The Influence of Supply Options of an Asynchronous Electric Motor on Emitted Noise

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Abstract

A comparison of the noise emitted by an asynchronous electric motor for various supply options has been presented in this paper. The star connection, one phase connection (with a run capacitor) and the use of an inverter have been taken under consideration. The test results show the effect of supply options of the electric motor on the sound power level, the shape of the noise spectra and directivity changes of the sound emitted by the tested asynchronous electric motor.

Keywords: asynchronous electric motor, noise, motor connection

1. Introduction

Asynchronous electric motors (AEM) are main components of drive units in most of (over 90%) machinery and devices [1, 2]. It results from simplicity of design and relatively low cost of ASE. According to EU directive in force nb 2006/42/WE [3] a machine must be designed and constructed in such a way that the risk resulting from its noise emissions is reduced to the lowest possible level. This has to be done taking into account technical progress and the availability of means of the noise level limitation.

Besides the other machine components electric motors can in many cases be a source of noise in machinery, hence motors' noise should be taken into account. The level of sound emitted by electric motors may depend on many factors such as its structure or technical condition resulting from various types of faults and damage [4, 5]. In addition to the noise propagating from the motor via air, transmission of vibrations to a structure, that can become a secondary (derivative) source of noise [6, 7], may also be important. Vibration isolation systems are used in order to limit those phenomena. It guarantees the minimization of dynamic impacts of the motor and as a consequence the noise. Such solutions are mainly used in household appliances such as washing machines and refrigerators [8] but also in other many industrial applications.

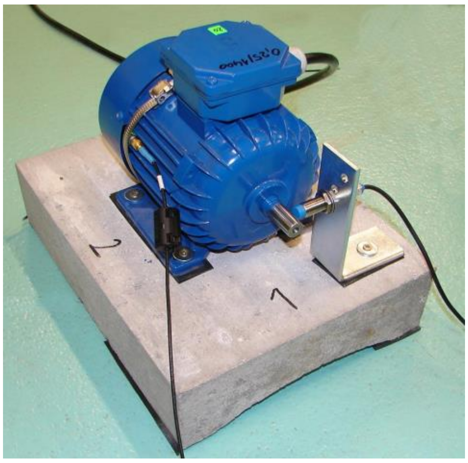
The noise emitted by the motor results mainly from occurring inside it mechanical and electromagnetic phenomena [2, 9]. The last one may be influenced by the way the motor is connected or by its power supply option [10]. The aim of the tests done within this work was to determine how the noise emitted by AEM depends on the option of its power supply.

The noise measurements were made for the following motor power supply options:

- classical star connection of a three-phase motor – normally used in most cases, if there is a need for continuous duty (duty cycle *D* 100%),
- power supply of a three-phase motor from a single-phase mains with a run capacitor – also used in the case of continuous duty; although this solution does not allow to achieve the nominal parameters of the motor operation, an additional unwanted effect is the heating of the motor,
- power supply through the inverter – used whenever the regulation of rotation speed is necessary.

2. The tested object and its power supply options

A view of the tested asynchronous electric motor as well as its basic data and parameters have been shown in the Figure 1. Figure 2 shows connection diagrams of 3-phase asynchronous induction motor for mentioned above options: star connections, one phase connection (with capacitor) and for the case when an inventor was used.



Type	Sh 71-4A
Rated power	0,25 kW
Supply voltage (Δ / Y)	230 / 400 V
Rotation speed	1380 rpm
Efficiency	66 %
Duty type	Continuous running duty (S1)
Width	112 mm
Length	223 mm
Height	182 mm (280 mm - with concrete base)

Figure 1. A view of the tested asynchronous electric motor and its technical specification

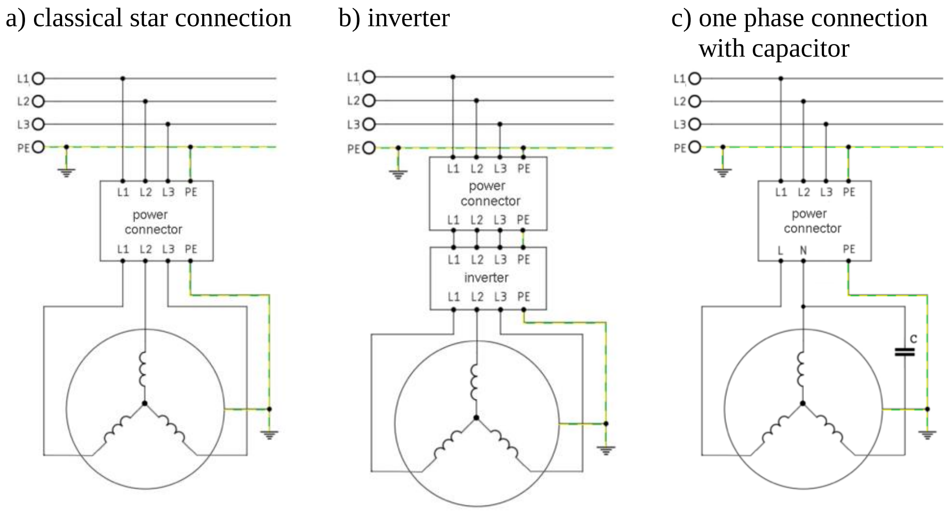


Figure 2. Power supply options of the tested AEM

3. Experimental

The experiments were performed in a laboratory meeting standard requirements for survey method [11] of sound power level determination. The distance *d* between measuring points (microphone position) and the reference box was equal to 0.25 m (see figure 3). The area of the measurement surface *S* was approx. equal to 1,5 m^2. The coefficient K_{2A} [11] was equal to 0.46 dB. It accounts for the influence of undesired sound reflections from testing room boundaries and/or reflecting objects near the sound source. The background noise level in the laboratory in each case was at least 10 dB lower than the noise level of the tested AEM measured on the measurement surface. Therefore the correction for background noise was not necessary.

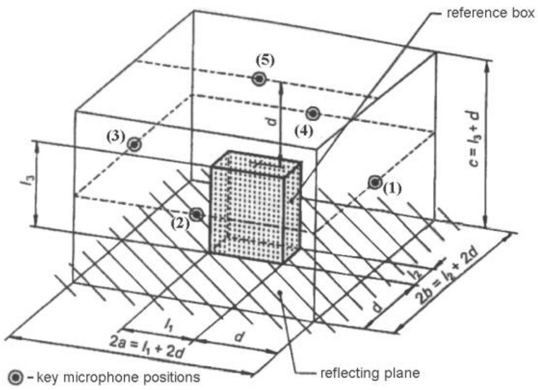


Figure 3. Key microphone positions according to ISO 3746:2011 [11]

The sound emitted by the working AEM was recorded by the measuring system that includes: polarized free-field microphone Roga RG-50, the data acquisition module Vib DAQ 4+ (24-bit) and workstation with DASY Lab software in which DSP dedicated application was elaborated[1]. This approach guarantied linear signal processing in full acoustic band in the frequency range from 20 Hz to 20 kHz. The DSP procedures allowed us to determine in the first stage octave and narrowband spectra. In the next step, the noise parameters like: linear sound pressure level averaged on the measurement surface $\overline{L_p}$, A-weighted sound averaged on the measurement surface $\overline{\mathrm{L_{pA}}}$, sound power level L_{WA} were obtained as a result of post-processing of characteristics mentioned above. The set of measurements results was also a base for determination of changes in sound directivity caused by the change of the motor supply options.

4. Results

All the tests were done at idle speed of the motor (without load). Figures 4-6 show octave spectra of the noise emitted by the ASE for three supply options. Generally, regardless of the supply option, sound pressure levels in octave bands up to 2 kHz had similar values. When comparing the motor noise spectra for star connection and single-phase connection, it can be noticed that in the 20 Hz - 20 kHz frequency band they do not differ much. In the case of one-phase connection only in the 500 Hz octave band the sound pressure level is higher by approx. 2 dB. Sound pressure levels (in linear terms) in octave bands 31.5 Hz, 63 Hz and 125 Hz are relatively high. However, due to the poor perception of low frequency noise by humans this is not important.

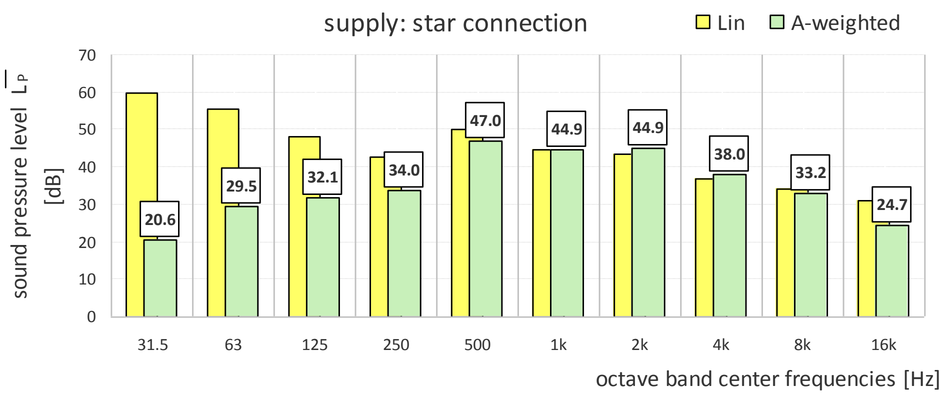


Figure 4. Octave spectra of the AEM noise obtained for star connection

[1] Calibration of the measurement system was carried out before and after measurements using the acoustic calibrator type KA-10, L_p = 94 dB for 1 kHz.

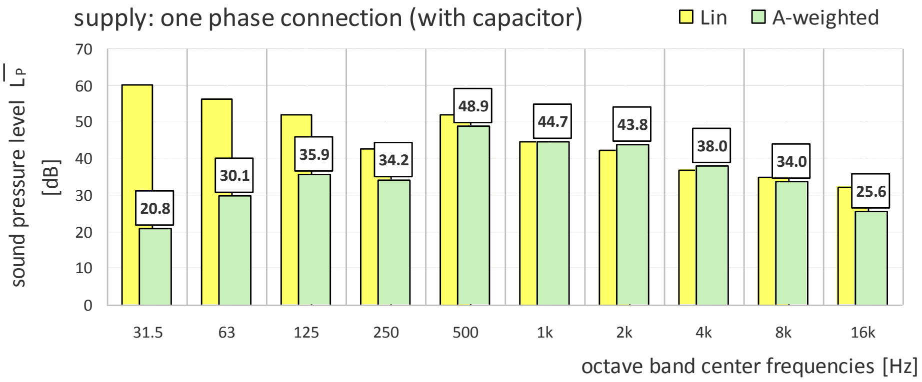


Figure 5. Octave spectra of the AEM noise obtained for one phase connection with the run capacitor

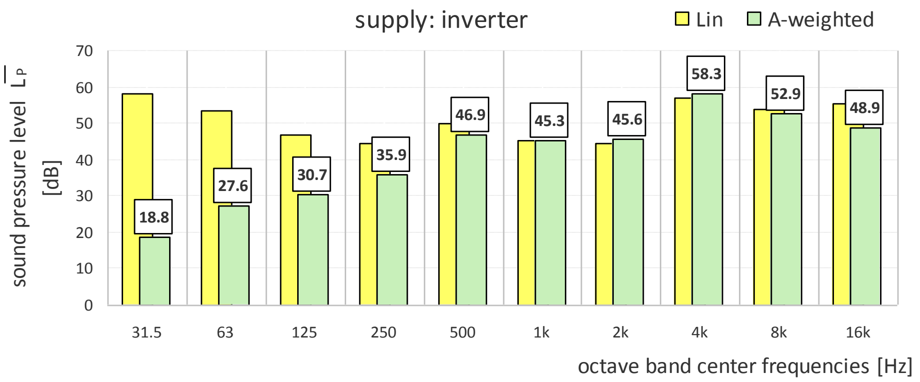


Figure 6. Octave spectra of the AEM noise obtained while using the inverter

The octave bands that are important due to the specificity of human perception of the noise are evident after correction of the spectra (A-weighting). The comparison presented in Figure 7 (containing A-weighted spectra) shows which octave bands for considered AEM supply options are the most important in the aspect of subjective noise perception. The comparison shows that the use of an inverter causes a significant increase of the AEM noise in octave bands 4, 8 and 16 kHz. It is worth mentioning that 4 kHz octave band where the highest level has been noted approximately corresponds to the range of the highest sensitivity of the human hearing. Thus, particularly this noise can be annoying.

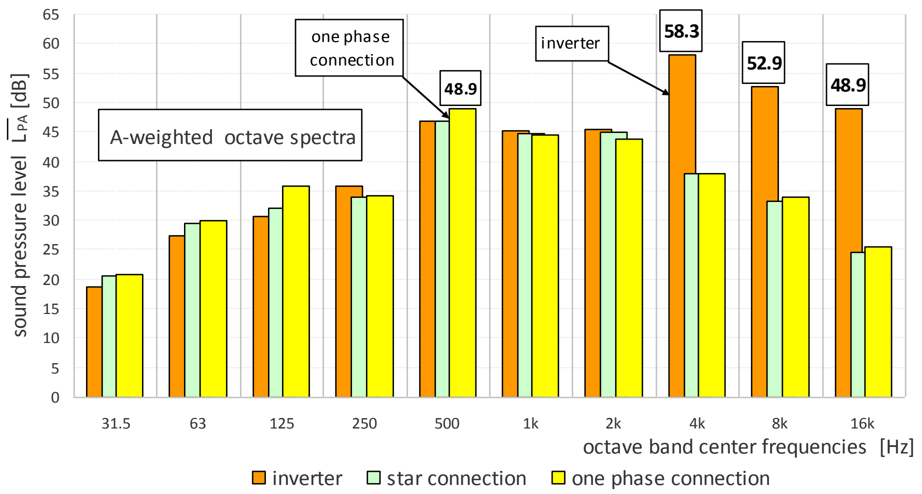


Figure 7. A comparison of A-weighted octave spectra of AEM noise
for various supply options

On the basis of the simplified analysis of the directivity of noise emitted by the engine, it can be stated that the engine emits the least noise towards the shaft (1) (see Fig. 8 a). The noise level emitted from the sides of the motor (perpendicular to the rotor axis) is 2 - 3 dB higher. In Figure 8 b, this asymmetry is better visible. The results were presented here in terms of acoustic pressure and additionally the normalization to maximum values was applied.

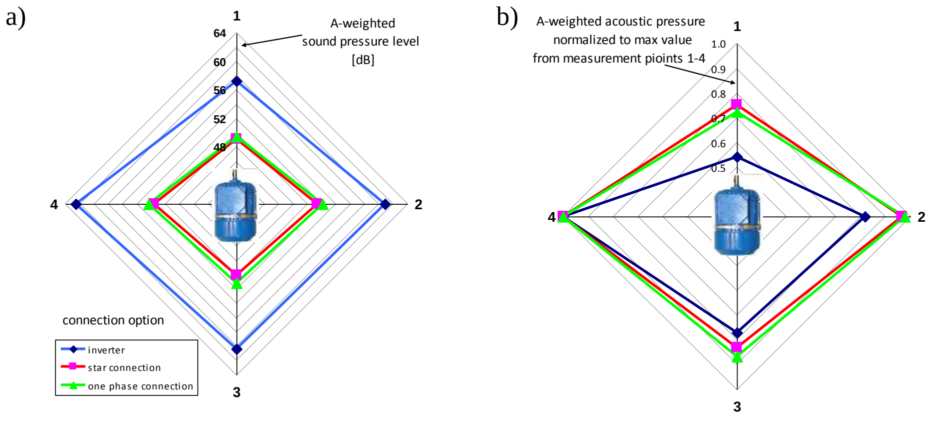


Figure 8. Simplified directivity analysis of noise emitted by AEM
(measurements at a distance d = 0.25 m)

Analysing the narrowband spectrum shown in the Figure 10, we can see that the 4 kHz octave band contains the dominant tonal component with a frequency of about 4.5 kHz and numerous side bands. Such components were not observed in the narrowband spectrum of AEM noise in the case of a star and one-phase connection (compare Fig. 10 and Fig. 11). The comparison of the sound power level (Fig. 9) shows that the use of an inverter causes an increase in L_{WA} of about 9 dB compared to the other two supply options.

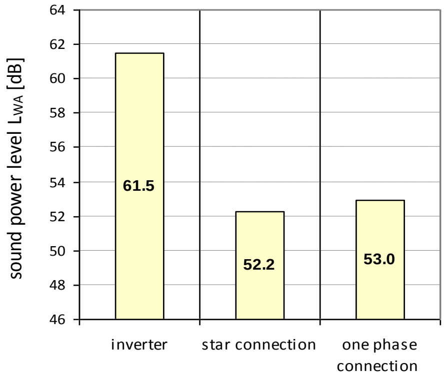


Figure 9. The sound power level L_{WA} of AEM for its various supply options

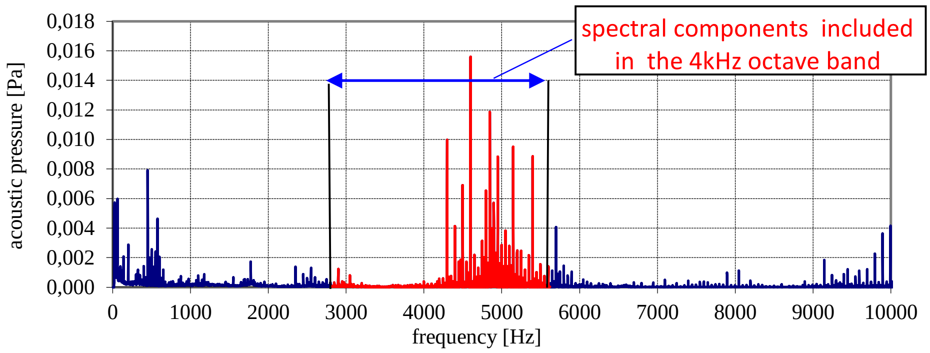


Figure 10. The narrowband spectrum of the noise of the tested AEM for a star connection with inverter

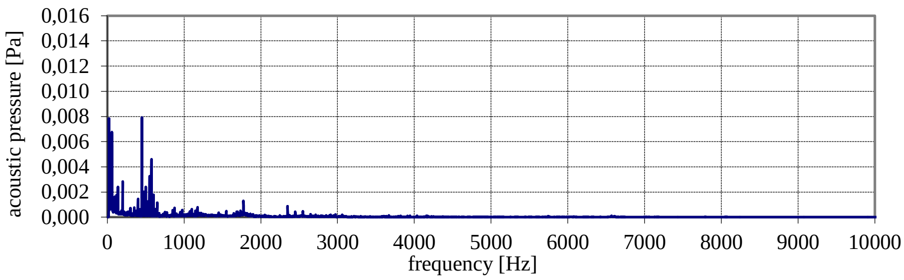


Figure 11. The narrowband spectrum of the noise of the tested AEM for the classical star connection

5. Conclusions

The use of an inverter in the AEM power supply circuit can significantly contribute to the noise level increase generated by the motor. In the presented case, compared to alternative supply options (classical star connection and one-phase connection), use of the inverter resulted in an increase in the L_{WA} by approx. 9 dB. A significant increase in the sound pressure level was noticed in octave bands 4 kHz, 8 kHz and 16 kHz. The sound pressure level reaches its highest value in the 4 kHz octave band. This band partially coincides with the frequency range (2-5 kHz) in which the human hearing is the most sensitive. The conducted tests show that using an inverter in an AEM power system may cause the electric motor to be a significant source of noise in machines or devices.

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