VFD Wiring Best Practices

Introduction

With a growing need for saving energy, variable frequency drives are being used in many general purpose applications where they are controlling 3-phase electric motors. With the use of the VFD not only saves energy but also saves the life of motors by providing a soft start and advanced process control for motor applications where in the past motors were started across the line. With using the VFD there are some new considerations that need to be made when installing and commissioning of the system. One of the biggest considerations that need to be made is the power, control, ground, communication, and analog control wiring techniques need to be understood fully to maintain proper operation, prolong the life of the system, and reduce the EMI (Electromagnetic Interference) that can be caused when introducing the VFD to the system.

Power Wiring

When looking at power wiring, there are a few things that need to be considered when applying it to a VFD.

- **Sizing** – The size of the power wires and fuses that are going to the VFD should be sized to handle the overall load and voltage rating of system. The wires going out the motor need to be sized based off the current and voltage that will be carried on them. In some applications this could be at a lower level depending on the motor load or if multiple motors are used the motor wiring should be sized for the load of all the individual motors.
- **Type** – When looking at the type of cable to use it comes down to the insulation level it has to the prevent EMI. Single wire conductors can be used but shielded power cable is the preferred cable. This is the case for both input and output cables but with output cables instead of the interference radiating from the conductors, a larger shield will force the current noise back to the VFD's bus. Specialty designed cables are made to handle VFD applications where four conductors are enclosed in a shielded cable, the voltage rating is typically higher in these cases due to the added insulation.
- **Routing** – Routing is a major issue when looking at the input and output side of the drive. It is suggested that the input wires are kept apart from any output wires going to the motor. There is no standard spacing between power wires due to the type of cable that is selected and how it is shielded, but it is suggested that there be at least one inch between cables if they have to run in parallel. If they have to cross each other it is suggested that they cross at a 90° angles to prevent interference.
- **Shielding** – For the input and output motor leads it is suggested to have the shielding terminated on both ends to the ground location, to keep a common ground throughout the system. Running wiring in conduit will also provide some protection if a shield wire is not provided, but there could potentially be some noise induced from the contact points.

Note: See the VFD User Manual for more information in regards to power wiring to the drive and to the motor.

Control Wiring

Similar consideration need to be taken when looking at the control wiring.

- **Sizing** – The sizing of the control wire is again going to be based off the current load and voltage that will be on them but it is suggested that it is rated for 600V. It is suggested to use 20 AWG shield cable when running analog signals, 14 AWG for relays, and 16AWG for any other control wires.
- **Type** – When it comes to the type of cable to use, there are many options depending on the size requirements (14 AWG 600V MTW Stranded for 120Vac wire and 16 or 18 AWG 600V MTW Stranded wire for 24Vdc wire for up to 10 and 5 amps). Standard twisted pair cables will provide protection for EMI but it is suggested to use a shielded twisted pair cable. Some communication protocols have their own cabling standard that should be followed.
- **Routing** – With the twisted pair cabling for control and communications they should not be routed by any high voltage (above 50Vdc) power wiring. If they have to run parallel with high voltage wiring, they should be spaced apart as much as possible, 2" minimum (2 ½ -3" is preferred on 120Vac and less, 4" for 480Vac). A grounded barrier is preferred if possible between cables in parallel. If crossing over any high voltage cables it is suggested that it crosses at a 90° angle to prevent noise transmitting onto the signal wires.
- **Shielding** – When having a shielded cable, it is suggest to ground the shield on one end of the cable, it most system at the drive is preferred. There are ground straps that can be used to clamp around the cable shield to terminate. Do not terminate the ground through the pigtail connections or on the other end of the cable or it will increase the high frequency impedance and remove the effects of the shield.

Note: See the VFD User Manual for more information in regards to power wiring to the drive and to the motor.

Grounding

Grounding the equipment to the panel and system ground is the most important aspect to look at when trying to mitigate EMI issues and prevent high frequency currents from effecting other equipment throughout the power network. A specific ground connection should be made between the VFD and the motor with a direct point of contact. From there the VFD should be grounded to the facility ground along with any other devices that are in the cabinet or are used for controls. Painted back panel creates an insulation barrier between the Ground lug and grounding cable that can cause a bad ground connection. Ground cables should be sized to the same size of the power wiring to again maintain the proper current level protection. Braided ground connections have lower high frequency impedance than round conductors and are preferred.

We view there a three level approach to a single drive installation, starting with the accepted standard. Use metal conduit that has a grounding strap on the outside of the conduit. Connect this strap to the VFD enclosure and also the motor grounded frame. Inside of the conduit, run a grounding conductor connecting the motor ground to the VFD ground. A shield is preferred over the cable, connecting the shield to the ground bus in the drive and terminating the motor end to the grounded motor.

The better method would be to use shielded armor cabled or PVC jacketed shielded cable instead of conduit from the drive to the motor. Use similar grounding practices as above.

The best method is to use shielded armored cable on the line and load side of the VFD, connecting all grounds as above.

The preferred method of using shielded or armored power cable is due the return path for common mode noise is the shield or armor. Unlike conduit, the shield or armor is isolated from accidental contact with grounds by a PVC outer coating. The coating makes the majority of noise current flow in the controlled path and very little high frequency noise flows into the ground grid. The armor prevents EMI coupling to

other cables because the radiated emissions are minimal as the armor completely covers the power wires.

Communication Wiring

For communication wiring similar considerations should be made as the control wiring. Depending on the communication protocol used will determine in many cases the type of cable to use along with its connectors. The communication wiring should be separated from any high voltage wiring (above 50Vdc) and if it should cross any high voltage wires (above 50Vdc) at a 90° angle. When running parallel with any high voltage wires they should be spaced as far away as it is permitted to prevent any EMI interference. Shielded Twisted pair cable is suggested with the shield terminated on one end will provide the best defense against EMI in in the system.

Analog Control Wiring

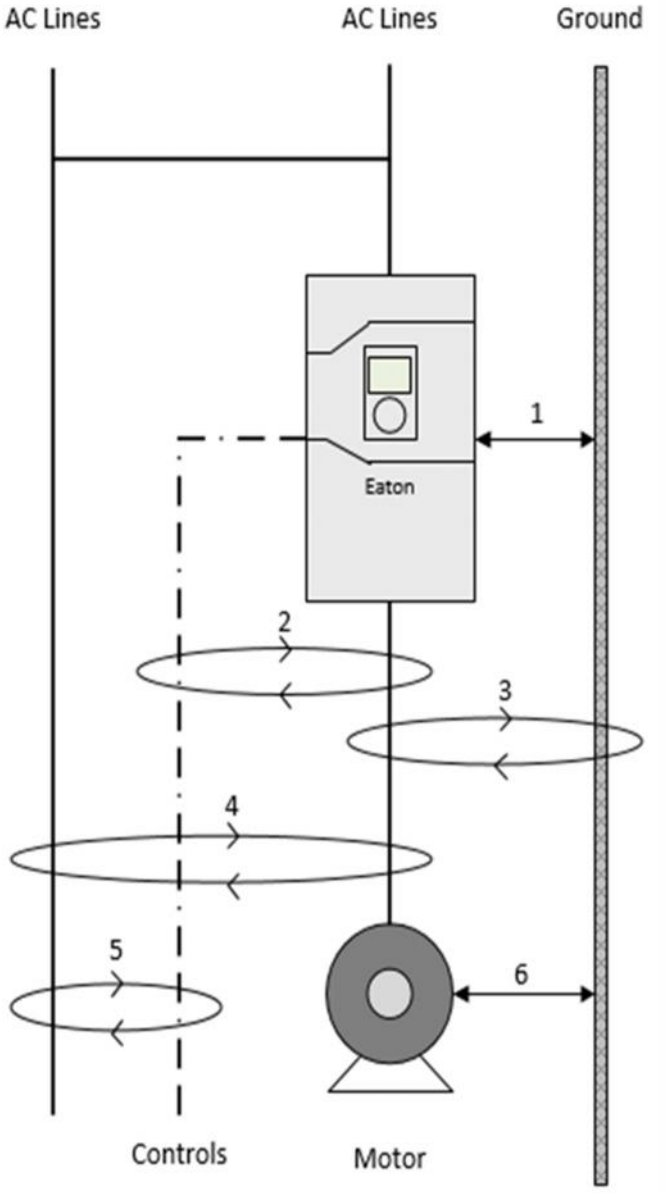
For analog control wiring similar considerations should be made as the control wiring. The analog control wiring should be separated from any high voltage wiring (above 50Vdc) and if it should cross any high voltage wires (above 50Vdc) at a 90° angle. When running parallel with any high voltage wires they should be spaced as far away as it is permitted to prevent any EMI interference. Shielded Twisted pair cable 600Vac is suggested with the shield terminated on one end will provide the best defense against EMI in in the system.

Other Components

For other power components such as power supplies proper wiring size should be used along with a direct connection to the ground bar or lug. We suggest you look at the devices manual for proper connections.

VFD Wiring System Considerations

When looking at a VFD wiring system there are several aspects that need to be consider due to interaction between various wiring in the system itself. These are outlined below:



1. Electromagnetic Interference (EMI) can be carried on the ground back to the drive via the ground connection shown above.
2. With motor cables and control cables running in parallel at a close proximity the PWM wave on the motor cable can be induced into the control wiring causing errors in the voltage levels due to the wires acting like capacitors, with Electromagnetic Interference can be transmitted.
3. With motor wires running in parallel and in proximity of the ground cabling the PWM can induce voltage onto the ground through Electromagnetic Interference which can be transmitted back to the drive and motor.
4. With other AC cables running near any output motor cables the PWM that is being transmitted through the motor cables from the drive as well as the AC voltage lines through Electromagnetic Interference. This induced voltage can then cause issues to the motor, drive and other devices in the system.
5. With other AC cabling ran in parallel and close proximity of any control wiring the AC voltage can be induced in the low voltage control wiring through Electromagnetic Interference, this will cause issue with the control voltage and current signals when the drive or other devices are trying to monitor them.
6. With grounds going to the motor, the large voltage waves of the PWM output on the drive if not properly grounded will feed stray voltage and currents back from the motor into the drive and other devices on the ground bus.

Additional Help

In the US or Canada: please contact the Technical Resource Center at 1-877-ETN-CARE or 1-877-326-2273 option 2, option 6.

All other supporting documentation is located on the Eaton web site at www.eaton.com/Drives

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