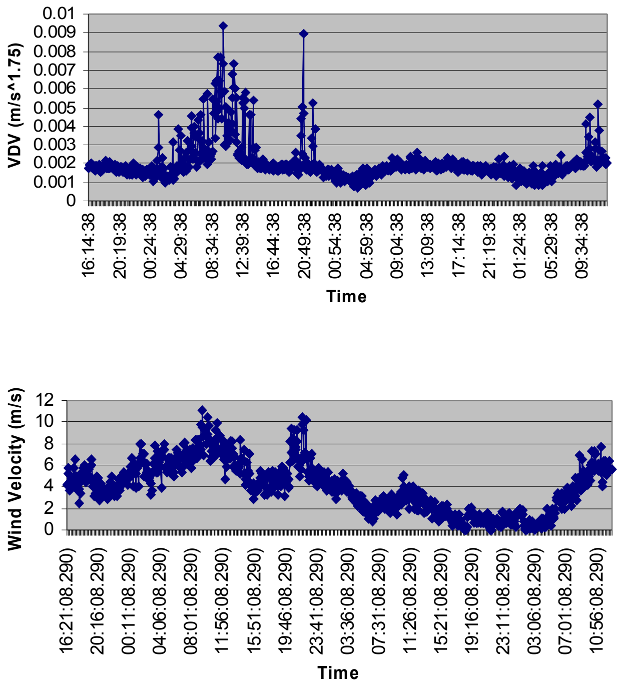

Fig 14.Vertical vibration (VDV) in a dwelling directly below the turbine under windy conditions

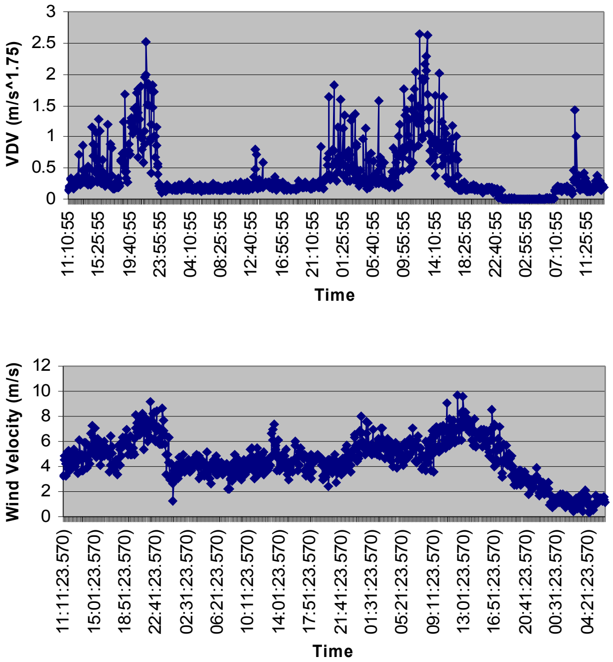

Fig 15. Vertical vibration (VDV) on the turbine frame

Measurements were also taken on the H-frame of the turbine over the course of 68 hours. Much larger vibration doses were found, VDV of up to 2.6 $m/s^{1.75}$ when the wind velocity was 10 m/s. This demonstrates the effectiveness of the vibration isolating pads, see Figure 16. The mass of the structure also helps to attenuate the vibrations to negligible values, see Fig 14. This demonstrated the effectiveness of the neoprene pads, the quality of the installation.

Fig 16. Turbine mounting uses vibration isolating pads

Currently, the Acoustics Group have no measurements for background vibration. However, buildings of similar construction and size have been measured. The results are in line with those reported here when the roof-top wind turbine was operating.

Conclusions

It was found that noise levels in the flat were not affected by the roof-top wind turbine, and hence no complaints from residents have been received over the last 9 months. The cause was the dominate traffic noise from the A2, which runs parallel to the building approximately 20m distant.

There was no correlation between wind speed and noise, as the road is the primary noise source in this location. However, during windy summer weekends it is possible for the turbine to be audible, as the manufacturer claims 45 dBA at 10m for a 5m/s wind velocity, assuming the nearest neighbour have their window open. During the more wind winter months the weekend traffic noise increases and hence the turbine becomes inaudible.

Typically wind speeds were of the order of 2, 3 or 4m/s for 57% of the entire measurement period during the summer, compared to 4, 5 or 6m/s for 60% of the time during the month of January. This resulted in electricity production significantly increasing in winter from around 4.8% efficiency, July-Nov 2007, to 13.2% efficiency, Dec-March 2008. Over the entire 9 months the turbine has been 9% efficient. Typical well sited English wind farms are 25% efficient.

Vibration for the building structure were minimal, an order of magnitude less than allowed for unlikely adverse comment from residents. On the turbine, in the worst case position, for the most sensitive direction the levels recorded were significant, although damped to a negligible level by well specified and installed anti-vibration pads.

Finally, the residents on the estate were friendly and interested in the wind turbine research. No complaints or negative comments were received from the public.

Future Work

This work only presents the initial 9 months of monitoring data. A greater range of wind speeds would be helpful, but can not be guaranteed; so long term monitoring is envisaged to at least 2009. At this point the Proven turbine will be moved to a site owned by London South Bank University.

A new Quiet Revolution roof top wind turbine of similar electrical output will be installed in the summer of 2008. This will be sited approximately 40m from the Proven turbine. Monitoring will continue on Ashenden House until 2010. At some point after this date the building will be demolished and the second turbine moved to an urban site at the University.

Acknowledgements

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