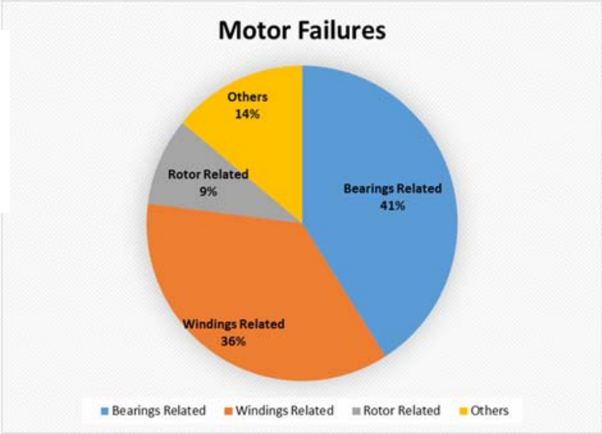
APPLICATION NOTE

Motor Analysis with the MPQ1000

Common Motor Failure Modes

The most common causes of motor failures are bearing failures, winding failures and rotor failures.



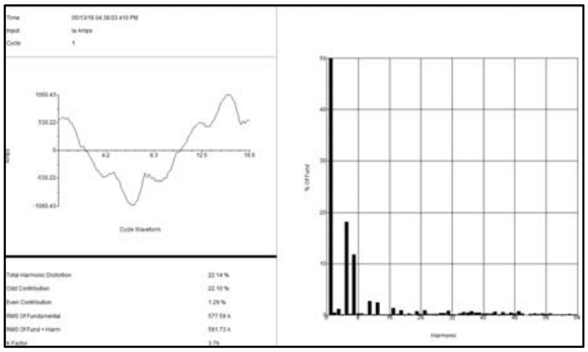
Bearing failures

Bearing failures are often blamed on poor lubrication. However, there are many other causes of bearing failures. Analyzing the failure cause can lead to higher motor reliability.

Mechanical issues such as misalignment, faulty mounting, contamination, or poor sealing can cause bearing failures. Other common causes include vibration and electric current passing through the bearing, causing arcing.

Vibration can be caused by mechanical imbalance, misalignment, faulty bearings or negative sequence harmonics. Negative sequence harmonics have magnetic fields that rotate in the opposite direction of the rotor's magnetic field. The negative sequence components act on the resultant field to produce extra currents. This generates added heat and can cause motor vibration. Six pulse converters commonly cause negative sequence harmonics. These are present in three-phase power supplies that are often used in variable frequency drives (VFDs).

Negative sequence harmonics are commonly caused by 6 pulse converters, which produce a dominate 5^{th} order negative sequence harmonic. These are present in 3 phase power supplies that are often used in variable frequency drives (VFDs)



Megger USA - Valley Forge Corporate Center
2621 Van Buren Avenue, Norristown, Pennsylvania, 19403, USA
T. 1-610 676 8500 F. 1-610-676-8610

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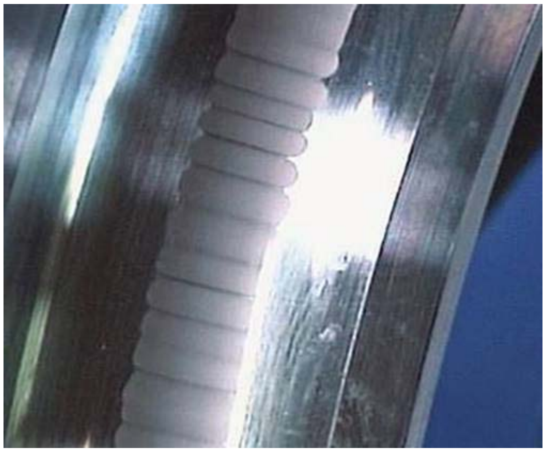
A certain level of negative sequence harmonics is always present in motors as a result of the stator field quantization as well as rectification. It is the presence of the harmonics at higher levels that increases heating effects as well as the likelihood of capacitive coupling resulting in bearing discharge and fluting failures.

Current passing through the bearings
All motors have a certain amount of shaft voltage. Generally, shaft voltage should be less than 0.5 V. When shaft voltage increases, it can lead to arcing between the bearings and the raceway, causing pitting, which will lead to fluting of the bearings. This can create motor vibration as well as audible noise resulting in motor failure.



Example of fluting

When the motor shaft is turning, the bearing grease acts as an insulator. It insulates the bearings from the bearing race and acts as a capacitor. The stator and the rotor generate charge through capacitive coupling. This is electrostatically induced into the motor shaft. This current then passes through the motor shaft to the bearings, creating a discharge between the bearing and the race. This discharge causes bearing pitting.

VFDs convert AC to DC. Then, insulated gate bipolar transistors (IGBTs) are used to convert the DC back to a variable frequency AC control. IGBTs have fast switching times, reducing energy losses. However, these fast switching times create parasitic capacitance between the motor's stator and rotor.

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Winding Failures

Shorted windings can be due to heating effects. High levels of heat will carbonize the insulation which can lead to coil shorts.
Heating can be due to under voltage, unbalance or harmonics. Excessive heating decreases the life of the motor, reduces the viscosity of the bearing grease and can cause windings to short.

Motor heating can occur due to several power quality phenomenon such as:

Under-voltage: Motors are constant power devices. As the voltage goes down the current must go up. Heating is a function of $I^2 \times R$. As current rises, so does the heat by an exponential factor!

Unbalance: Just a one percent unbalance in the phase voltages can lead to a six to ten percent unbalance in phase current. This current unbalance will generate unbalanced heating effects in the coils. This leads to uneven phase heating. Depending on the winding configuration, wye or delta, a phase or two respectively will be heated more than the others. This can lead to a failure of these coils.

Harmonics: Harmonics create eddy currents in wires. The eddy currents create magnetic fields that push the current going through the wire to the outside edge of the wire – this is known as skin effect. This increases heating effects in the wire. In addition to skin effect, coil wires are adjacent to each other. Adjacent wires create magnetic fields that push the current in the adjacent wire to the outer edge of that wire known as proximity effect. This further increases motor heating effects.
The higher the frequency of the harmonic, the greater the heating effects.

Transients: Transients will create high instantaneous differences in voltage potential. This can lead to arcing. Arcing through insulation will carbonize the insulation. This will lead to insulation failure leading to shorted coils.

Arcing across bearings will lead to pitting and fluting as previously discussed.

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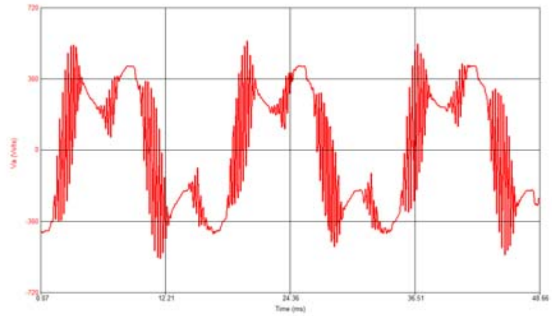
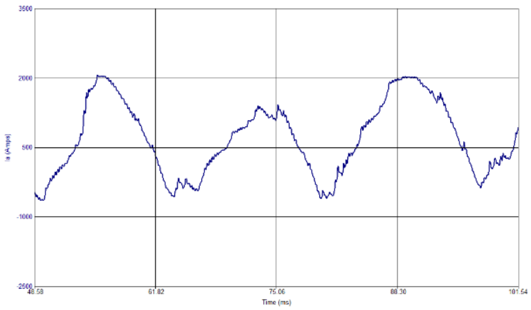
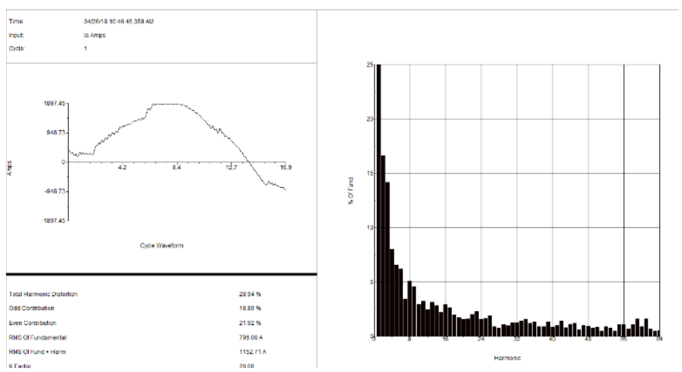
VFDs use high speed switching IGBTs. These produce a great deal of high frequency voltage harmonics.



A filter is used to produce a relatively clean drive current.



However high frequency harmonics still exist.



The high speed switching will also generate transients. These transients can be magnified due to the added capacitance and resulting wave reflection of long cable runs.

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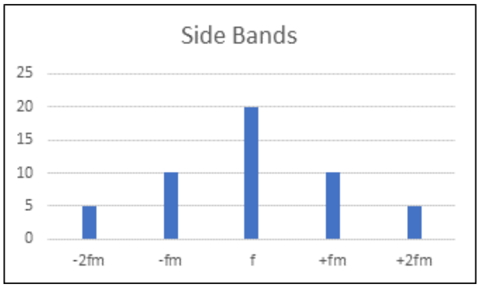
Rotor bar failures

A rotor bar can be partially or completely cracked. This can occur due to manufacturing defects or frequent starts at rated voltage. Additionally, thermal stresses can lead to metal fatigue and cause a rotor bar failure. Mechanical stresses due to vibration can also cause rotor bar failures.

Pole pass frequency sidebands are always present in motors due to design factors such as rib supports, number of bars, mechanical “looseness” and porosity.
An increase in sideband magnitude indicates the potential for broken rotor bars.



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Motor Analysis with the MPQ1000

The MPQ1000 can be connected to a motor while it is still online and record for days, weeks, months or years. It will record the following parameters:

- Voltage
- Current
- Sags / Dips / Under voltages
- Swells / Over voltages
- Sub-cycle waveform distortion
- High Speed Transients
- Voltage and Current Unbalance
- Total Harmonic Distortion (THD)
- Total Demand Distortion (TDD)
- Harmonics
- Inter-Harmonics
- Waveform capture
- Frequency
- Active Power
- Reactive Power
- Apparent Power
- Displacement Power Factor
- True Power Factor

The MPQ1000 will allow you to verify the power supply voltages are correct and well balanced. It will record both voltage and current harmonics, and inter-harmonics. High levels of current harmonics as well as high frequencies cause elevated heating in motors that can lead to a host of failures.

The MPQ1000 will analyze harmonics by sequence factor. This allows you to view the negative sequence harmonics that can lead to motor vibration and additional coil heating. It will record both transients and sub-cycle distortions that can cause bearing pitting and fluting, as well as insulation breakdown which will lead to shorted coils.

The MPQ1000 can perform an FFT analysis to view the current harmonics to identify high side band frequencies, which are a sign of rotor bar damage.

The MPQ1000 will also record all power parameters as well as power factor. A low power factor can cause motors to be unable to obtain full power. This can be caused by long cable runs that are not a sufficient gauge.

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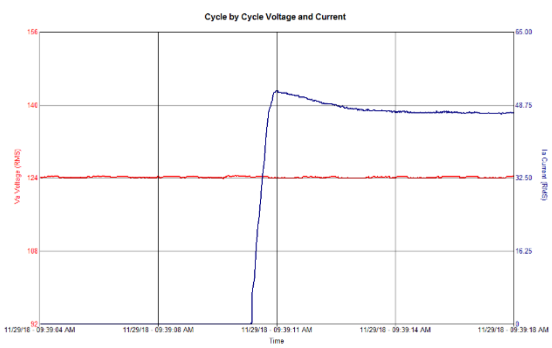
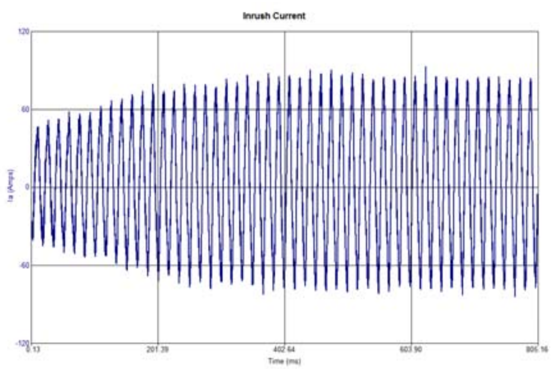
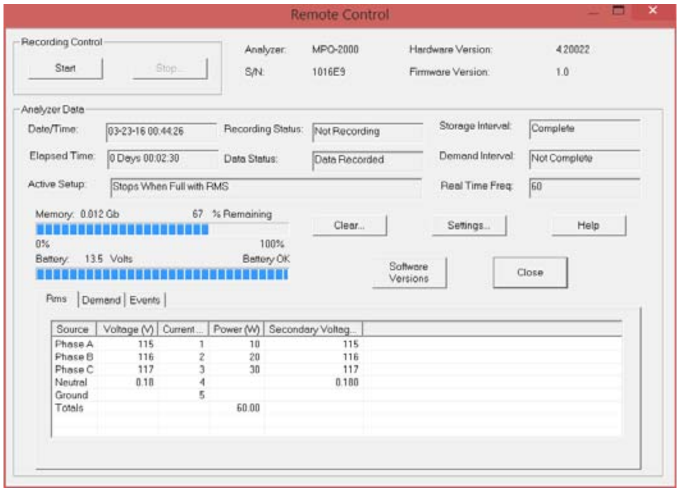
The MPQ1000 can also perform motor start up testing. The analyzer will record all parameters on a cycle-by-cycle basis. When the motor starts up it will capture over 600 cycles on inrush current on all channels. The unit allows you to perform on line motor analysis as well as motor inrush (startup) testing. During startup the “In rush” current can be as high as 13x the full load amp rating of the machine. Additionally the rotor bars are under their highest torque loading of up to 3x full load torque during this start up period. As a result of this high current draw voltage can sag. Excessive sag results in longer start up times and additional winding heat and rotor bar stress. Quantifying the voltage sag can identify power supply stiffness issue that when corrected could improve system efficiency and prolong motor life.

Understanding peak current during a startup can be helpful when identifying issues with protection limits of circuit breakers and other current interrupting devices.





In addition the MPQ1000 can be connected to a network. This allows you to remotely view results, start and stop recording, view real time data, change the analyzer configuration and transfer data remotely. You can also automatically have the data transferred periodically, which is ideal for long evaluations.



The MPQ1000 is a powerful, simple, portable tool for analyzing motors.

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