PREVENTING VFD PRODUCTED SHAFT CURRENT DAMAGE TO ELECTRIC MOTOR BEARINGS

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Many customers with Variable Frequency Drive (VFD) applications have had problems with the service life of their electric motors.

VFD's are here to stay with many benefits for motor driven applications. Processes are more efficient and there can be significant energy savings. Unfortunately, these devices also produce harmful side effects that can destroy the bearing elements in electric motors. This has been a chronic issue for more than a decade. We found the more time spent troubleshooting this phenomena the more variables we encountered. Settings in the VFD like carrier frequency and programs designed to provide quiet or efficient operation have an effect along with the length, size and placement of conductors between the VFD and motor. The type and design of iron used in the motor's magnetic circuitry can also influence the problem.

These are frustrating situations for many because the damage is already done by the time the problem is evident. It is not uncommon for motors in new applications to have problems within months of the initial installation. In such cases much time is spent determining who's at fault and responsible for the removal, motor repair, reinstallation and ultimately the cost. Production time is lost while the motor is in for repair. New replacement motors will need some type of upgrade to the motor and/or circuitry to prevent a re-occurrence.

The degree of the upgrade and subsequent cost to repair a motor in a VFD application is a concern at the shop. The installation of new steel ball bearings and shaft grounding brushes can be fairly inexpensive but might not work. More elaborate shaft grounding devices along with insulated or ceramic ball bearings and machine work get costly fast. Load reactor/filters or shielded power cable installed between the VFD and motor also has a positive effect but add more cost. With so many variables involved we often can't predict the extent of the upgrade needed by looking at the damaged bearing elements.

Until recently troubleshooting motors in service for this problem was tough because there has been no practical way to measure shaft currents. The most common method was to measure the voltage drop between the motor output shaft and frame-ground while the motor was in service. This measurement is the potential voltage reached before the charge arcs through the grease film and bearing elements. A lower voltage reading might mean there are no problems, or it might mean the grease lubricant is contaminated with metal particles resulting in little volt drop.

The good news is 3E has a new product designed to mitigate VFD shaft currents. It is an inductive absorber core that is easily installed on the leads between the VFD and motor. We also purchased test equipment designed to measure the amount of stray currents so we can see the effect the installation of these reactor cores has on a specific application.

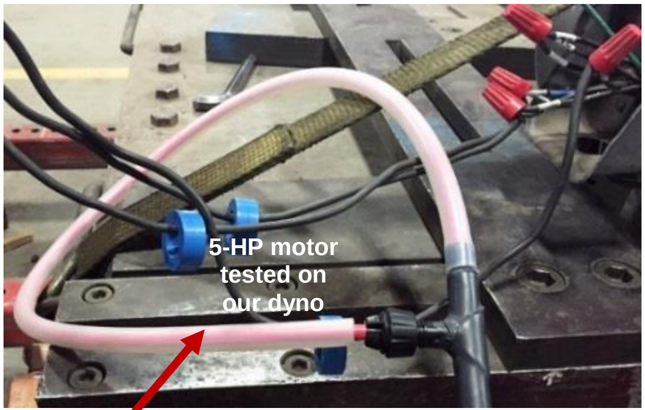
The inductive absorbers are an inductor and common mode choke designed to absorb damaging current before it gets to the motor. The inductive absorber cores are placed in series over the three power conductors between the VFD and motor, and the NaLa® differential mode cores are mounted around each of the three conductors individually. These products have been in use in Europe for some time but are just now available in the USA.

We initially tested this product with a 5 horsepower motor and VFD on our shop dynamometer and the results were impressive. Before reviewing our test results I need to briefly describe my understanding of the basics of this phenomenon:

First it's important to understand how current flows through a load. If you plug an appliance into a typical 120 volt single phase circuit all the current flows through the hot and neutral lines. This is the principal of a ground fault interrupter (GFI) receptacle common in most homes. Internally a GFI has the hot and neutral conductors wired through a current transformer coil designed trip if the amperage of the conductors becomes unbalanced. The GFI is wired so that amperage conducts in opposite directions through the current transformer cancelling the fields. If you throw the hair dryer in the sink current flows through the hot lead but bypasses the neutral by flowing through the plumbing, ground wire, or you. The fields no longer cancel each other and the GFI trips. The same is true with a three-phase motor application on line power (without a VFD). All motor current is conducted back to the adjacent phases so the sum of the amperage draw on all three phases at any point in time is zero. In other words you can measure motor amperage on any one of the three phases, but if you measured the amperage on all three phases simultaneously the amount would be zero.

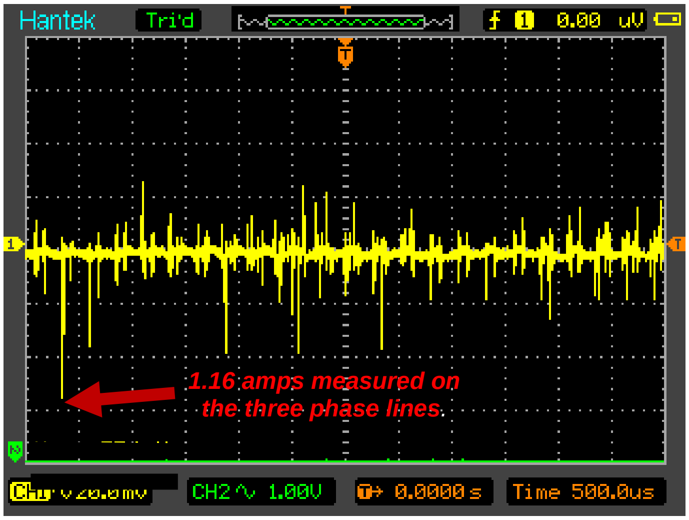
VFD's are a different matter. These devices convert three phase power into direct current, and switch that power with software and transistors to the motor windings allowing the motor to operate at variable speeds. VFD switched power produces strong magnetic fields around the motor windings and lead conductors creating stray capacitive currents within other apparatus in close proximity. These stray currents are loads that can become unbalanced with the random placement of phase and ground wiring in the conduit and other parts such as the "rotor" in the motor. As a result some current does not flow back to adjacent phases but rather back through the ground wiring and other components such as the rotor bearings, motor frame, conduit and steel foundations. The rotor in close proximity to the stator windings seems to get the brunt of the capacitive charges with the only path for discharging currents through the bearing inner races and balls. As capacitive charges build up and discharge through the bearing elements, pitting and scoring of the balls and inner races lead to premature failure of the bearings.

For our shop test we purchased a "Rogowski Coil"- a sensitive current transformer that when used with an oscilloscope can measure the amount of current that is *NOT* flowing back to adjacent 3-phase lines. The coil has a rating of 50 millivolt (mv):1-amp.



Rogowski coil installed around the 3-phase lines to the electric motor to measure the amount of current "not" flowing back to the 3-phase lines

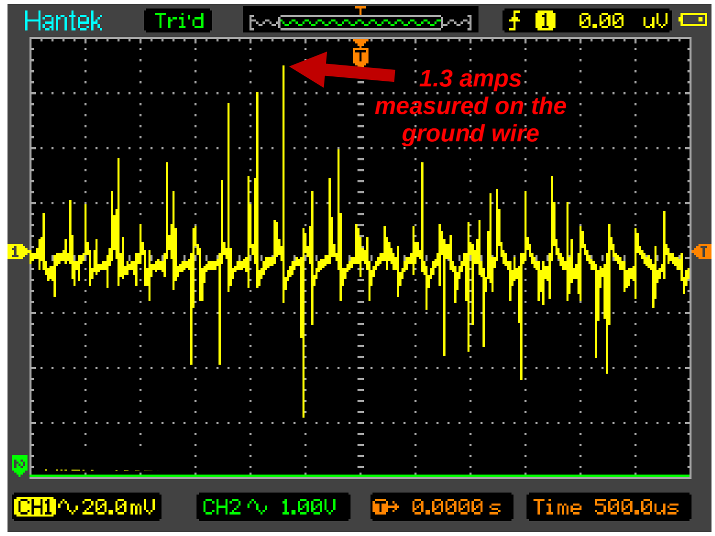
Similar to a GFI current transformer the Rogowski coil is installed around all three phase leads between the VFD to the motor. With this we can measure the amount of common mode current (current not flowing back through the adjacent phases).



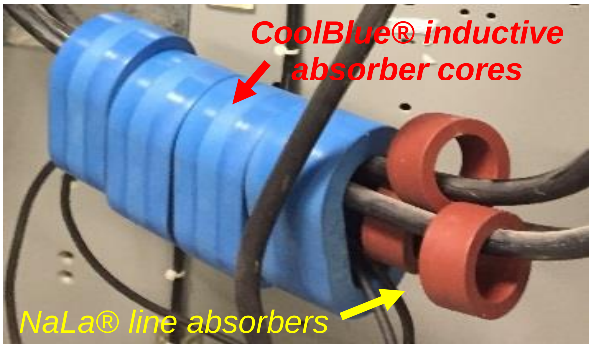
We operated a 5 horsepower motor and VFD on our shop dynamometer and recorded the common mode and stray currents to ground.

At 20 volts/division we measured peak voltage of approximately 58mv on the three phase leads. This converts to 1.16 common mode amps on the phase leads.

We also measured peak voltage of 65mv on the ground wire between the VFD and motor. This converts to 1.3 amps on the ground lead.



The inductive absorber cores were installed in series over the three power conductors between the VFD and motor.

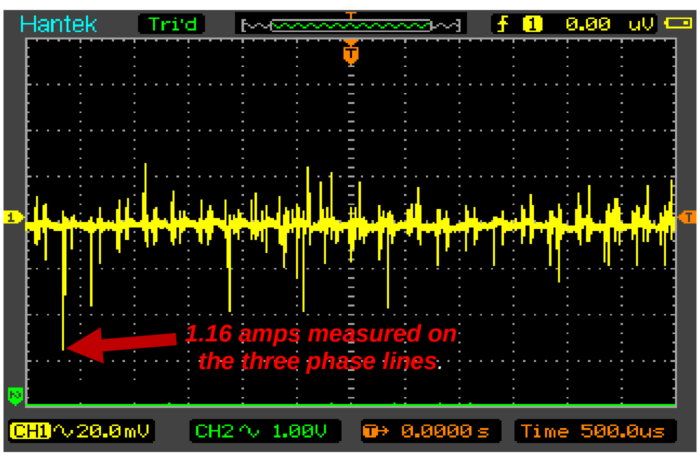


The NaLa® line absorbers were mounted around each of the three conductors individually.

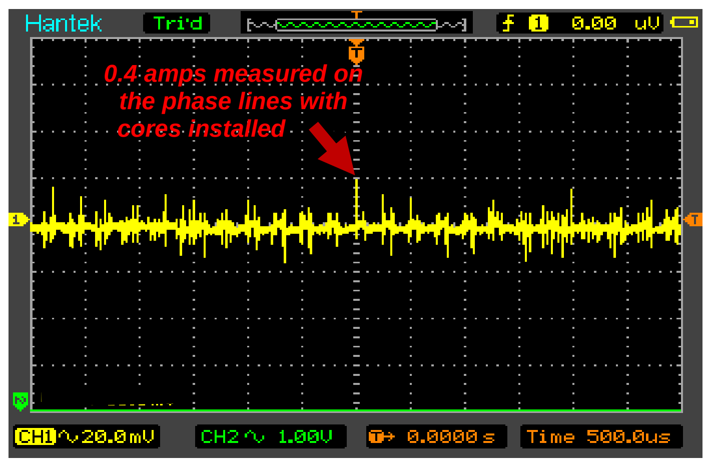
In our test the peak phase amperage was reduced from 1.16 amps to 0.4 amps with the installation of the inductive cores and line absorbers. This is a 65% reduction.

There was also a significant reduction in the returning ground current from 1.3 peak amps to 0.6 amps, a 54% reduction. The reduced ground current confirms the effect the inductive cores and line absorbers have on the phase leads.

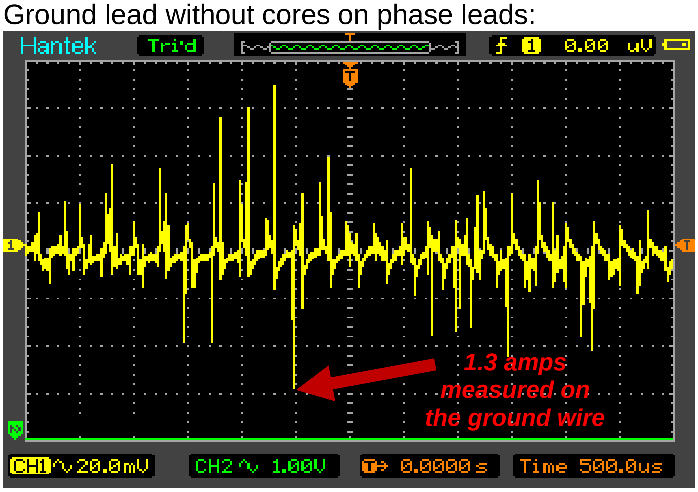
Phase leads without the cores:



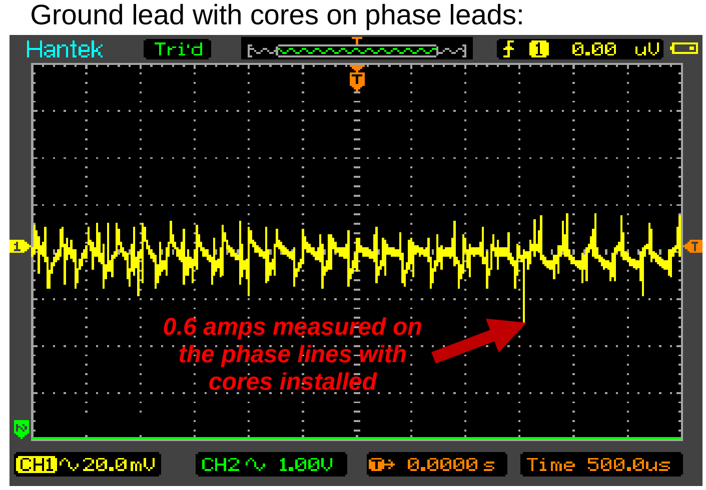
Phase leads with cores installed:



Ground lead without cores on phase leads:



Ground lead with cores on phase leads:



To summarize, current measured on the phase leads is current not being cancelled by the adjacent phases. The missing current is flowing around the phase leads through ground and back to the chassis of the VFD. The ground current measured is essentially what is missing from the phase leads. CoolBlue® cores are designed to balance phase current thus reducing the ground current. It is important to note the path of least resistance for ground current is not always the ground wiring in the conduit or cabling. Ground current can conduct through the machine framework, conduit, plumbing and process materials like in a pump application.

The goal is to get the shaft current potential down to a level that will not damage the bearing elements. For that we have a “go/no go” calculation used to determine a safe amount of current for a specific ball bearing in an electric motor. According to this program the 6205 bearing in our 5HP test motor will have no problem conducting the reduced current at 0.4 amps.

The inductive absorbers are a type of load reactor and a common mode choke. A load reactor slows the VFD pulse rise times and as a result minimizes the diameter of the magnetic fields around the windings and lead conductors. This reduces stray capacitive loads in apparatus that is in close proximity to the windings like the rotor in the motor. The NaLa® differential mode absorbers further diminish the pulse rise time and stray capacitive loads. These products also lessen the damaging effect VFD’s have on motor windings.

The common mode choke feature balances the three phases between the VFD and motor by absorbing the unwanted common mode currents and high frequency noise. As a result the cores get warm depending on the amplitude of the problem. We recommend monitoring the temperature of the inductive absorbers post installation to make sure temperatures do not exceed 150°F. If so, additional cores will need to be added to reduce operating temperatures.

At this point in time we have installed a number of inductive absorber cores at various customers’ facilities, and so far the results have been very good. We have also had success installing cores on the line side of motor control centers to eliminate incoming power issues.

These products are now standard on many types of OEM equipment like Chillers, CNC equipment and Wind towers to name a few.

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Please contact your 3E representative if you are interested in more information or a demonstration.

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