Environmental Potentials

Power Quality For The Digital Age

REDUCING MOTOR SHAFT VOLTAGES

A Report by Environmental Potentials' Research & Development Department

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Introduction

Motors are a vital part of the production process. Motors power conveyor systems, compressors and robotics. Most facilities rely on variable frequency drives to control the speed and output of motors. Variable frequency drives generate both current and voltage high frequency noise. This noise takes several paths. It goes both to the load and supply side and noise will also flow from the shaft through the motor bearings. These currents are called bearing currents or shaft currents.

Bearing currents are defined as the currents that flow through the bearings of a motor. The bearing is the part of the motor which connects the load to the rotor shaft. Bearings are not a movable part and are not supposed to carry any current. Design criterion requires the rotor shaft to be light weight and have a large shaft diameter for more torque.

Environmental Potentials' engineering team prepared a motor and tested EP's waveform correction technology ability to reduce bearing currents.

Causes of Bearing Currents

Approximately 41% of the total faults in motor are due to bearing currents.

What causes bearing currents?

1) Asymmetrical machines and its unbalanced current distribution

2) VFDs (Variable Frequency Drive) and ASDs (Adjustable Speed Drive)

Among the two causes of bearing currents, VFD and ASD are the main cause of bearing currents. Most of the motors used today are VFD/ASD driven and this study mainly addresses bearing currents with respect to VFD/ASD.

Even though the study of bearing currents in electric motors began more than 30 years ago, the importance increased after the invention of VFD/ASD. During recent years, an increase in bearing failures has been seen in VFD fed electrical motors, gearboxes, and other connected machinery. These failures are caused by electric current flowing through such bearings. Although all the bearings in a motor will always carry some current, excessive levels of current will lead to the bearing failure and decreased life span of the motor.

Problems with Bearing Currents

1) Frosting/Fluting: The deterioration that appears on bearing race surface. Both Frosting and Fluting creates craters and grooves on the bearing surface.

2) Spark Tracks: A damaging effect on the bearings that leave irregular tracks on the bearing surface.

3) Pitting: A damaging effect similar to frosting but larger in size occurring in gear teeth or on the backs of bearings or seals.

4) Welding: Welding of splits, bearing pads and seals can occur.

5) Overheating of Motor: Increased i2R losses and excess heat on the motor. Overheating of the motor will cause breakdown of dielectric strength of the lubricant used in the bearings resulting in bearing failure

6) Decrease in Life Span of Motor: Extended use of motor under unbalanced current distribution decreases the life of the motor

7) Vibrational Noise: Bearing failures and their deterioration in the motor causes the shaft and motor case to vibrate. This process creates vibrational noise on the motor.

Test Setup:

Figure 1 shows the test setup for measuring bearing currents. The motor is 3ph 480V delta motor with no load connected. A brush is installed at one end of the shaft and wires are connected to this brush. A separate wire is connected to motor casing. An oscilloscope is connected between these two wires (brush wire and ground wire) to measure the shaft voltage.

Figure 1: Test setup to measuring bearing currents. Brush connected at the shaft with green wire out, and black wire out from motor casing.

Figure 1 shows the block diagram of the test setup.

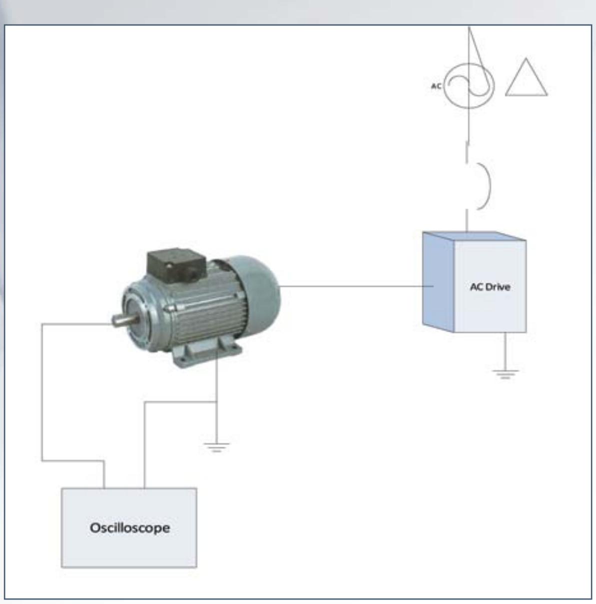
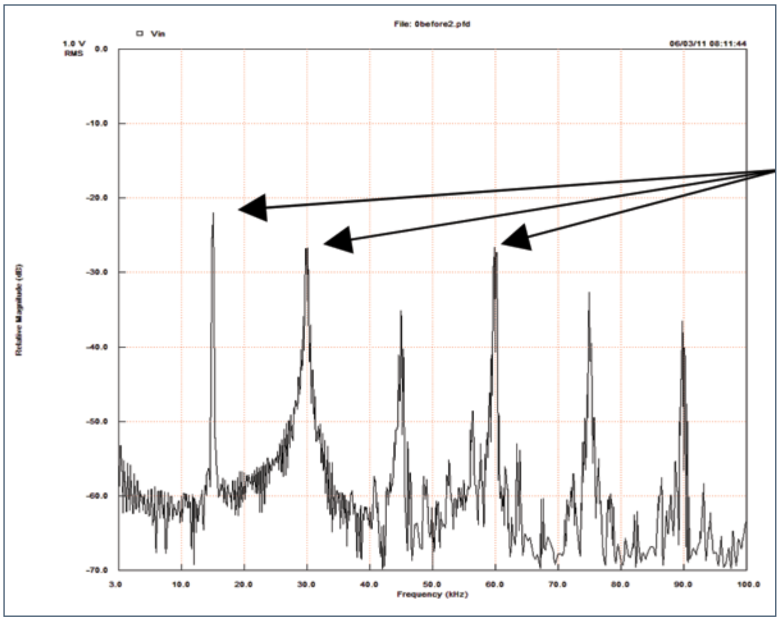


Figure 2: Block diagram of the test setup

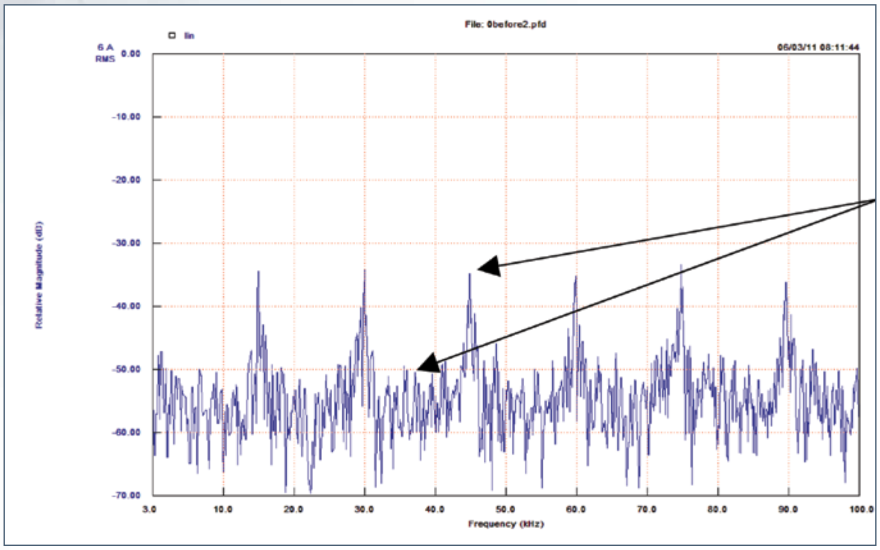
A Power Sight 4000 power quality meter with a high frequency option was used to measure the voltage and current high frequency noise between these two wires. Figure 3 shows the voltage high frequency noise between these two wires.



The bearing voltage high frequency noise reaches approximately -22dB at 15kHz and approximately -27dB at 30kHz and 60kHz.

Figure 3: Voltage high frequency noise between shaft and ground between 3kHz-1MHz

Voltage high frequency noise was peaking at regular intervals. It is approximately -22dB at 15kHz, while reaching -27dB at 30kHz and 60kHz. This is the common mode voltage between the shaft and the ground. Theoretically, there should not be any voltage noise between shaft and ground. However, the VFD powering the motor was creating this common mode voltage noise. This common mode voltage noise generates bearing currents as shown in Figure 4.



The bearing current peaks reach approximately -35dB while the noise is approximately -50dB.

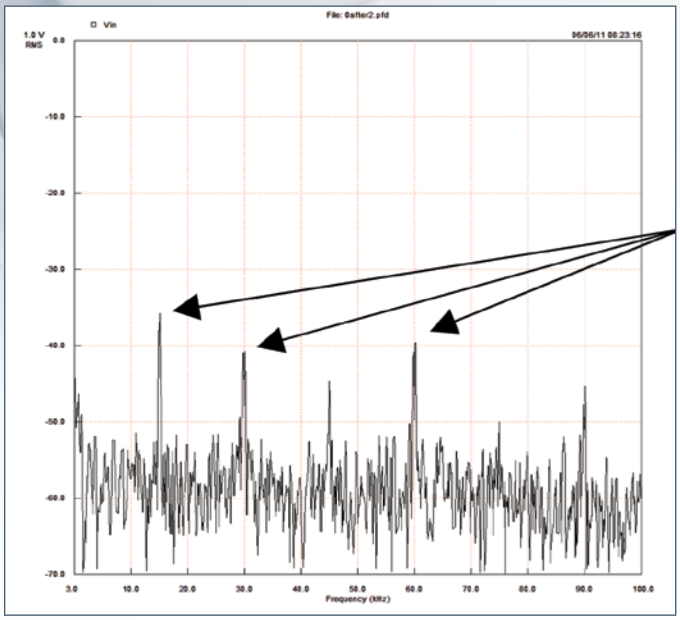
Figure 4: Current high frequency noise in shaft between 3kHz-1MHz

Bearing currents are not at fundamental frequency, but at higher frequencies. Figure 4 shows the bearing current noise for this motor. The noise has peaks of -35dB at frequent intervals. This noise is created by the common mode voltage. This amount of frequency noise is significantly large for common mode noise. This noise can generate bearing currents in the motor shaft.

Readings after Installing EP's Waveform Correctors

An EP-2000 and EP-2750 ground filter were installed at the line side of the VFD. This installation should help reduce common mode voltage generated by the VFD. Removing this common mode voltage will decrease bearing currents. The EP-2000 waveform corrector helps remove both the high peak transient noise and high frequency noise in the system. This waveform corrector will reduce the common mode voltage noise in the motor and noise on phases. The EP-2750 reduces ground currents, high frequency noise on the ground, and also protects the motor from transients entering through the ground. Therefore, the EP-2000 removes noise on the phases, while the EP-2750 helps remove noise on ground.

Figure 5 shows the voltage high frequency noise between the shaft and the ground after installing the EP-2000 waveform corrector and EP-2750.

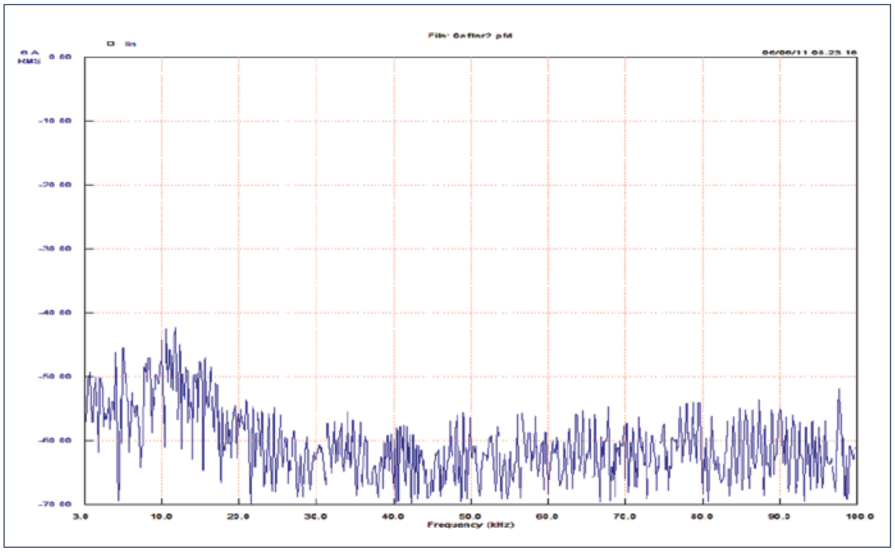


After installing EP the common mode voltage is significantly reduced. The peaks were reduced by approximately -14dB when compared to the readings in figure 3.

Figure 5: Voltage high frequency noise between the shaft and ground of the motor after adding EP's waveform corrector and ground filter.

Figure 5 shows the voltage high frequency noise was significantly reduced after installing EP's waveform correctors. The peaks were reduced to -36dB from -22dB (from figure 3The other peaks were reduced to -40dB from -27dB. This reduction in the voltage high frequency noise indicates EP's waveform correctors are reducing shaft voltage between the shaft and ground of the motor.

Figure 6 measures the current high frequency noise at the motor shaft after adding the EP waveform corrector and ground filter.



After installing EP's waveform correctors, all of the bearing current peaks were removed. The noise was also reduced to less than -55dB.

Figure 6: Current high frequency noise between 3kHz-1MHz on the motor shaft after adding EP's waveform corrector and ground filter.

Compared to the readings in figure 4 all of the current high frequency noise peaks at -35dB were eliminated. The noise is reduced to approximately -57dB. This is a significant amount of reduction in the current high frequency noise. This demonstrates EP's waveform corrector reduced shaft voltage.

Figure 7 shows the signal between motor shaft and ground of the motor using an oscilloscope.

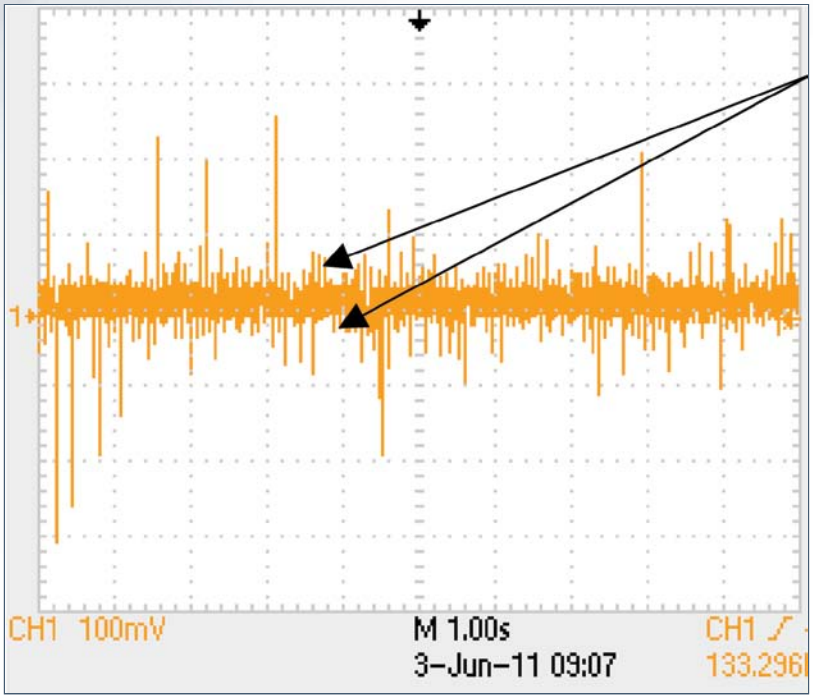


Figure 7 shows significant levels of voltage noise. There are regular peaks and significant hash. The thickness of the hash shown with the arrows is significant enough to cause bearing currents in the motor.

Figure 7:
Oscilloscope reading between shaft and ground before adding the filter

Figure 7 shows the voltage between the ground and the shaft. There is significant levels of noise reaching peaks at -300mV and +260mV, and there is lot of hash on the signal as well. Hash in the signal indicates random noise and this can cause common mode voltage noise and bearing current noise.

After installing the EP unit, Figure 8 is captured with the oscilloscope.

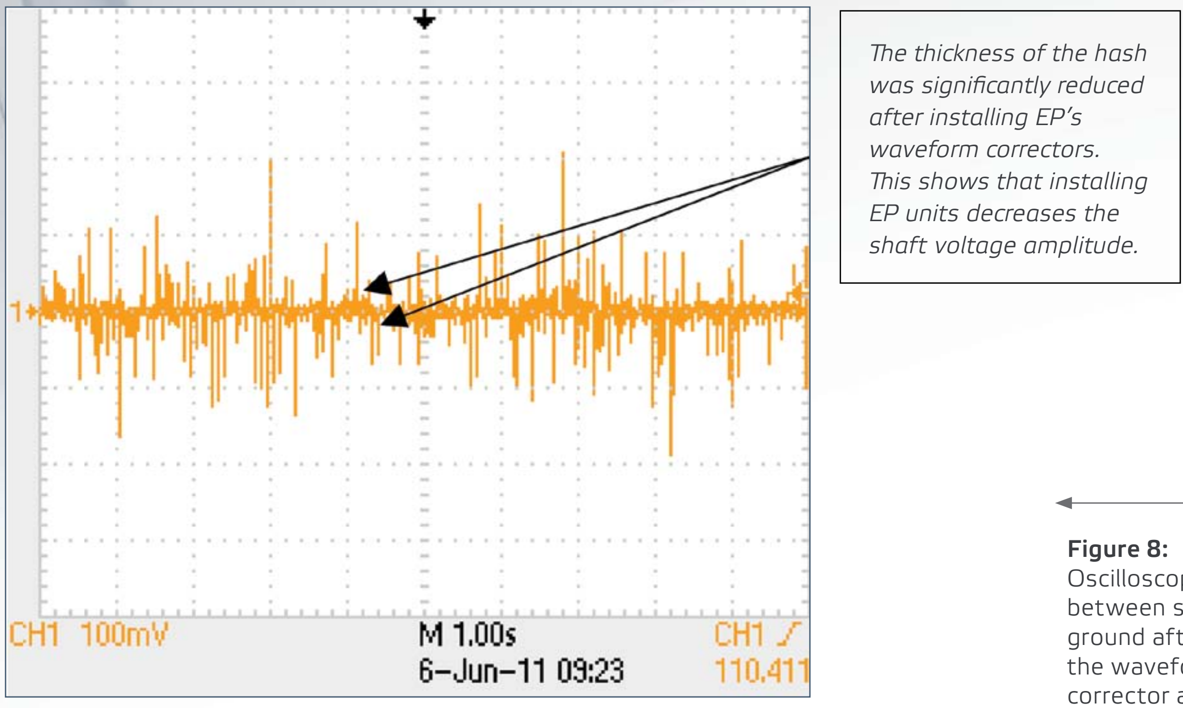


Figure 8: Oscilloscope reading between shaft and ground after adding the waveform corrector and ground filter.

From Figure 8, it is seen that lot of spikes in the voltage are removed. There is no significant amount of hash at the center line, while highest peak only have -180mV and +200mV amplitude. This indicates the EP waveform corrector and ground filter removed a significant amount of shaft voltage and this eliminates bearing currents. Removing high frequency noise from the motor shaft and the system increases the life of bearings and the life of the motor, while decreasing heat, motor maintenance and vibrational noise.

Conclusion

Bearing currents are unwanted currents that flow through motor shaft and bearings. Common mode voltage between motor shaft and grounding generates these unwanted currents. Bearing currents are not at fundamental frequency, but at higher frequencies.

Consistent flow of bearing currents will decrease the life span of the motor and create a need for frequent replacements of the bearings. Approximately 41% of the total faults in a motor are caused by bearing currents. Reducing these bearing currents is critical to increasing the life span of the motor and saving money on maintenance. A typical cost of replacing bearings for 100HP motor is $2000.00.

As mentioned earlier in this document, bearing currents are generated by 1) imbalance in the current distribution and 2) common mode voltage noise by VFD/ASD. Imbalance in the current distribution is generally caused by proximity effect on the wire. EP filters reduce proximity effect by removing high frequency noise in the system. Please read proximity effect white paper for detailed analysis.

EP's waveform correctors are designed to remove high frequency noise from the electrical system, while EP's ground filters are designed to remove ground currents. Successful installation of EP waveform correctors at the line side of the drive will remove common mode voltages generated by the drive. Reducing common mode voltages from the system will reduce the amount of bearing current noise in the motor shaft.

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