



NEWSLETTER

June 1, 2002

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CONSULTANTS' NETWORK OF CONNECTICUT (CNC)

CNC is associated with the Institute of Electrical and Electronics Engineers, Alliance of IEEE Consulting Networks (AICN). CNC members are expert, independent contractors who can provide quick help and a can-do approach. Advantages of using CNC members are objectivity and generation of new ideas. Further, CNC members can supplement existing staff very cost effectively.

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NEWSLETTER

This is the fourth quarterly newsletter. These newsletters are published electronically on the first of the month in which meetings are held.

Each newsletter contains general information and articles written by group members. The membership is invited to submit articles to the editor, Clem Skalski.

Reader feedback is invited and appropriate letters will be published.

The **Connector** (newsletter) of the IEEE Connecticut Section provides more general information to IEEE members and associates. To view the current Connector, go to www.ieee.org/ct.

MEETINGS

These are held quarterly on the third Wednesday of March, June, September, and December. There are exceptions as noted below.

The June meeting is on the **12th** at ARRL, 225 Main Street, Newington at 7:00 PM. The first half hour is devoted to networking. Then the business meeting starts at 7:30 PM. The atmosphere is casual and there is no admission fee. The usual date for the meeting would have been June 19. It was moved ahead to permit members to participate in The International Maintenance Institute (IMI, <http://www.imionline.org/>) trade show on that day.

CONNECTIONS

CNC is an affiliated member of the Connecticut Technology Council <http://www.ct.org>. Additionally, CNC members participate in various organizations of consultants outside of IEEE. The next big event for us is a booth at the IMI show. This will be manned by Frank Martino and Clem Skalski.

INTRODUCTION TO ARTICLE

“**AC Drives and EMI/RFI Mitigation**,” deals with a timely subject that involves considerable art and science. The author Frank Martino has been an application engineer for variable speed drives and motor controls for twenty-nine years. He maintains a website at <http://www.powerqualityanddrives.com/>. He can be reached at FMartino3@aol.com.

Abstract: AC Drives and EMI/RFI Mitigation

The hard-switching of IGBT devices and high frequencies of AC PWM drives have given rise to EMI and RFI problems being spread throughout facilities. An understanding of the problem and the various choices of solutions will allow the proper selection of mitigation techniques

AC Drives and EMI/RFI Mitigation

Frank. Martino

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Abstract

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Introduction

A variable frequency drive (VFD) will generate radio frequency interference (RFI) in the range of 0.5 MHz to 1.7 MHz, and electromagnetic interference frequencies (EMI) in the range of 1.7 MHz to 30 MHz. The high frequency generation is caused by the high carrier frequencies of the pulse-width modulation, the associated short rise times of the IGBT output devices, and the reflected waves from the motor terminals. EMI is also produced by the harmonics which are generated by the carrier frequencies, rise times and reflected waves. "Reflected waves" are caused by the capacitive effects of long motor leads and the resulting impedance mis-match between the motor cables and the motor windings. EMI/RFI is also referred to as electrical noise.

The EMI/RFI will travel to the motor along the motor leads and will be transmitted to ground via the capacitive effect between the motor windings and the motor frame, the capacitive effect between the line conductors and bond wire, and the capacitive effect between the line conductors and conduit. The EMI/RFI will then seek a return path to the source, that is, to the input of the VFD.

The return path to the input power terminals of the VFD will be from the ground grid, through the grounded neutral of the wye secondary of the upstream power distribution transformer, and through that transformer's load lines. See Figure 1.

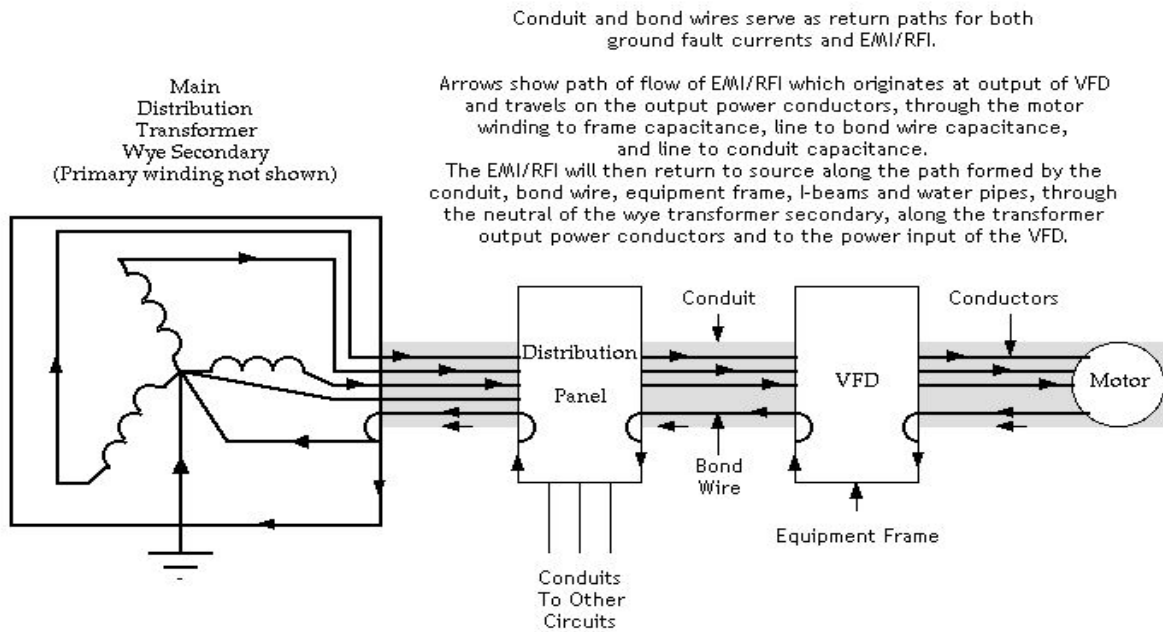


Figure 1

The return path to source of EMI/RFI along a conduit or other portions of the facility ground grid will cause a voltage gradient on both the conduit and grid that may effect the proper operation of other equipment.

The grounding grid normally consists of motor and electrical enclosure frames, cable conduit, conduit straps, structural I-beams, water pipes, and grounding rods. Thus, EMI/RFI and the associated voltage gradients may be spread around the facility, allowing problems to be created along the path of return.

Solutions to Power Cable Problems

In older installations which utilize a conduit for a ground return, and in all new installations, introduce a bond wire that will pass through the conduit. A bond wire will appear as low impedance to low frequency EMI/RFI, causing the low frequencies to pass on the bond wire and not on the conduit. Thus those frequencies will be kept off the facility ground grid and will create a lower voltage gradient than would otherwise be created if they traveled along the conduit.

However, due to "skin effect" of high frequencies passing on a wire, the bond wire will appear as a high impedance path to those frequencies. The higher frequencies will therefore continue to pass along the conduit rather than the bond wire.

Cable with both a metallic shield and an outer insulating jacket is preferred over conduit. The aluminum or copper braid of a shielded cable or the clad of a metal clad cable will present a lower path of impedance for the higher frequencies than does conduit, allowing a minimal voltage gradient to develop along the braid or clad on the return path. The outer insulating jacket will eliminate the problem created by conduit and conduit straps which pass the EMI/RFI to the structural I-beams and water pipes with which they come in contact.

A continuous corrugated aluminum sheath is preferred over interlocked aluminum or interlocked steel. The effectiveness of interlocked shielding will be lost over time due to oxidation increasing the turn-to-turn contact resistance.

A cable with a "bond wire" consisting of three symmetrically placed grounding conductors is preferred over a cable with a single grounding conductor.

A ferrite core (also referred to as a choke) may be used to attenuate common mode noise (noise that is passed from line to neutral and line to ground) on AC and DC circuits by passing all output power lines through the core. The properties of the core are such that it provides an inductance to the fields created by the noise.

If the bond wire is passed through a ferrite core along with the output power conductors, then the bond wire will present a higher impedance to the EMI/RFI, thus encouraging the lower frequencies to remain on the conduit.

Differential noise (noise that is passed from line to line) may be attenuated by passing a single wire through a ferrite core. However, for an application with DC or with with a low fundamental frequency AC power, the permeability of the core will be reduced by the saturation effects of the DC component of the line current. In those applications, the effective attenuation will be reduced and the impedance offered to the EMI/RFI by the core must be de-rated. A typical cylindrical ferrite core may have an internal diameter of 1.0 inch, an outside diameter of 2.0 inches and a length of 2.0 inches. See Figure 2.

Main
Distribution
Transformer
Wye Secondary
(Primary winding not shown)

With the addition of a common mode choke, the EMI/RFI path remains the same. Noise attenuation is achieved by the choke adding impedance to the electric field of the EMI/RFI. The added impedance causes the line to ground di/dt rise time to be reduced. However, line to line dv/dt remains unchanged

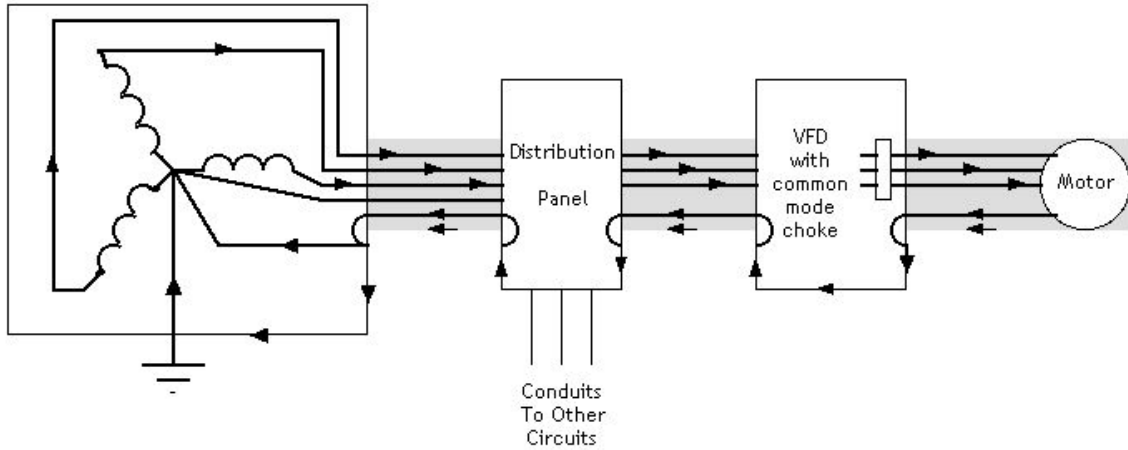


Figure 2

An EMI/RFI filter located close to the drive or wired at the input terminals of the drive will utilize its load end capacitors to remove the noise from the ground grid and return it to source in the shortest possible route. The filter capacitors on the line side will serve to return to ground any noise coming in from other sources. The filter inductors will provide a high impedance for incoming noise, thus preventing the noise from entering the drive.

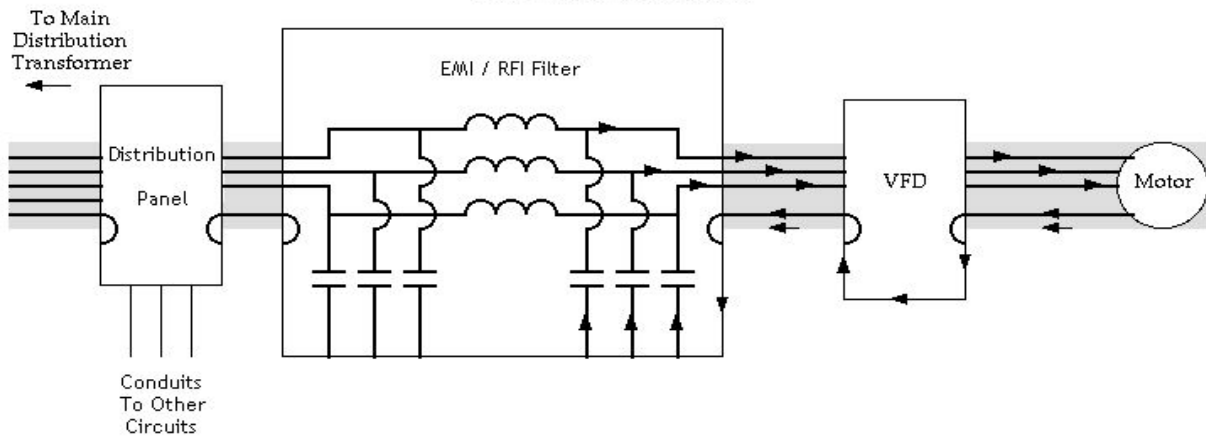


Figure 3

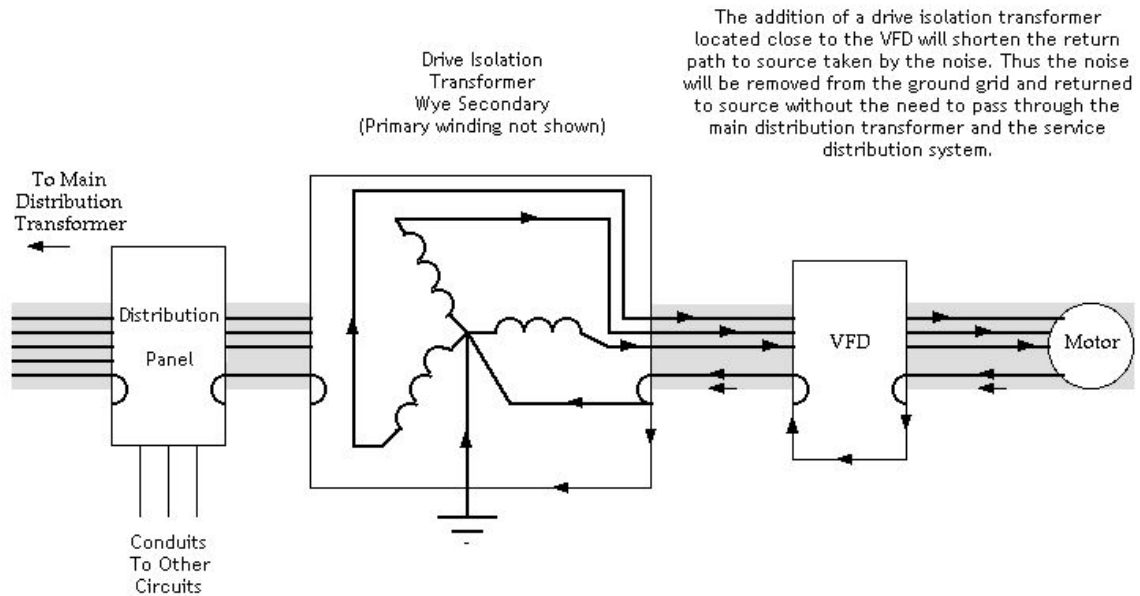


Figure 4

An EMI/RFI filter at the drive input terminals will provide a return path for noise that will effectively reduce the distance of noise travel along the ground grid and keep the noise away from the upstream transformer and incoming power lines. See Figure 3.

A drive isolation transformer with a solidly grounded neutral will also provide a return path that will keep the noise away from the upstream transformer and incoming power lines. See Figure 4.

Both a load reactor or a dv/dt filter will reduce the high rate of change of output voltage which is caused by the rapid switching of the IGBT devices. The dv/dt filter derives its name from the high rate of change (d) of voltage (v) with respect to a small change in time (t).

The reduction of the rate of change of voltage will reduce the capacitive effects which cause EMI/RFI. Thus, a load reactor or dv/dt filter wired directly to the output terminals of a VFD will reduce both common mode noise and differential noise.

In addition to reducing the rate of change of output voltage, the filtering of the high carrier frequencies via a dv/dt filter will also yield a reduction of the impedance mis-match at the motor terminals and, consequently, a reduction in the reflected wave. A dv/dt filter consists of a load reactor with a parallel capacitor.

Keep in mind that a load reactor or dv/dt filter with 1 1/2% impedance will cause a reduction in output voltage to the motor of 1 1/2%. A 5% impedance will cause a corresponding 5% reduction in voltage to the motor.

Solutions to Signal Problems

When building a control panel, if the incoming power cables, mechanical bonds and wire bonds enter to the right, then mount all sensitive electronics on the left. Also install the exiting power cables, mechanical bonds and wire bonds on the right. That configuration will cause the bond path on which EMI/RFI flows to remain on the right side of both the enclosure and the enclosure panel and will keep the EMI/RFI away from the portion of the panel on which the electronic equipment is mounted.

Reduction of noise on signaling circuits may be achieved by using shielded cable and a common mode ferrite core with both wires and the cable shield passing through the core. It is generally preferred to ground the shield at the source of the signal rather than at the receiving end, thus preventing the need of noise returning to source via the ground grid.

The use of optical signal isolators will also reduce noise on signaling circuits. Control signals transmitted on fiber optic cables will prevent noise problems caused by long runs and, in some applications, may also allow a VFD to be placed at the motor location, thus eliminating both long motor lead cables and the need for dv/dt filters. In addition, short motor leads, when used with an EMI/RFI filter or drive isolation transformer, will also shorten the return path along the system grid.

For long lead lengths on run speed potentiometers and other signaling sources, use #12 AWG EMC (Electromagnetic Compatibility) cable. The EMC cable has a copper braided sheath which provides shielding from EMI/RFI and will offer a lower resistive voltage drop per foot than the standard #18 AWG shielded cable.

For exceptionally long leads, signal conditioning is required at the potentiometer to convert the potentiometer voltage output signal into a 4 to 20 mA signal. A milliamp signal is less susceptible to EMI/RFI than a voltage signal.

Measurement of EMI/RFI

Common mode noise (line to neutral/ground) may be measured by connecting to the line leads three one-meg ohm resistors in a wye configuration. With an oscilloscope, you may then observe and measure the noise that exists between the neutral of the wye and common.

It is possible for a standing wave at the motor terminals of a 480 VAC system to be as high as 2300 volts or more. If it is necessary to measure at the motor terminals, use isolated leads, insulated gloves and safety glasses. Remove wrist watches, bracelets and rings which might possibly get caught on the ground grid and thereby restrict a hasty retreat in the event of flashover at the test leads.

A hazard also exists with long motor leads that are run in parallel with other motor leads in a cable tray. When a VFD is operating, EMI/RFI will be coupled from one cable into another. As a result, when replacing a motor, the motor cable may be found to have a high potential at the end of its conductors even though the motor's drive is disconnected from the line.

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