High Frequency Noise from Variable Speed Drive Electric Motors.

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Summary

Large electric motors are normally noisier when connected to a frequency converter, also called a variable speed drive. The extra noise is caused by over harmonic frequencies generated by the frequency converter panel. The purpose of the frequency converter panel is to generate an electric sinusodial signal with a different frequency than the incoming frequency from the power grid. The characteristic sound frequency emitted by the motor is dependent of the type and set up of the frequency converter panel. Thyristor equipped panels generate a frequency that is dependent on the number of thyristors included in the panel. The disturbance/fluctuations on the sinusodial signal is being transmitted by the power cables to the electric motor and transmitted as noise from the motor casing. Narrowband analysis show that the noise emitted at the characteristic frequency is up 30 dB above the adjacent frequency bands. The potential overall noise reduction is about 9 dB. The noise from the motor can be reduced by locating filters between the frequency converter panel and the motor. Another mitigating action is to use a different type of frequency converter panel that generates less fluctuations on the generated sinusodial signal. A third option is to apply viscoelastic plates on the motor casing to reduce the noise emitted from the motor. Due to low cost and significant noise reduction the option with viscoelastic plates has been chosen.

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1. Introduction

The processing plant at Nyhamna in the municipality of Aukra on the west coast of Norway is now being upgraded to handle reduced well pressure in the Ormen Lange gas field in Norwegian continental shelf. The processing capacity is also being upgraded to take into account gas supplied to Nyhamna from the new Polarled pipeline.

The project is the biggest brown field project in Northern Europe. Project owner is Norske Shell with Kvaerner as EPCM (Engineering, Procurement Construction Management) contractor. Aker Solutions is the engineering sub-contractor.

Kolbjørn Selvåg hired in from Multiconsult to Aker Solutions has been responsible for the noise engineering for the Kvaerner EPCM contract. Anders Krogvig from Aker Solutions has been part of the engineering noise team.

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Community third party noise and working environment noise has high focus in the project. The outdoor plant noise is dimensioned by the strict community noise levels. The indoor noise levels are dimensioned by the NORSOK (Norwegian shelf requirements) noise limits and project noise limits.

3 new compressors are being installed at the Nyhamna site, 2 Booster compressors and 1 export compressor. Each compressor train consists of an electric driver motor, a gearbox and a compressor. The drivers are VSD (Variable Speed Drive) electric motors. The power to the motors is supplied by LCI (Load Current Inverter) panels. The motors are found to be the dominating noise source and this paper highlights the possible noise mitigation solutions for the two booster compressors.

1.1. Description of Motor and Frequency Converter

The electric drive is a 37.000kW, 4 pole, 2x3 phase motor from ABB with an operating range of 1500-1890 RPM. Normal operating condition is 1800 RPM. The motor is driven by a variable speed drive VSD. The VSD is an LCI type, with a 12 pulse bridge consisting of 12 thyristors that trigger on current thresholds in order to create a DC (Direct Current) signal. The DC signal is in turn converted into the desired frequency, controlling the speed of the motor. The DC signal in the LCI is not perfectly flat, but consists of a sequence of 12 tops that are let through from the incoming current phases. When the thyristors construct the AC (Alternating current) signal from the DC signal, these 12 tops, or pulses, are carried over to the AC signal. The signal from the VSD to the motor is shown in Figure 1.

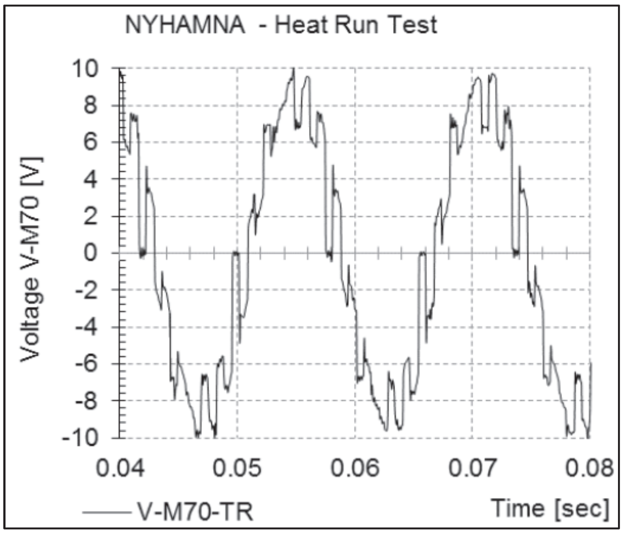

Figure 1. Signal output from LCI to the electric motor at 1890RPM.

2. Pre-measurements

During Back to Back test of the booster compressor motors, simple noise measurements were performed. Two identical motors were used in the test. One motor was used as driver, and one as load. 1/3 octave band measurements were conducted at one of the long sides of the driver for 1761, 1800 and 1890 RPM.

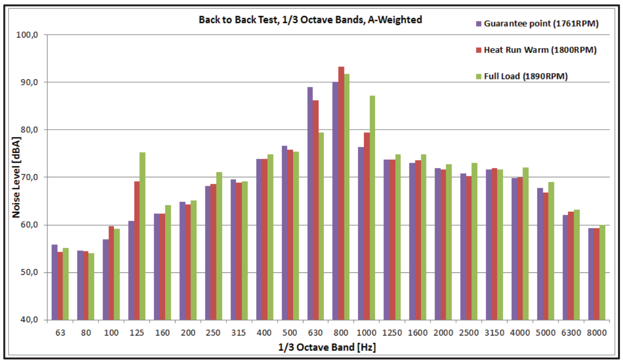

Figure 2. 1/3 Octave band sound pressure levels for 1761, 1800 and 1890 RPM.

3. Measured Sound Power Levels

The compressor supplier (Mitsubishi Heavy Motor Company) has measured the Sound Power Level (SWL given in dBA) for one of the Booster Compressors to be:

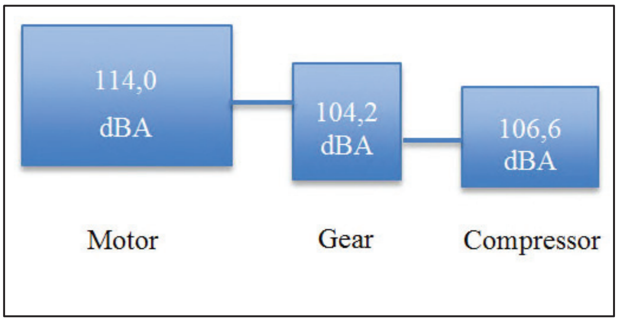

Figure 3. Booster compressor skid block diagram with Measured Sound Power Levels.

4. Noise Measurements Results

In this section noise measurements results from the string test are analyzed as Fast Fourier Transform (FFT) in figure 4, and as 1/3 octave band view (figure 5). The measurements results and possible noise reduction actions are discussed.

4.1. Frequency Analysis of String Test Measurements.

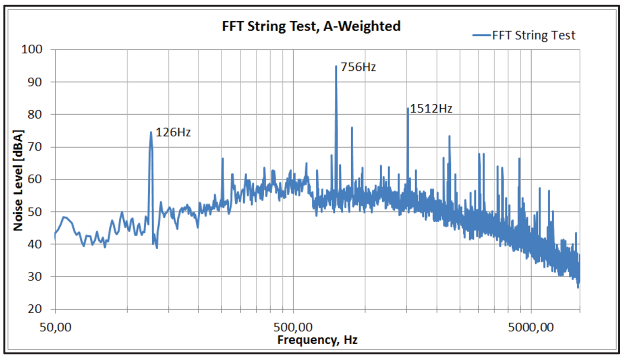

Figure 4. FFT String Test sound pressure levels, A-weighted.

Looking at the FFT in Figure 4, 3 peaks have been identified. The 126Hz peak is identified as a characteristic frequency for a 4 pole motor running at 1890 RPM. The 756Hz and 1512Hz peaks are identified as the fundamental frequency and the first harmonic of the LCI induced frequency. When the motor is running at 1890 RPM, the LCI delivers a frequency of 63Hz.

$$f_{LCI} = \frac{\text{RPM} \times \text{P}}{60}$$

Where f_{LCI} is the frequency delivered to the motor, P is the number of pole pairs and 60 are seconds in a minute.

$$f_{LCI} = \frac{1890 \times 2}{60} = 63Hz$$

The LCI is delivering 63 signal periods per second. Each period has 12 noise pulses created by the LCI 12 pulse bridge. This results in a signal of 756Hz being delivered to the motor and emitted from the motor casing.

$$LCIpeak1 = 63 \times 12 = 756Hz$$

As can be seen in figure 2 (from the pre-measurement) the contribution in the 800Hz and neighbouring bands drops in frequency when the rotational speed of the motor is reduced. The octave band filters are band pass filters that do not have a perfectly vertical transition slope. Frequencies close to the edge of a band may give a contribution to the adjacent frequency band. The peak frequency for 1800 RPM and 1761 RPM are close to the 630Hz band. This may explain the increasing level in this band when reducing the RPM of the motor, hence reducing the frequency output from the LCI.

Table 1. RPM and theoretical LCI induced peak frequency from the motor.

RPM	f_{LCI} *[Hz]*	f_{peak} *[Hz]*	*1/3octave band [Hz]*
1890	63	756	800
1800	60	720	800
1761	58.7	704	630

4.2. Calculation of Theoretical Reduction

If the motor had been powered by a perfect sinusoidal signal, the peaks at 756 and 1512 Hz had not been present. By removing a narrow frequency band around the 756Hz and 1512Hz peaks, a theoretical 9,1dBA reduction of the total noise level would be achieved for the string test case. It means that running the motor without the LCI panel, the noise level from the motor will 9 dB lower. See figure 5 for a 1/3 octave band view of the string test results with the 2 peaks removed. Noise Reduction Possibilities

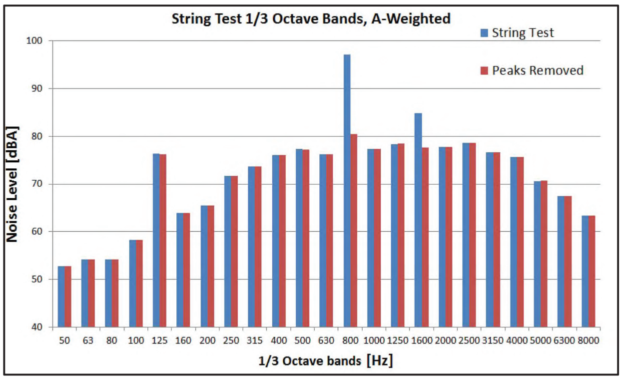

Figure 5. 1/3 Octave Bands, String Test sound pressure levels, A-weighted, with and without the 756Hz and 1512Hz peaks.

In order to achieve the theoretical noise reduction showen in section 4.2 several measures can be applied.

4.2.1. Filter

An electrical filter between the LCI and the motor can smooth the sinusoidal signal created by the LCI. With a smooth sinusodial signal, the pulses creating the 756Hz signal to the motor will be gone, and the peak will not be emitted by the motor casing. However, the filter itself is still exposed to the 756Hz frequency, and may emit the frequency peak instead of the motor. An appropriate filter will definitely be a cost and space driver and is not regarded as cost effective solution.

4.2.2. Different Frequency Converters

A different type of VSD, or an LCI with a different number of pulses may reduce the frequency peak, or move the frequency peak to a more desirable frequency. This topic is covered in detail in the Whitepaper "Audible Noise Reduction", [1] . The conclusion is that this reduces the noise but is costly and may introduce additional heat generation and increased losses.

4.2.3. Noise Reducing Actions on Motor

Removing the source for the emitted noise is normally the preferred way of noise reduction. The options with an extra filter unit or a modified VSD drive are costly and not without negative side effects. The possibility of reducing the noise from the motor casing has been evaluated.
The noise is emitted from the plane surfaces of the motor as shown in the figure 6. The findings during the final test of the unit strongly indicate that the noise emitted from each surface is very different. The noise emitted from the right hand side of the lower part of the motor is dominating.

The side surface of the motor circled on figure 6 represent 5 % of the surface of the motor, but represent 44 % of the noise emission. It has been predicted that a noise reduction of 8 dB for this part of the motor will result in a total noise reduction of 2 dB for the motor in total. 2 dB is not a large noise reduction, but the cost related with installation is very low. Hence, in a cost – benefit perspective it is a very good solution.

4.2.4. Viscoelastic Plates of Parts of Equipment

The noise emitted from the motor casing is caused by vibration in the motor casing surface. A good way to reduce the emitted noise is to reduce the vibration in the plates.
It is predicted that mounting of a 1mm viscoelastic layer, with a constraining layer of steel on top, will reduce the noise emitted from this part of the motor by 8dB for the critical frequencies. The constraining layer of steel should be 1/4 to 1/3 of the thickness of the casing plate in order to give the optimal noise reduction effect.

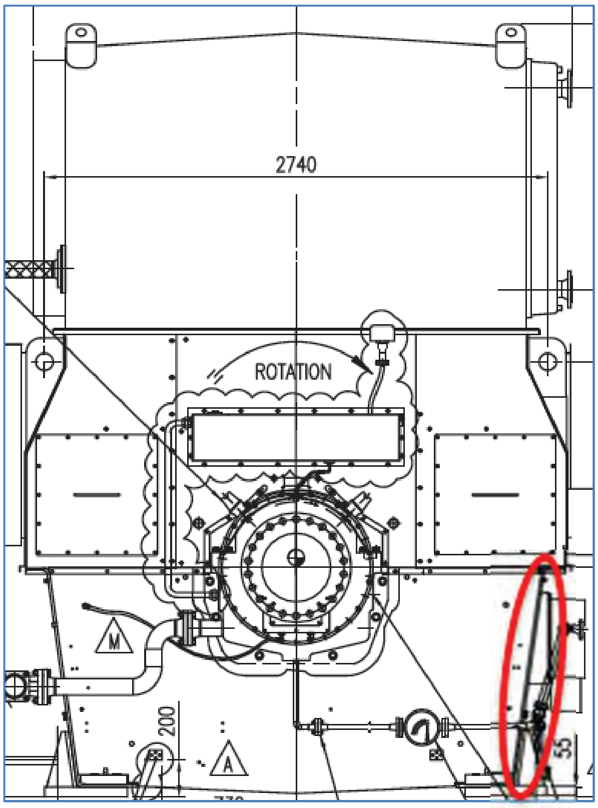

Figure 6. Drive end of motor showing area of high noise emission

4.2.5. Recommended Solution

Based on the consideration carried out the solution with viscoelastic plates of parts of equipment is the preferred solution. The solution is at the moment not yet implemented so the actual effect has not been measured.

4.3. Further Work

Hopefully noise measurements will be carried out at site during normal operation conditions to quantify the noise reduction effect.

Acknowledgement

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References

[1] Danfoss Whitepaper 1/11, 2011