Technical Guide No. 105

AC Drive Motors
-- influence of drive on acoustical noise

ABB

Technical Guide:

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1.0 Introduction

Drive Contribution to Acoustical Noise

The output voltage waveform of an adjustable frequency drive is not a sine wave but a series of square wave voltage pulses that result in a reasonable approximation of a sine wave current. Although there is an extensive history of successful use of standard motors on this waveform, the possible effects of the waveform should be carefully considered. One effect is the generation of acoustical noise in addition to the noise ordinarily produced by an AC motor. This technical guide explains this phenomenon and gives recommendations on minimizing noise when using ABB adjustable frequency drives.

Using This Guide

This guide has been designed to provide an understanding of the characteristics of adjustable frequency drives as related to acoustical noise produced by the motors used with them. The background discussion leads to recommendations for selecting and applying drives and motors to limit motor noise to an acceptable level.

Readers wanting to gain an understanding of AC drives and their influence on motor noise should start at Section 2.0 (page 2).

For recommendations on selecting, specifying and applying motors and drives, please go straight to Section 4.0 (page 4).

The material is summarized in Section 5.0 (page 6).

2.0 PWM Adjustable Frequency Drives

ABB adjustable frequency drives and most other AC drives that are available today are Pulse Width Modulated (*PWM*) drives. Figure 1 illustrates the basic principles of PWM drives. The rectifier converts input line power, which has a nominally fixed voltage and frequency, to fixed voltage dc power. A filter then reduces the ripple voltage resulting from the rectification of the ac line. The inverter changes the fixed voltage dc power to ac output power of an adjustable voltage and frequency.

The output waveform consists of a series of rectangular voltage pulses with a fixed height and adjustable width. Adjusting the overall pattern of positive vs. negative pulses establishes the output frequency. The width of the individual pulses is varied so that the effective voltage is regulated in proportion to the frequency. Proper motor performance requires an essentially constant ratio of output voltage to output frequency (*volts per hertz* or *V/Hz*).

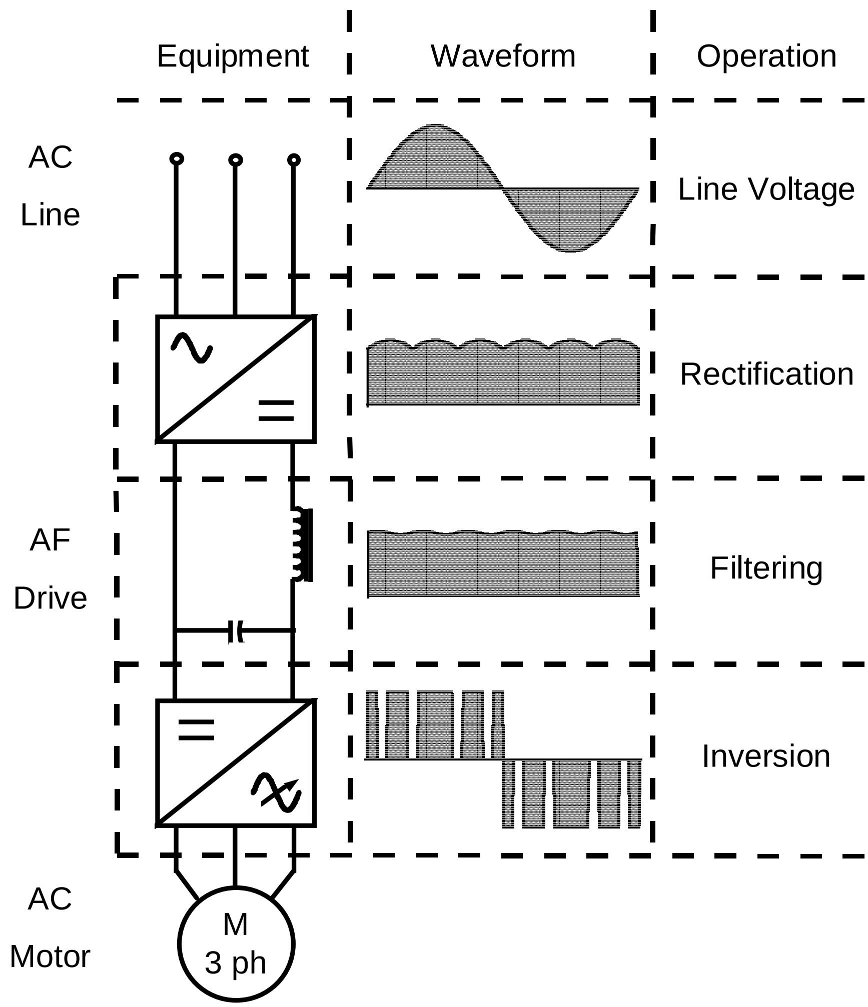

Figure 1 Principles of Operation for ABB Adjustable Frequency Drives

The characteristics and effects of adjustable frequency waveforms are often analyzed using Fourier analysis. The basic principle of Fourier analysis is that any periodic waveform is equivalent to the sum of an infinite series of variable amplitude sine waves with frequencies which are integral multiples of the fundamental frequency. These sine wave component parts are called *harmonics*.

One cycle of the output waveform at a given output voltage can be made from many narrow pulses or fewer wider pulses. To generate a waveform containing more pulses, the switching devices in the inverter must switch more often. The rate at which the switches operate is called the *switching frequency* or *carrier frequency*.

3.0 Acoustical Noise Produced By Motors

Regardless of power source, all AC motors produce a significant level of acoustical noise during normal operation. The predominant sound is the sound produced by the air that is forced through the motor or over its surface to cool the motor. In addition, noise results from the small amount of vibration caused by the normal electromagnetic and mechanical forces inside the motor.

The harmonic voltages that are present in the PWM waveform produce harmonic currents in the stator of the motor. The magnetic fields produced by the harmonic currents can cause vibrations in the mechanical structure of the motor stator. This effect is more significant if the frequency of the harmonic currents corresponds to the mechanical resonant frequency of some part of the motor. The most noticeable effect of these vibrations is the resulting sound, which has a pitch equivalent to the harmonic frequency.

The primary concern is the effect of noise on the comfort and safety of personnel. If the sound level in a work area is near the upper limit for personnel safety, the effect of adjustable frequency power on a motor might push the sound level over the limit, but this is not a common problem. A more common problem is the disturbance of a relatively quiet office area by a minor change in background noise due to the sound produced by an adjustable frequency driven motor.

There may be some concern that the motor may be damaged by the vibrations producing the sound. This should not be a concern. These vibrations occur at frequencies where only a tiny vibration amplitude can produce a noticeable sound. There have been a few reports of mechanical damage to winding insulation due to vibration of winding coils that were not well secured, but such problems have been very rare.

4.0 Recommendations

If, when operating on 60 Hz sine wave power, the acoustical noise produced by the motor is at least 3 dB below the maximum acceptable level, some combination of the following measures will usually limit the noise to the acceptable level when the motor is connected to an ABB adjustable frequency drive. These measures are presented in order of usual preference.

Every motor reacts differently with respect to acoustical noise produced by a particular waveform. Two motors of the same design and rating from the same manufacturer have been known to produce significantly different noise levels under identical operating conditions due to subtle variations in motor manufacturing. Therefore, it is not possible to accurately predict noise level for any given motor.

Use good quality, high efficiency motors

Motors that are well designed and constructed are generally less susceptible to the effects of PWM waveforms. High efficiency motors are designed to operate at a lower magnetic flux density, resulting in quieter operation.

Operate at reduced V/Hz

Reduced V/Hz operation can be employed in variable torque applications. These are applications where the required torque is proportional to the square of speed such as centrifugal pumps, fans or centrifugal compressors. By reducing the V/Hz at lower speeds where less torque is required, the motor is allowed to run at a reduced magnetic flux density resulting in quieter operation.

Operate at the optimum switching frequency

There are three ways in which adjusting the switching frequency may reduce the level of sound produced by the motor.

1. If the switching frequency or some harmonic of the switching frequency corresponds to a mechanical resonant frequency of the motor, it may be possible to reduce the noise level by raising or lowering the switching frequency to avoid the resonant point.
2. As the frequency of sound increases above 2000 Hz, more sound power is required to produce a given level of loudness as sensed by the human ear or by a sound level meter that is calibrated in dBA. Therefore, increasing the switching frequency and thus the sound produced by the motor, may reduce the level of sound perceived.
3. Because the motor is an inductive load, it represents a higher impedance for harmonic voltages at higher frequencies. As a result, harmonic currents are reduced by raising the switching frequency. Reducing harmonic currents usually also reduces the noise level.

Although increasing the switching frequency usually reduces the noise produced by the motor, increasing the switching frequency also has a disadvantage. Every time a switching device switches on or off, power is lost in the process. When the switching frequency is increased, the switching devices are switched more often causing an increase in power losses. Increased power losses mean increased operating temperature and reduced efficiency.

> **Caution:** Before increasing the switching frequency above the factory setting, consult the instruction manual and check with ABB to insure that, based on the ambient temperature and output currents present, safe operating limits will not be exceeded.

To minimize operating frequency and maximize efficiency, it is best to set the switching frequency at the lowest setting at which the sound level is acceptable. This optimal switching frequency adjustment must be performed under actual service conditions for each individual motor. Note: Some models may not have a switching frequency adjustment.

Use The Critical Frequency Avoidance Adjustment

If the motor produces unacceptable noise only at a few specific operating speeds, the “Critical Frequency Avoidance” adjustments can possibly be set to prevent the drive from operating at specific speeds where problems are observed. In many applications, the drive can be “locked out” of a few narrow bands of the operating speed range without significantly limiting the overall process performance.

5.0 Summary

This technical guide has described the influence of adjustable frequency operation on the sound produced by AC motors and recommended measures to limit the noise to an acceptable level. Following are some important points to remember:

- Regardless of power source, all AC motors produce a significant level of acoustical noise during normal operation.
- The harmonic content of the PWM drive output waveform causes additional noise at a pitch that is related to the harmonic frequency.
- In some installations, a motor may produce an objectionable level or frequency of noise when operating on PWM drive power.
- It is not possible to accurately predict the total noise level for any given motor.
- It is usually possible to limit the noise to an acceptable level by applying one or more of the following measures:
  - Use a good quality motor of high efficiency design.
  - Use reduced V/Hz operation in variable torque applications.
  - Operate at the optimum switching frequency.
  - Use the critical frequency avoidance adjustment.

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