Signal and Power Wiring Considerations for VFD Electro Magnetic Compatibility

Introduction

Variable Frequency Drives [VFDs] have been proven to increase the energy efficiency and versatility of many installations. Over the years, VFD technology has greatly improved allowing them to be easily and cost effectively applied with little concern about reliability. While applying VFDs to applications has become nearly fool proof, some important installation considerations still apply.

This document presents an overview of general signal and power wiring considerations when addressing the Electro Magnetic Compatibility [EMC] concerns for typical commercial and industrial equipment. Only certain high-frequency phenomena (RF emissions, RF immunity) are discussed. Low-frequency phenomena (harmonics, line voltage imbalance, notching) are not covered. Special installations or compliance to the European CE EMC directives will require strict adherence to relevant standards and is not presented here. Danfoss has the expertise to provide assistance in these cases. Several authoritative industry standards are listed in the reference section below.

The Effects of EMI

Danfoss VFDs have been developed for reliable performance in severe commercial and industrial environments. Built-in RFI filtering, multiple isolated signal grounds, and a robust design insure trouble free performance. While Electro Magnetic Interference [EMI] related disturbances to the VFD's operation are uncommon, the following detrimental EMI effects may be seen;

-Motor speed fluctuations
-Serial communication transmission errors
-VFD CPU exception faults
-Unexplained VFD trips

A disturbance to other nearby equipment is more common. Generally, other industrial control equipment has a high level of EMI immunity. However, non-industrial, commercial, and consumer equipment is often susceptible to lower levels of EMI. Detrimental effects to these systems may include the following;

-Pressure/flow/temperature signal transmitter signal distortion or aberrant behavior
-Radio and TV interference
-Telephone interference
-Computer network data loss
-Digital control system faults

Sources of EMI

Modern VFDs utilize Insulated-Gate Bipolar Transistors [IGBTs] to provide an efficient and cost effective means to create the Pulse Width Modulated [PWM] output waveform necessary for accurate motor control. These devices rapidly switch the fixed DC bus voltage creating a variable frequency, variable voltage PWM waveform. This high rate of voltage change [dV/dt] is the primary source of the VFD generated EMI.

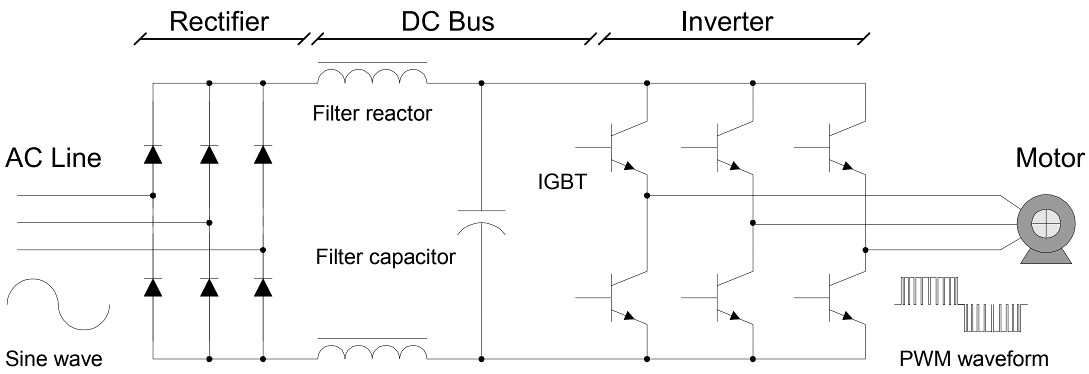


Diagram #1: VFD elementary diagram-
The high rate of voltage change caused by the IGBT switching creates high frequency EMI.

<u>EMI Propagation</u>
VFD generated EMI is both conducted to the AC line and radiated to nearby conductors. The diagrams below illustrate the effect.

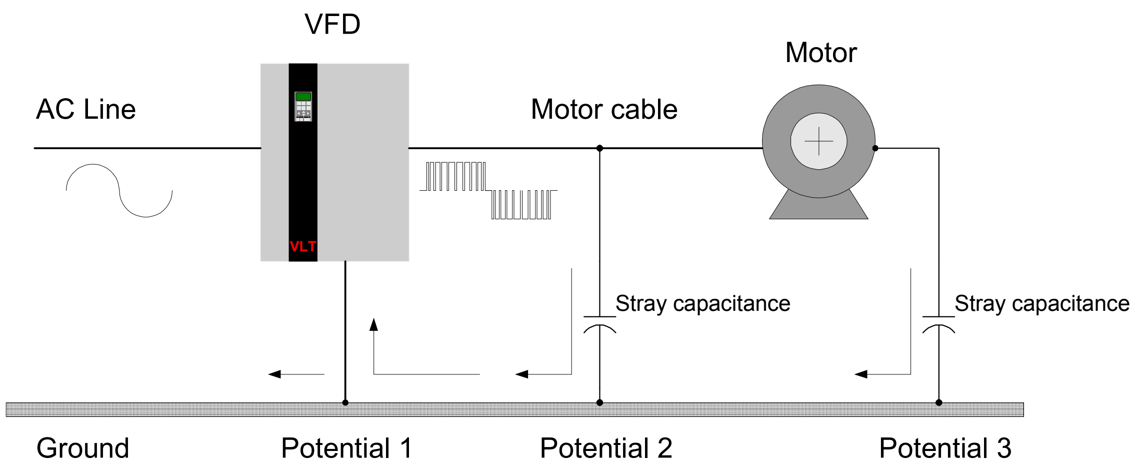


Diagram #2: Ground currents-
Stray capacitance between the motor conductors, equipment ground, and other nearby conductors results in induced high frequency currents.

High ground circuit impedance at high frequencies results in an instantaneous voltage at points reputed to be at "ground potential". This voltage can appear throughout a system as a common mode signal that can interfere with control signals.

Theoretically, these currents will return to the VFD's DC bus via the ground circuit and a high a frequency [HF] bypass network within the VFD itself. However, imperfections in the VFD's grounding and the equipment's ground system can cause some of the currents to travel out into the power network.

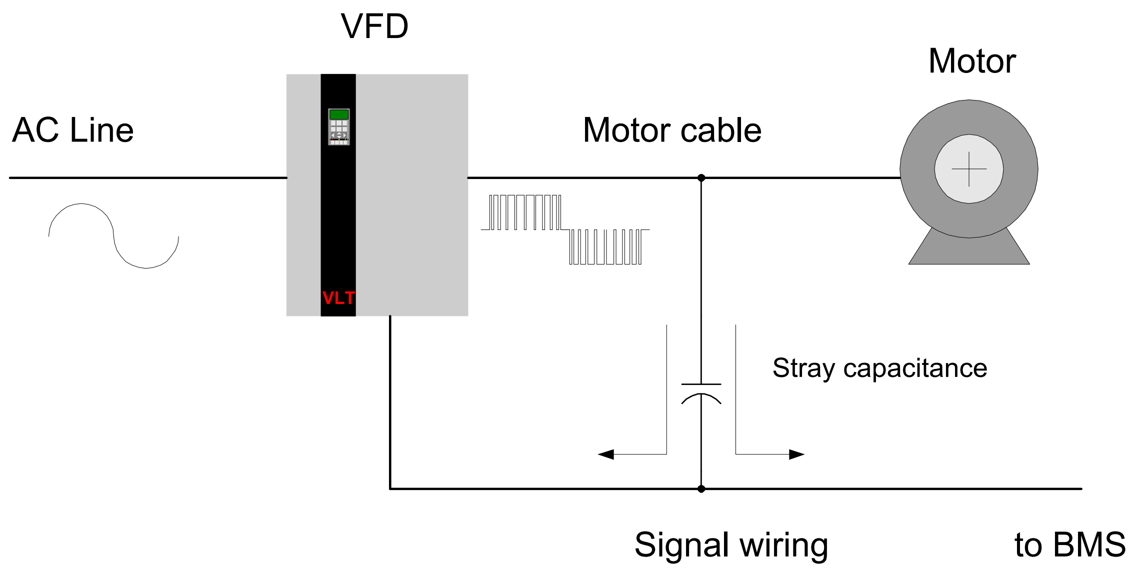


Diagram #3: Signal conductor currents-
Unprotected or poorly routed signal conductors located close to or in parallel to motor and AC line conductors are susceptible to EMI.

Signal conductors are especially vulnerable when they are run parallel to the power conductors for any distance. EMI coupled into these conductors can affect either the VFD or the interconnected control device.

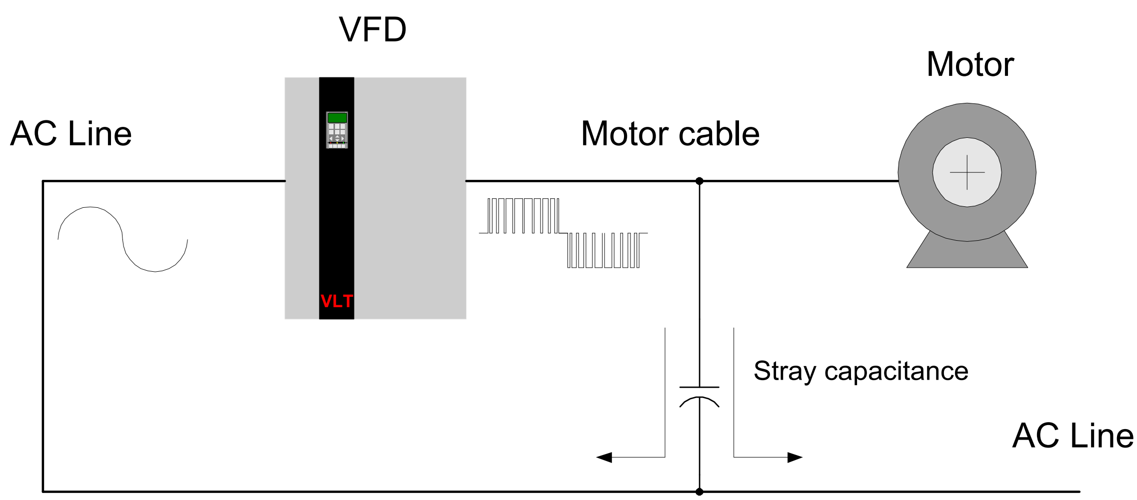


Diagram #4: AC line currents-
HF currents can be coupled into the AC line supplying the VFD when the AC line conductors are located close to the motor cables.

While these currents will tend to travel back to the VFD, imperfections in the system will cause some current to flow in undesirable paths thus exposing other locations to the EMI.

Preventative measures

EMI related problems are more effectively alleviated during the design and installation phases rather then after the system is in service. Many of the steps listed here can be implemented at a relatively low cost when compared to the cost to later identify and fix the problem in the field.

Grounding-

The VFD and motor should be solidly grounded to the equipment frame. A good HF connection is necessary to allow the HF currents to return back to the VFD rather than to travel thorough the power network. The ground connection will be ineffective if it has high impedance to HF currents, therefore it should be as short and direct as practical. Flat braided cable has lower HF impedance than round cable. Simply mounting the VFD or motor onto a painted surface will not create an effective ground connection. In addition, running a separate ground conductor directly between the VFD and the driven motor is recommended.

Cable Routing-

Avoid routing motor wiring, AC line wiring, and signal wiring in parallel. If parallel routing is unavoidable, try to maintain a separation of 6 - 8 inches between the cables or separate them with a grounded conductive partition. Avoid routing cables through free air.

Signal cable selection-

Single conductor 600 volt rated wires provide the least protection from EMI. Twisted-pair and shielded twist-pair cables are available which are specifically designed to minimize the effects of EMI. While unshielded twisted-pair cables are often adequate, shielded twisted-pair cables provide another degree of protection. (Refer to Addendum II for information on the relative effectiveness of various shielding methods.)

The signal cable's shield should be terminated at one end only using a clamp around the exposed cable shield. Avoid terminating the shield through a pigtail connection as this increases the HF impedance and spoils the effectiveness of the shield. (Refer to Addendum III for information on shield termination methods.)

A simple alternative is to twist the existing single conductors to provide a balanced capacitive and inductive coupling thus canceling out differential-mode interference. While not as effective as true twisted-pair cable, it can be implemented in the field using the materials on hand.

Motor cable selection-

The management of the motor conductors has the greatest influence on the EMI characteristics of the system. These conductors should receive the highest attention whenever EMI is a problem. Single conductor wires provide the least protection from EMI emissions. Often if these conductors are routed separately from the signal and AC line wiring then no further consideration is needed. If the conductors are routed close to other susceptible conductors, or if the system is suspected of causing EMI problems then alternate motor wiring methods should be considered.

Installing shielded power cable is the most effective means to alleviate EMI problems. The cable's shield forces the noise current to flow directly back to the VFD before it gets back into the power network or takes other undesirable and unpredictable high frequency paths. Unlike signal wiring, the shielding on the motor cable should be terminated at both ends.

If shielded motor cable is not available then 3 phase conductors plus ground in a conduit will provide some degree of protection. This technique will not be as effective as shielded cable due to the unavoidable contact of the conduit with various points within the equipment.

Serial communications cable selection-
There are various serial communication interfaces and protocols on the market. Each of these recommends one or more specific types of twisted-pair, shielded twisted-pair, or proprietary cables. Refer to the manufacturer's documentation when selecting these cables. Similar recommendations apply to serial communication cables as to other signal cables. Using twisted-pair cables and routing them away from power conductors is encouraged. While shielded cable provides additional EMI protection, the shield capacitance may reduce the maximum allowable cable length at high data rates.

References

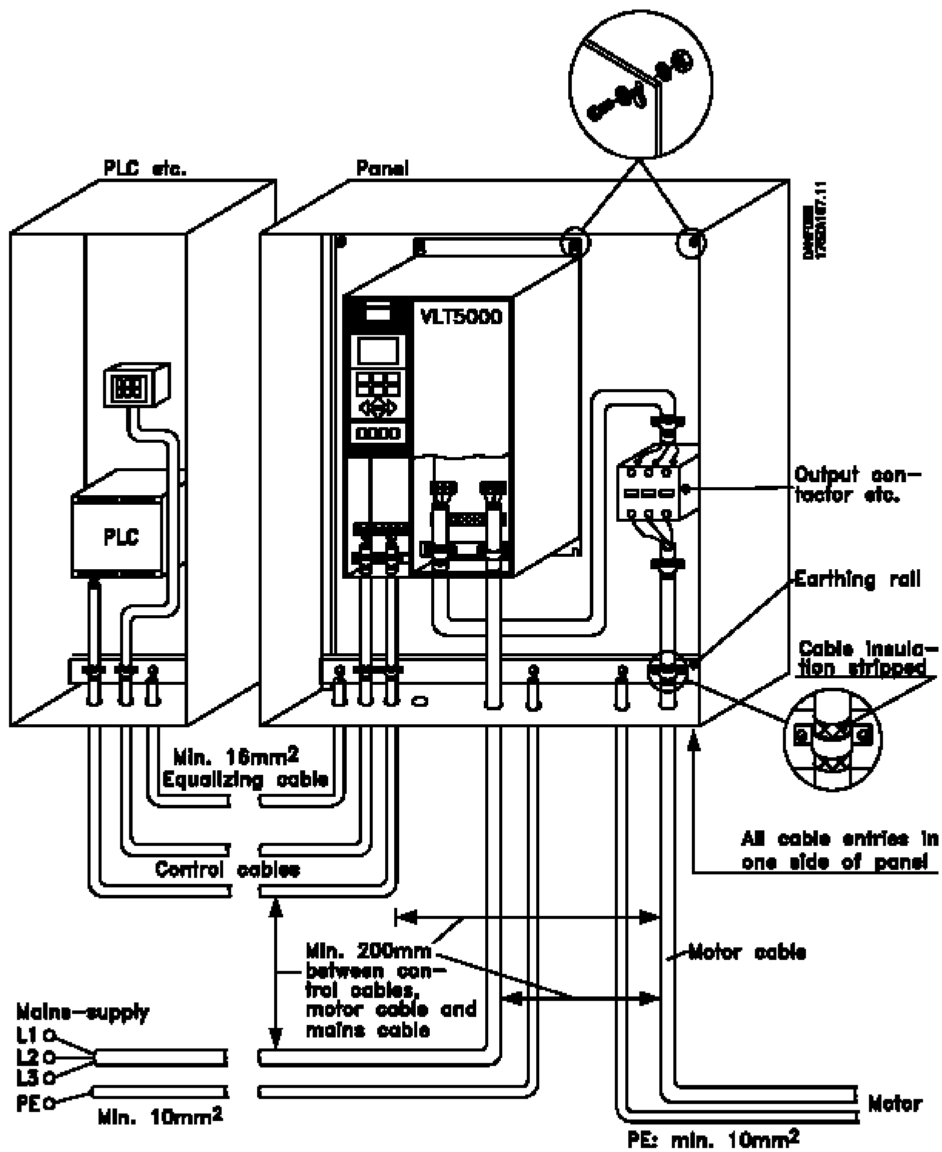
1. IEEE 1100-1999 Emerald Book; "IEEE Recommended Practice for Powering and Grounding Electronic Equipment"

2. NEMA Standards Publication ICS 7.1-2000; "Safety Standards for Construction and Guide for Selection, Installation, and Operation of Adjustable-Speed Drive Systems"

3. IEC EN61800-3; "Adjustable Speed Electrical Power Drive Systems - Part 3: EMC Product Standard Including Specific Test Methods"

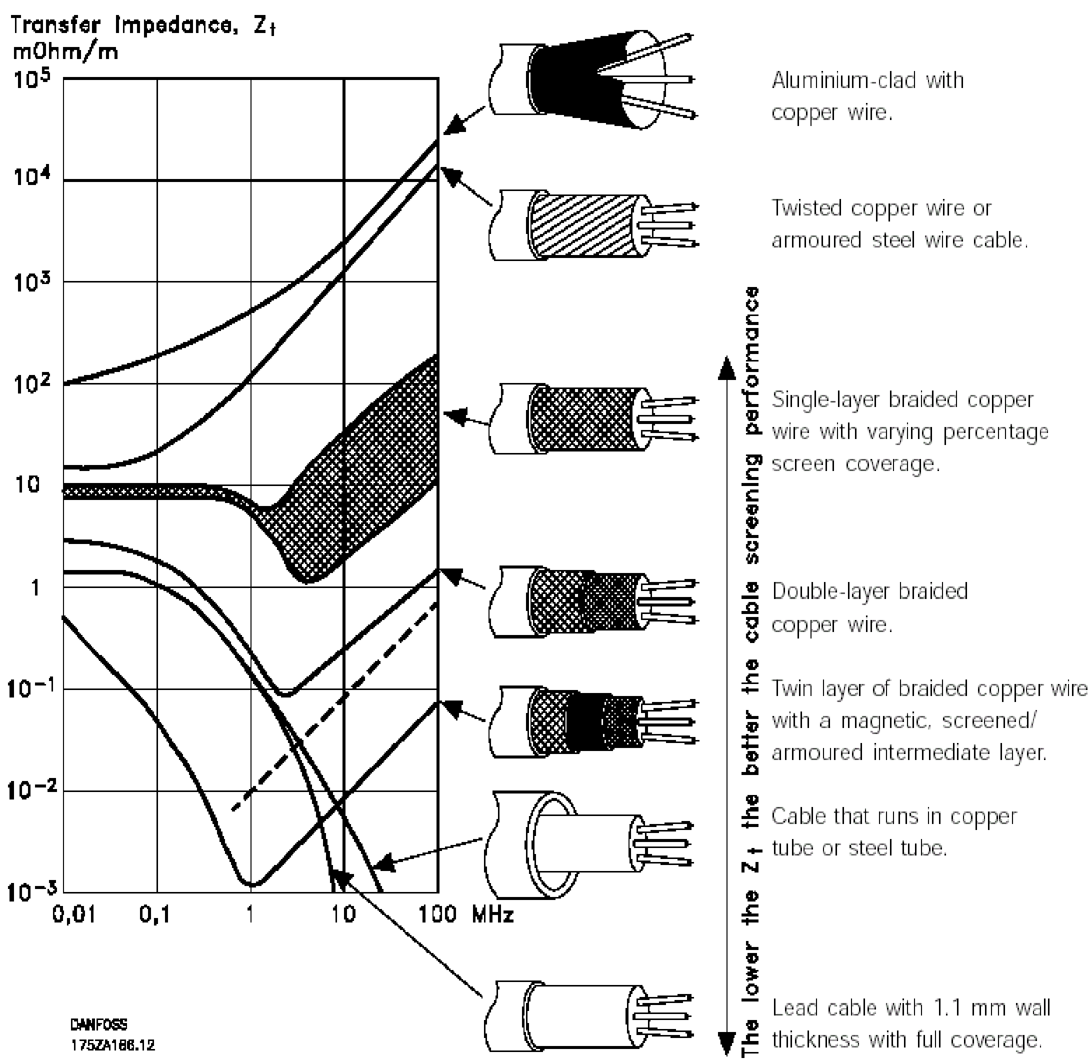
Addendum I

EMC correct installation



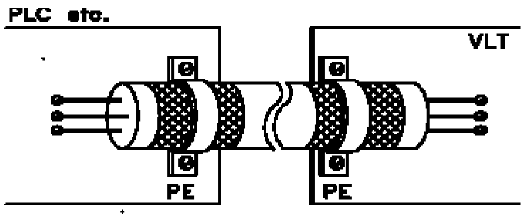
Addendum II

Cable shield effectiveness

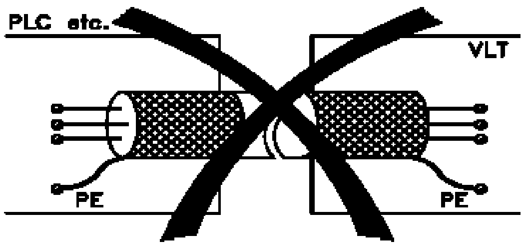


Addendum III

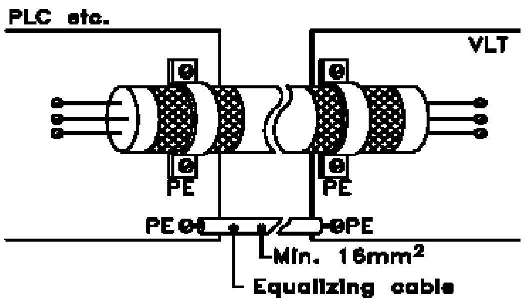
<u>Cable shield termination</u>



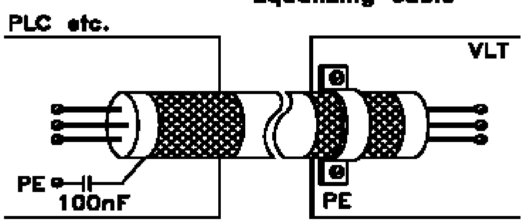
Correct earthing
Control cables and cables for serial communication must be fitted with cable clamps at both ends to ensure the best possible electrical contact.



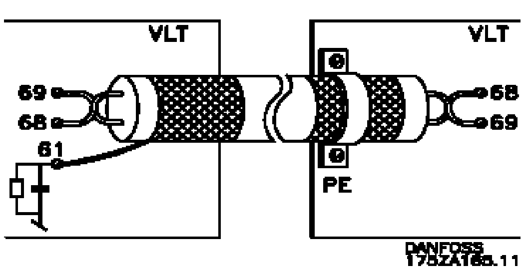
Wrong earthing
Do not use twisted cable ends (pigtails), since these increase the screen impedance at high frequencies.



Protection with respect to earth potential between PLC and VLT
If the earth potential between the VLT frequency converter and the PLC (etc.) is different, electric noise may occur that will disturb the whole system. This problem can be solved by fitting an equalizing cable, to be placed next to the control cable. Minimum cable cross-section: 16 mm^2 .



For 50/60 Hz earth loops
If very long control cables are used, 50/60 Hz earth loops may occur. This problem can be solved by connecting one end of the screen to earth via a 100nF capacitor (keeping leads short).



Cables for serial communication
Low-frequency noise currents between two VLT frequency converters can be eliminated by connecting one end of the screen to terminal 61. This terminal is connected to earth via an internal RC link. It is recommended to use' twisted-pair cables to reduce the differential mode interference between the conductors.