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CoolBLUE® and NaLA®

A More Powerful Solution

The Effects of EMI on VFD's and Servo Motors

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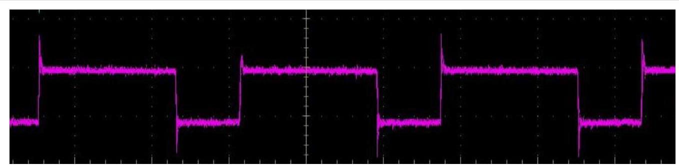
Automation equipment with several servo motor applications.

With the increase of automation technology, the electromagnetic interference (EMI) generated from the control center for servo motors has not gone unnoticed. Due to the precision and intricate accuracy of the function of production equipment, the use of VFDs and servo motors is prevalent.

The servo motor control, or VFD, runs on AC power, and is able to control the speed of the servo motor by adjustment in the frequency. The servo motor has the ability maintain and hold a specific position accurately; virtually working even when not moving. The technology behind both the VFD and Servo Motor operation is Pulse Width modulation, or PWM. PWM is a series of pulses that serve to imitate a sinusoidal waveform.

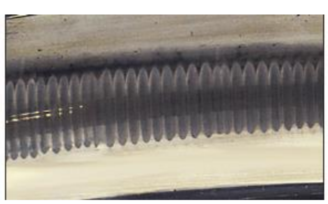
Rapid switching within the VFD causes voltage overshoots in the PWM signal as it is sent to the servo motor. The rise and fall times are as short as a few Nano-seconds in time and up several MHz. The rapid rise and fall sequence of the signature of these pulses cause overshoots which in turn cause several issues.

- Damage to motor bearings
- Winding insulation damage and overheating
- Increased levels of EMI on ground wires
- Increased levels of EMI radiated from cables
- Interference with sensors and electronic equipment



Overshoots of voltage spikes from PWM leading to high frequency currents

The high frequency component of these overshoots builds capacitance in the rotor, which causes current flow to the ground through the path of least resistance, the bearings. The intermittent contact between the balls and the bearing's race is intensified by the insulation characteristics of the lubrication. Combined, these voltage spikes and current, machine the metal of the races, cutting away small pieces at a time (EDM) with each persistent discharge. These discharges occur thousands of times per second. The result of this continuous EDM is known as fluting, a series of washboard-like ridges across the bearing race. When EDM is not addressed, the most probable outcome is lubrication breakdown within the bearing, leading to bearing failure. This results in downtime of the production equipment while the servo motor is being repaired or replaced, a halt in production and loss of revenue.



Fluted Bearings

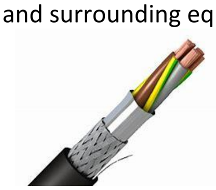
Servo motors with VFD's are used as part of automation equipment in manufacturing. Usually manufacturing devices have several servo motors/VFD applications installed and each application performs a precise and exact function in the process. When EMI is generated from the VFD, the entire machine becomes susceptible to the EMI. Drive pulses cause sharp changes in current consumption from the power source which causes high frequency conducted emissions to flow back to the main. VFD manufactures recommend line filters to solve this problem. The focus of these filters is to regulate how a piece of equipment effects the operation of other nearby equipment. The design is addressed towards the entire machine, with it's several VFD controlled servos, not to affect the operation of another machine that is nearby. There is no focus on each individual VFD/Servo on the equipment and how it will affect another VFD and servo installed on the same piece of equipment. The result is the EMI travels through the frame of the equipment and interferes with the operation of other functions of the machine, such as sensors, control signals, encoder feedback, monitoring equipment and the bearings of other servo motors.

EMI issues from the VFDs manifest as radiated and/or conducted emissions, noise on the equipment ground cable, equipment frame and wiring. The unwanted ground current infiltrates the entire grounding system and alter sensor signals. Some VFD/Servo controlled equipment is very sensitive, and any EMI interference could interrupt normal automated operations.

The regulation for EMI emissions testing is based on each component of a piece of equipment. Each individual piece is tested to ensure that it meets the regulations before it can be released for production. The VFD, servo motor and cables each independently meet the regulatory requirements for EMI emissions. What happens when each individual component is used in a complete system, adding the variables of the system ground, sensors, cable lengths, connectors, and incoming AC power? There are no EMI regulations for an entire system, since each individual component has been approved, so there is no testing performed to make sure that the complete piece of equipment meets the EMI regulations. This is when the EMI issues become prevalent.

Measurements of the high frequency currents interfering with the entire system can be taken utilizing a 200mHz Oscilloscope and Rogowski coil. The Rogowski coil is looped around the three lines that are between the VFD and servo to take the high frequency current readings. The same can be done on the ground wire. The voltage spikes are generated from the PWM switching of the VFD, which create the high frequency current that flows through the system. This issue is not new and is a wide spread problem. There are several preventive measures available in the market, each with different objectives and levels of success.

Shorter cable runs have been a recommendation to reduce the capacitance of the high frequency currents through the cables. Shielded cables or "VFD Cables" have been recommended by VFD manufactures in their installation guides. VFD cables reduce radiated emissions when installed properly. For the most part, the shielded cables are not used or are installed incorrectly, resulting in no help with the problem. This is a costly recommendation and the conducted emissions are still present and remain a problem within the equipment and surrounding equipment.

VFD Rated Cable

Insulated bearings or Ceramic bearings are non-conductive and isolate the rotor from ground when installed on both ends of the shaft, but the capacitive coupling remains. The goal of this recommendation is to protect the bearings, and the EMI will continue to look for a source to ground. This is a costly band aid, and due to the insulating of the bearing and the presence of the EMI, increase in heat within the bearings is result. High frequency current is still present in the equipment's electrical system which will continue to be negatively impacted. This option requires routine maintenance and periodic replacement of the insulated bearings.

Iso-Coated Bearing

Ceramic Bearing

Bearing with Ceramic Rolling Elements

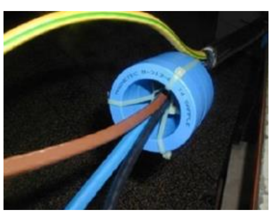
Grounding of the motor's shaft using special brushes is another common practice. This method diverts the induced shaft voltages to ground via a direct path. This solution focuses on mitigating bearing damages only, and still leaves the high frequency current looking for a way to the ground, preserving the EMI issues. Only if the system has good ground, shaft grounding may do as it promotes, and divert the voltage. This option requires routine maintenance and periodic replacement of the shaft grounding device. Normal practice is to install shaft grounding on the drive end of the motor but should be installed on both ends of the shaft, with proper grounding. This is a costly option and does not address the high frequency current still circulating from the rotor shaft, through the motor frame, to ground and the entire piece of equipment.

Samples of shaft grounding devices

Installing load reactors between the VFD and motor have the main function to extend the dV/dt time of the rise and fall edges, lower the current through the bearings and ground and reduce the EMI on the rest of the equipment. This option isn't as costly as the previous suggestions and does not require maintenance once installed. The overall performance of the equipment is marginal, and the load reactors tend to be bulky and heavy. Load reactors focus on the symmetrical frequency ranges that are not nearly as high as what is generated from the VFD. This will improve the situation, but not to the frequency levels necessary to mitigate damages or interference problems.

Typical load reactor

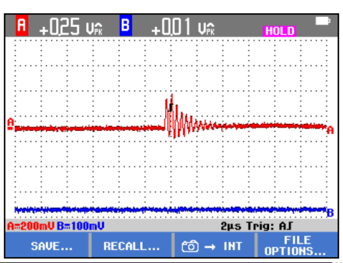
CoolBLUE® Inductive absorbers are light-weight and easy to install over the three motor drive cables (common mode). CoolBLUE® absorbs the high frequency current generated from the VFD when installed close to the source of the EMI. This is a low-cost option and requires no maintenance or monitoring as there are no wearable components. Inductive absorbers focus on reducing the asymmetrical high frequency current, rendering the voltage spikes in the PWM to be non-damaging. This solution increases the overall performance of the equipment to its maximum potential. This absorption of high frequency current at the source, keeps if off the ground wires, and away from sensors and other electronic equipment. Inductive absorbers are designed to absorb both radiated and conducted emissions, when utilizing both the CoolTUBE® and CoolBLUE®/NaLA® components.



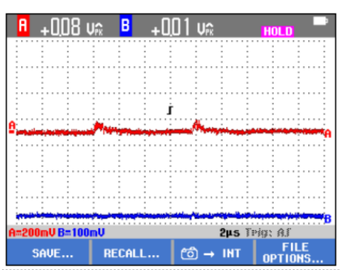
CoolBLUE® installed on leads between VFD and servo

CoolTUBE®

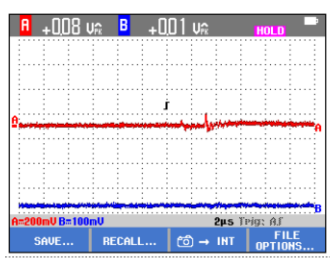
CoolTUBE® installed on VFD leads to servo



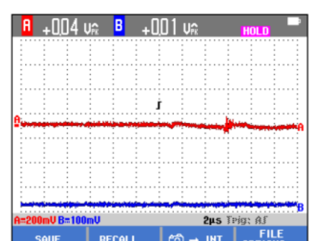
Readings taken on the t-leads without protection



Readings taken on the t-leads with CoolTUBE®, CoolBLUE® and NaLA®



Readings taken on the ground wire without protection



Readings taken on the ground wire with CoolTUBE®, CoolBLUE® and NaLA®

EMI issues in VFD/Servo systems are not going to go away without intervention and utilization of a complete solution.   As automation technology continues to increase in manufacturing industry, the need to get the problematic EMI under control will become more prevalent. The only way to mitigate the EMI issues, conducted and radiated, that affect manufacturing equipment, sensors, electronic devices like metal detectors and item counters, servo motors and other sensitive equipment, is to utilize a solution that targets all aspects of the problem. Only then, do you truly have a "solution" to the EMI issue.