Noise Control of Variable Speed Drive Fans: A Case Study

Adrienne Fowlie Larocque[1] and Hugh Williamson[2]
[1]National Research Council, NRC-ASPM, 1200 Montreal Road, Building M19, Ottawa, ON, Canada, K1A0R6
[2]Hugh Williamson Associates Inc, PO Box 74056, RPO Beechwood, Ottawa, Ontario, K1M 2H9, Canada
Email: hughwilliamson@hwacoustics.ca

1. INTRODUCTION

Variable Speed Drive (VSD) motors allow building exhaust systems to operate more efficiently and, in principle, should lead to less noise due to a general reduction in fan speeds. Therefore, the National Research Council replaced old rooftop fans at one of its facilities, with fans selected for low-noise characteristics and equipped with VSD electric motors (Figure 1). However, as was found on this occasion, VSD can cause high frequency noise to be radiated by the electrical motor drive. This case study documents the effectiveness of the three measures to control this high frequency noise in inverter controller-type VSD electric motors: (1) insertion of acoustic lining into the electric motor enclosure; (2) modifications to the VSD electronic control parameters; and (3) vibration isolation of the electric motor.

2. METHODS

The three noise control measures were implemented for each fan as follows.

1. A one-inch acoustically absorbing lining was fitted inside the electric motor enclosure.
2. Control parameters within the VSD electronic controller were varied as follows: (a) switching frequency was set at 4, 8 or 12 kHz, and (b) the noise smoothing feature (dynamically varying the switching frequency over a small range) was turned on or off.
3. The electric motor was mounted on a new base plate, which was vibration-isolated from the support framework with a neoprene vibration isolation pad.

Noise measurements were made on the roof of the building, at a distance of 5 m, with all three fans operating simultaneously and under identical controller conditions. Two Bruel and Kjaer Type 2250 sound level meters were used; one was set to measure narrow band noise spectra and the other was set to measure 1/3-octave noise spectra.

3. RESULTS AND DISCUSSION

None of the noise control measures dramatically affected the overall noise level of the fans. Rather, treatments differed in how they affected the 4 kHz peak that was caused by the VSD controller (Figure 2).

The fitting of the acoustic absorptive lining was early in the investigation and not well documented. Anecdotal evidence comparing noise from the fans with lined enclosures to those with unlined enclosures, suggests that the differences were small and insignificant.

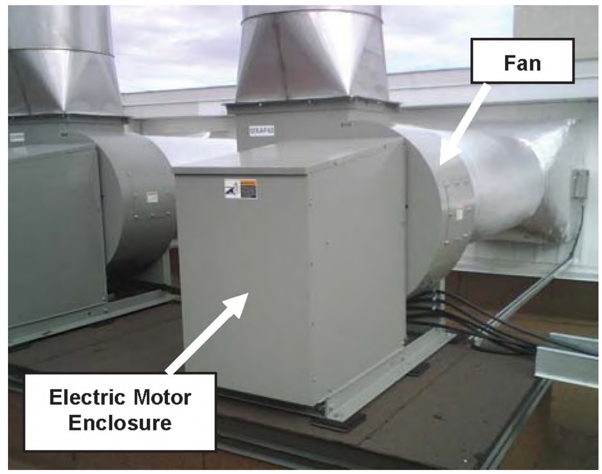

Figure 1: Roof-top exhaust

As shown in Table 1, changing the VSD electronic controller switching frequency (4, 8 or 12 kHz), was also found to have little effect on the sounds pressure level at 4 kHz octave band.

Table 1: Effect of Varying Switching Frequency on A-weighted Sound Pressure Level in the 4000 Hz 1/3-octave band (no vibration isolation, noise smoothing off)

VSD Inverter Controller Switching Frequency	Motor Speed	
	1500 rpm	1800 rpm
4 kHz	56.9	60.8
8 kHz	54.6	60.0
12 kHz	56.0	59.0

However, Table 2 shows that vibration isolation resulted in significant noise reductions at the 4 kHz band. This effect was enhanced by operating the fans with the noise smoothing feature on.

Table 2: Effect of Vibration Isolation and Noise Smoothing on A-weighted Sound Pressure Level in the 4000 Hz 1/3-octave band (Averaged over 4, 8, and 12 kHz. Basic VSD refers to operations with noise smoothing off).

Noise Control Measures	Motor Speed	
	1500 rpm	1800 rpm
Basic VSD	55.8	59.9
VSD with noise smoothing	55.8	57.6
Basic VSD with vibration isolation	49.1	49.7
VSD with noise smoothing and vibration isolation	43.4	44.3

Figures 2 and 3 show that noise smoothing in the inverter controllers distinctly reduced noise in the 4 kHz band.

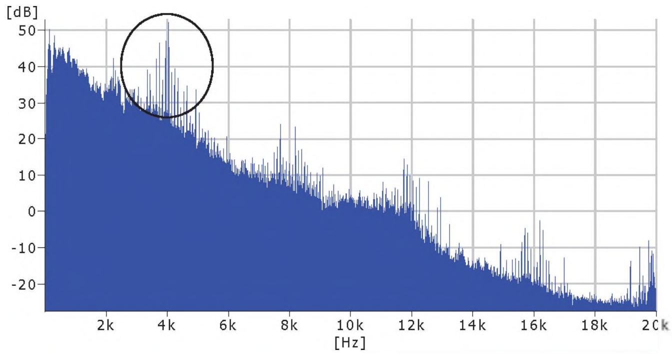

Figure 2: A-weighted Narrow Band Noise Spectrum, Smoothing Off. Note distinct peaks near 4 kHz.

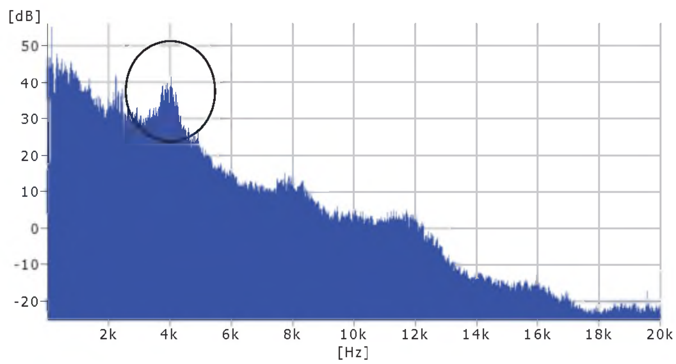

Figure 3: A-weighted Narrow Band Noise Spectrum, Smoothing On. Note broad peaks near 4 kHz

A characteristic of this type of VSD controller is that noise is generated when high frequency components in the electrical power to the motor cause electromagnetic resonances in the stator of the electric motor. These electromagnetic resonances induce vibrations in the stator and motor structure which produce noise. In this particular case, the noise profile generated from the VSD fans had a series of peaks in the noise spectrum at approximately 4 kHz and its higher harmonics (Figure 2). To the human ear, the sound is a high-pitched whine, and can annoy some receptors (On a piano, this frequency corresponds approximately to a high C, four octaves above middle C.).

The high frequency whine was detected when the fans were first installed. The fan enclosures were lined with a 1” thick acoustically absorbing lining, but this was ineffective. In principle, when a noise source is in a vented enclosure, and the enclosure is lined with an acoustically absorbing material, the amount of noise exiting via the enclosure vents should be reduced. However in this case, the motor was rigidly connected to the frame, transferring the vibrations to the enclosure walls. The lining was ineffective because the noise was being radiated by the whole of the enclosure walls and frame. Subsequently treating the motor with vibration isolation significantly reduced the whine noise.

Contrary to the results of previous studies (Gieras *et al*., 2006), changing the switching frequency of the VSD controller did not significantly affect the noise profile (Table 1). Regardless of the treatment, increasing the motor speed from 1500 rpm to 1800 rpm increased the noise peak(s) in the vicinity of 4 kHz.

However, our results were consistent with observations by Gieras *et al*., (2006), who noted that noise smoothing reduces the tonal quality of the high frequency noise from the motor. With noise smoothing off, the distinctive high-pitched whine is audible and can be very annoying to human receptors. This corresponds to the multiple peaks in the narrow band spectrum in the vicinity of 4 kHz (Figure 2). When noise smoothing is on, the whine was significantly reduced (Figure 3). This reduction of the whine noise was essentially the same regardless of the motor speed or the switching frequency.

Furthermore, when the noise smoothing and vibration isolation treatments were combined, the whine noise was very significantly reduced. As seen in Table 2, the sound pressure level (SPL) measured in the 4 kHz 1/3 Octave band was reduced by up to 13 dBA. The noise, and its associated adverse effect on human receptors, virtually disappeared.

4. CONCLUSIONS

Inverter controller-type VSD electric motors can cause a distinct high-pitched whine noise. In this study, the noise corresponded to peaks in the narrow band sound spectrum in the vicinity of 4 kHz.

When both noise smoothing and vibration isolation were applied, the whine noise virtually disappeared. For the three fans studied, the application of noise smoothing in combination with vibration isolation was the most effective noise control measures for the high pitched whine associated with VSD motors.

REFERENCES

Gieras, J.R., Wang, C., Lai, J.C. (2006). *Noise in Polyphase Electric Motors* (Taylor & Francis).

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