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VFD Installation Considerations

Tim Sheerer – IA Specialist

Products and Solutions for the Electrical Industry

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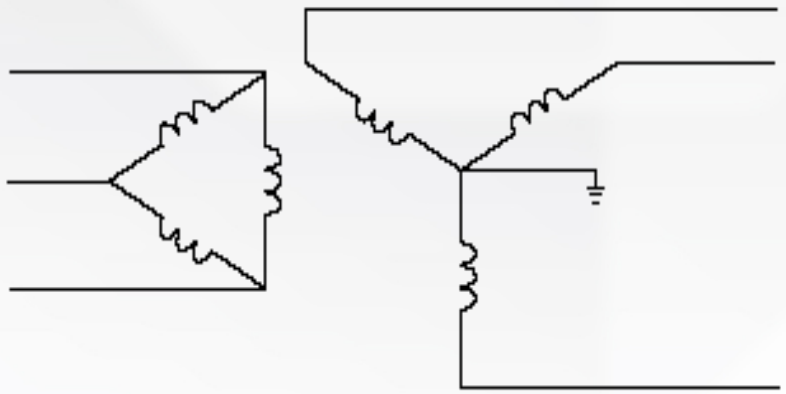
Line Side Installation

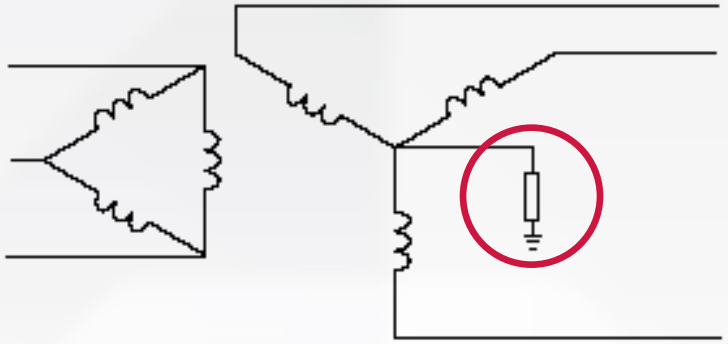
Types of Supply Transformer Grounding

Solidly Grounded Delta-Wye

Best Practice!

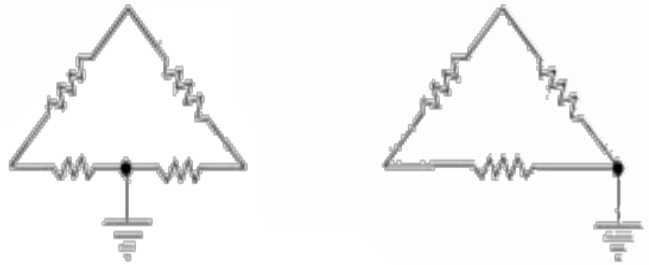


Resistance Grounded Wye

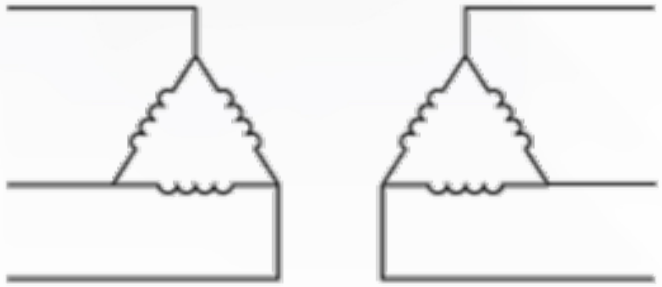


Ungrounded Wye

Leg or Corner Grounded Delta



Ungrounded Delta



Grounding Jumpers and Upstream Transformers

- When installing drives, you must know the details of the upstream transformer ground configuration
- Read the installation guidelines to understand all ground jumper considerations
- Improper (or guesswork) installation/removal of jumper(s) can cause:
  - Severe equipment damage
  - Electrical noise / EMI
  - Stress on drive and motor

Kinetix 5700 DFE Example

Ground Configuration	2198-P*xxx* DC-bus Power Supply
Grounded (wye)	Ground screw installed (default setting) (1)
• Impedance grounded • Corner grounded • AC-fed ungrounded	Remove ground screw/jumper

(1) Ground screw is factory installed.

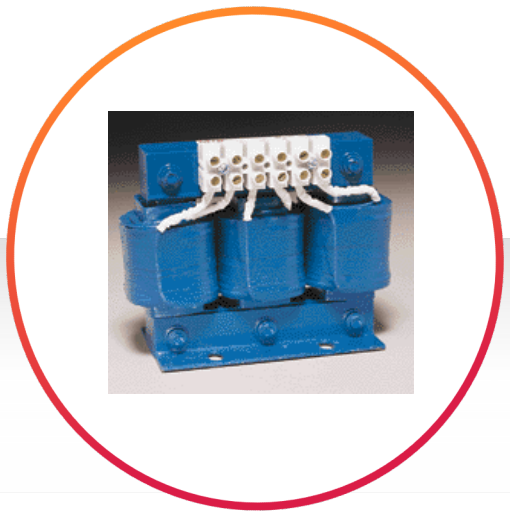
PowerFlex 755 Example

Recommended Power Jumper Configurations – Frames 1...7

Power Source Type	Jumper PE-A (1) (2) (MOV / Input Filter Caps)	Jumper PE-B (DC Bus Common Mode Caps)	Benefits of Correct Configuration on Power Source Type
Non-solid Ground • AC fed ungrounded • Impedance grounded • B phase ground • DC fed from an active converter	Disconnected	Disconnected	Helps avoid severe equipment damage when ground fault occurs.
Solid Ground • AC fed solidly grounded • DC fed from passive rectifier, which has a solidly grounded AC source	Connected	Connected	Reduced electrical noise, most stable operation, EMC compliance, reduced voltage stress on components and motor bearings.

(1) When MOVs are disconnected, the power system must have its own transient protection to maintain known and controlled voltages.
(2) Frame 5...7 Common DC Input drives do not have the PE-A jumper.

Isolation Transformer vs Line Reactors



Isolation Transformers

Are generally used to:

- Used to adjust Voltage with Taps
- Establish a grounded secondary
- Provide additional source impedance
- Add a neutral secondary
- Helps prevent upstream power distribution from creating high-phase to neutral voltage
- Evaluate SCCR may be needed to reduce available fault current.

Transformers will not saturate as quickly as a reactor and therefore provide a better solution on distributions having Power Factor correction capacitors or subject to non-sinusoidal transients.

Cost $$$, Size $$$

Line Reactors

Are generally used to:

- Provide additional source impedance
- Dampen input voltage signal from poor power quality
- Line Reactors also help reduce harmonics back into the power system
- Up to (5) drives may be grouped on (1) input line reactor
- Line Reactors help buffer the drive from transients

Cost $, Size $ - Pub 1321

Rule of Thumb

1. Is the transformer kVA greater than the drive kVA?
   - **10x** for drives **without** built-in inductors
   - **20x** for drives **with** built-in inductors

2. Is the transformer impedance less than 0.5% of the VFD?

If so, ADD IMPEDANCE

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Load Side Installation

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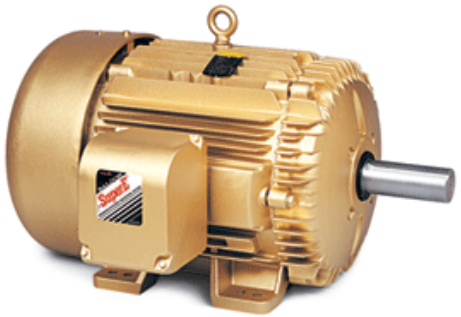
Motor Recommendations

Must be capable of withstanding voltage spikes of **2x** with rise time of > 0.1 µS.

"Inverter Duty Rated" or "Premium" usually specifies better THERMAL rating, not insulation breakdown; don't be confused by thermal ratings and voltage ratings

Motor manufacturers are improving their design to increase their insulation. Many motor manufacturers offer 0.5-600+ HP motors (1600, 1850 volt category) that meets the NEMA MG1 specification

Motors that meet NEMA MG1, Part 31, 1992 480-690 volt applications provides assurance of insulation robustness



Did you know?

NEMA MG1, Part 31 titled "Definite-purpose Inverter-fed Motors"

Is an industry standard that deals with PWM drives and motors. Part 31of NEMA MG 1 states that motors rated for operation at 600V or less should be capable of withstanding voltage peaks up to 1600V with a rise time that is not less than 0.1µS.

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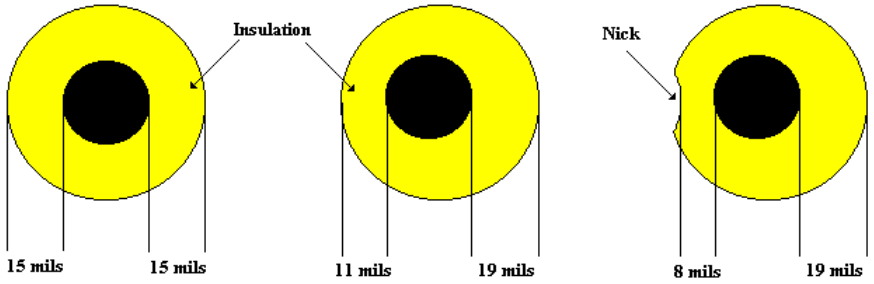
THHN vs VFD Cable



- Notoriously inconsistent insulation thickness.
- Brittle nylon coating that lends itself to damage (i.e. nicks, cuts) when pulled through long conduit runs with multiple 90 degree bends in the conduit.
- Nicks reduce the thickness of the insulation which may be a starting point for corona that leads to insulation degradation.

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Motor Cable Length is Important!

Motor Cable Length Restrictions Tables

The distances listed in each table are valid only for specific cable constructions and may not be accurate for lesser cable designs, particularly if the length restriction is due to cable charging current (indicated in tables by shading). When choosing the proper cable, note the following definitions:

Unshielded Cable

- Tray cable - fixed geometry without foil or braided shield but including an exterior cover
- Individual wires not routed in metallic conduit

Shielded Cable

- Individual conductors routed in metallic conduit
- Fixed geometry cables with foil or braided shield of at least 75% coverage
- Continuous weld or interlocked armored cables with no twist in the conductors (may have an optional foil shield)

IMPORTANT Certain shielded cable constructions may cause excessive cable charging currents and may interfere with proper application performance, particularly on smaller drive ratings. Shielded cables that do not maintain a fixed geometry, but rather twist the conductors and tightly wrap the bundle with a foil shield may cause unnecessary drive tripping. Unless specifically stated in the table, the distances listed ARE NOT applicable to this type of cable. Actual distances for this cable type may be considerably less.

Type A Motor

PowerFlex 753 & 755 Drives

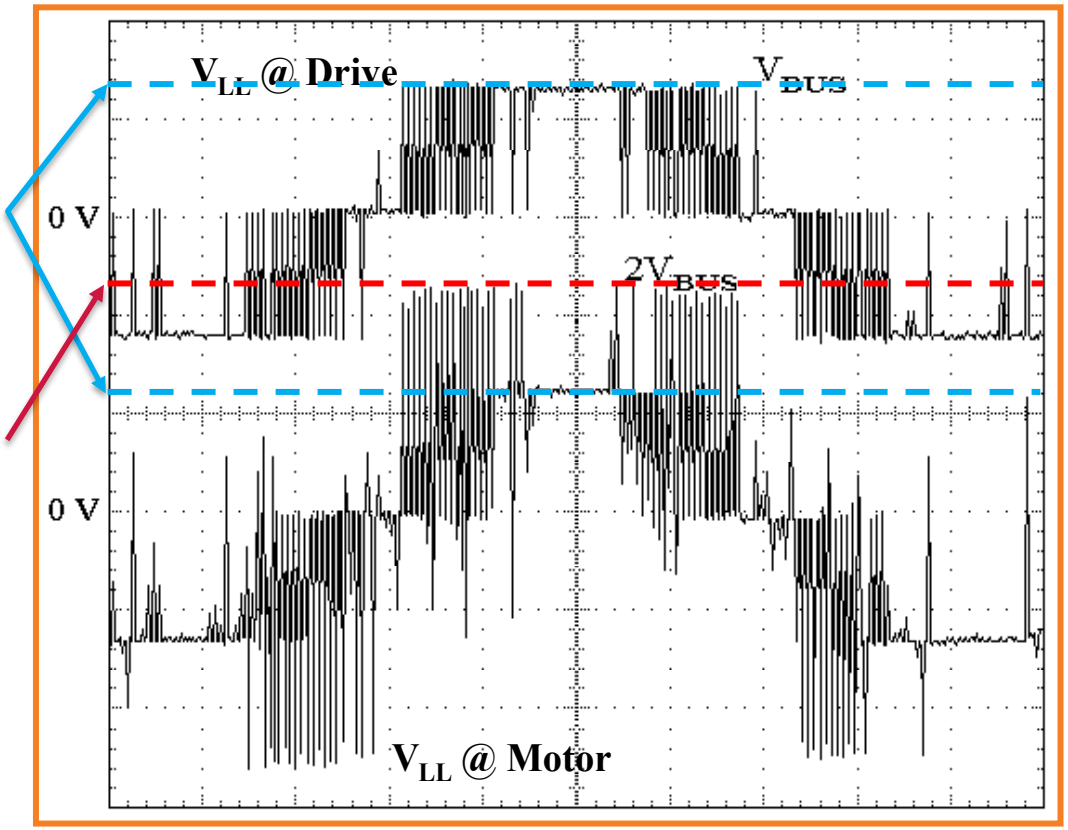
Table 43 - PowerFlex 753 & 755, 400V Shielded/Unshielded Cable - Meters (Feet)

Drive	Rating		No Solution				Reactor Only				Reactor + Damping Resistor or 1321-RWR				Reactor/RWR (see page 113)	Resistor		Available Options			
Frame	kW	kHz	1000V	1200V	1488V	1600V	1000V	1200V	1488V	1600V	1000V	1200V	1488V	1600V	Cat. No.	Ohms	Watts	TFA1	TFB2	RWF2	RWC
2	7.5	2	7.6 (25)	137.2 (450)	365.8 (1200)	365.8 (1200)	91.4 (300)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	1321-RWT18-DP				●		●
		4	7.6 (25)	91.4 (300)	152.4 (500)	213.4 (700)	18.3 (60)	91.4 (300)	365.8 (1200)	365.8 (1200)	182.9 (600)	304.8 (1000)	365.8 (1200)	365.8 (1200)	1321-RWT18-DP						●
	11	2	7.6 (25)	137.2 (450)	365.8 (1200)	365.8 (1200)	91.4 (300)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	1321-RWT25-DP				●		
		4	7.6 (25)	91.4 (300)	152.4 (500)	213.4 (700)	18.3 (60)	91.4 (300)	365.8 (1200)	365.8 (1200)	182.9 (600)	304.8 (1000)	365.8 (1200)	365.8 (1200)	1321-RWT25-DP						
3	15	2	7.6 (25)	137.2 (450)	365.8 (1200)	365.8 (1200)	91.4 (300)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	1321-RWT35-DP				●		
		4	7.6 (25)	91.4 (300)	152.4 (500)	213.4 (700)	18.3 (60)	91.4 (300)	365.8 (1200)	365.8 (1200)	182.9 (600)	304.8 (1000)	365.8 (1200)	365.8 (1200)	1321-RWT35-DP						
	18.5	2	7.6 (25)	137.2 (450)	365.8 (1200)	365.8 (1200)	91.4 (300)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	1321-RWT35-DP				●		
		4	7.6 (25)	91.4 (300)	152.4 (500)	213.4 (700)	18.3 (60)	91.4 (300)	365.8 (1200)	365.8 (1200)	182.9 (600)	304.8 (1000)	365.8 (1200)	365.8 (1200)	1321-RWT35-DP						
	22	2	7.6 (25)	137.2 (450)	365.8 (1200)	365.8 (1200)	91.4 (300)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	1321-RWT45-DP				●		
		4	7.6 (25)	91.4 (300)	152.4 (500)	213.4 (700)	18.3 (60)	91.4 (300)	365.8 (1200)	365.8 (1200)	182.9 (600)	304.8 (1000)	365.8 (1200)	365.8 (1200)	1321-RWT45-DP						
4	30	2	7.6 (25)	137.2 (450)	304.8 (1000)	365.8 (1200)	91.4 (300)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	1321-RWT55-DP				●		
		4	7.6 (25)	91.4 (300)	152.4 (500)	213.4 (700)	18.3 (60)	91.4 (300)	365.8 (1200)	365.8 (1200)	182.9 (600)	304.8 (1000)	365.8 (1200)	365.8 (1200)	1321-RWT55-DP						
	37	2	12.2 (40)	137.2 (450)	304.8 (1000)	365.8 (1200)	91.4 (300)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	365.8 (1200)	1321-RWT80-DP				●		
		4	12.2	91.4	152.4	213.4	18.3	91.4	365.8	365.8	182.9	304.8	365.8	365.8	1321-RWT80-DP						

Reflective Wave Waveforms

Peak Voltage generated at VFD output terminals

Peak Voltage generated at Motor terminals due to reflected wave



Drive

Motor

Did you know?

What is reflected wave?

- They are the high frequency voltages on top of the DC bus voltage that dealt with at the motor and are seen at the cable, motor and back at the VFD.
- Reflected waves occur due to a mismatch in impedance between the motor cables and the motor.
- Caused by the voltage rise time (dv/dt) of the IGBT switching and made worse by long cable lengths.

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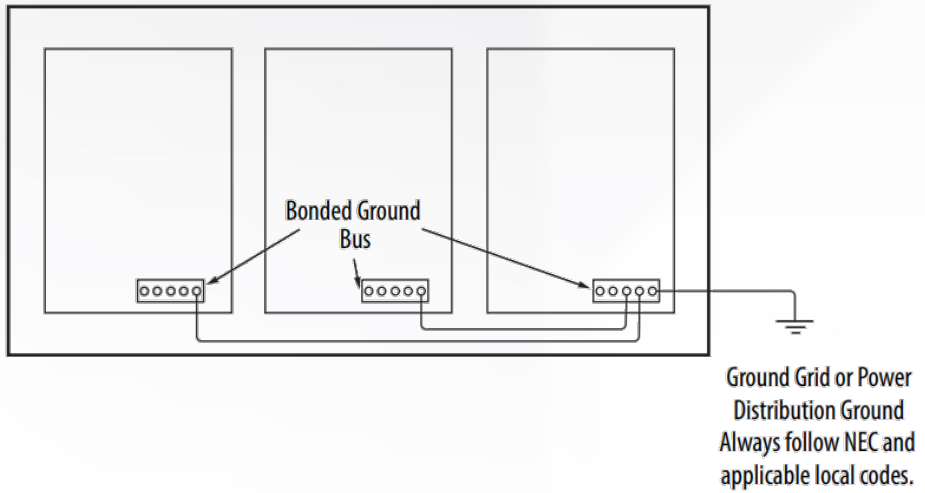
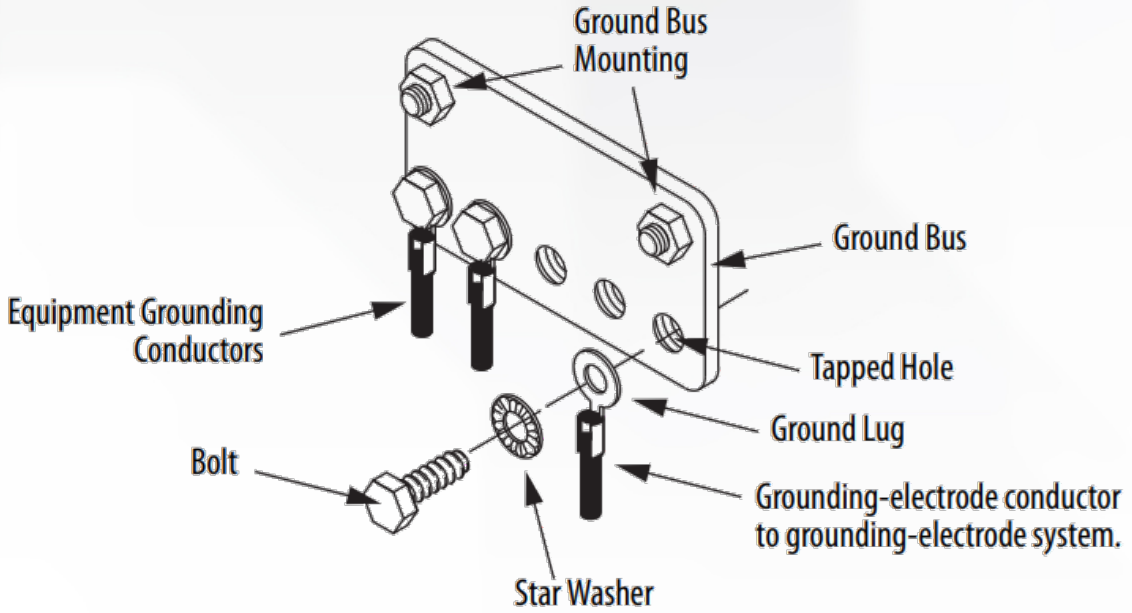
Grounding

- All ground should have one and only one path to utility earth ground (**Star Grounding**)
- Multiple ground bars, subpanels, enclosures, or equipment should not cross-connect
- Minimize the risk of **ground loops** which can cause undesirable performance of equipment
- Grounding must be accomplished by dedicated conductor – mechanical connection is not sufficient
- Design ground connections to be gas-tight and robust against age and corrosion
- Follow NEC and local codes for sizing grounding conductors
  - 14 AWG is typically the smallest permissible grounding conductor





Panel Layouts and Wire Segregation

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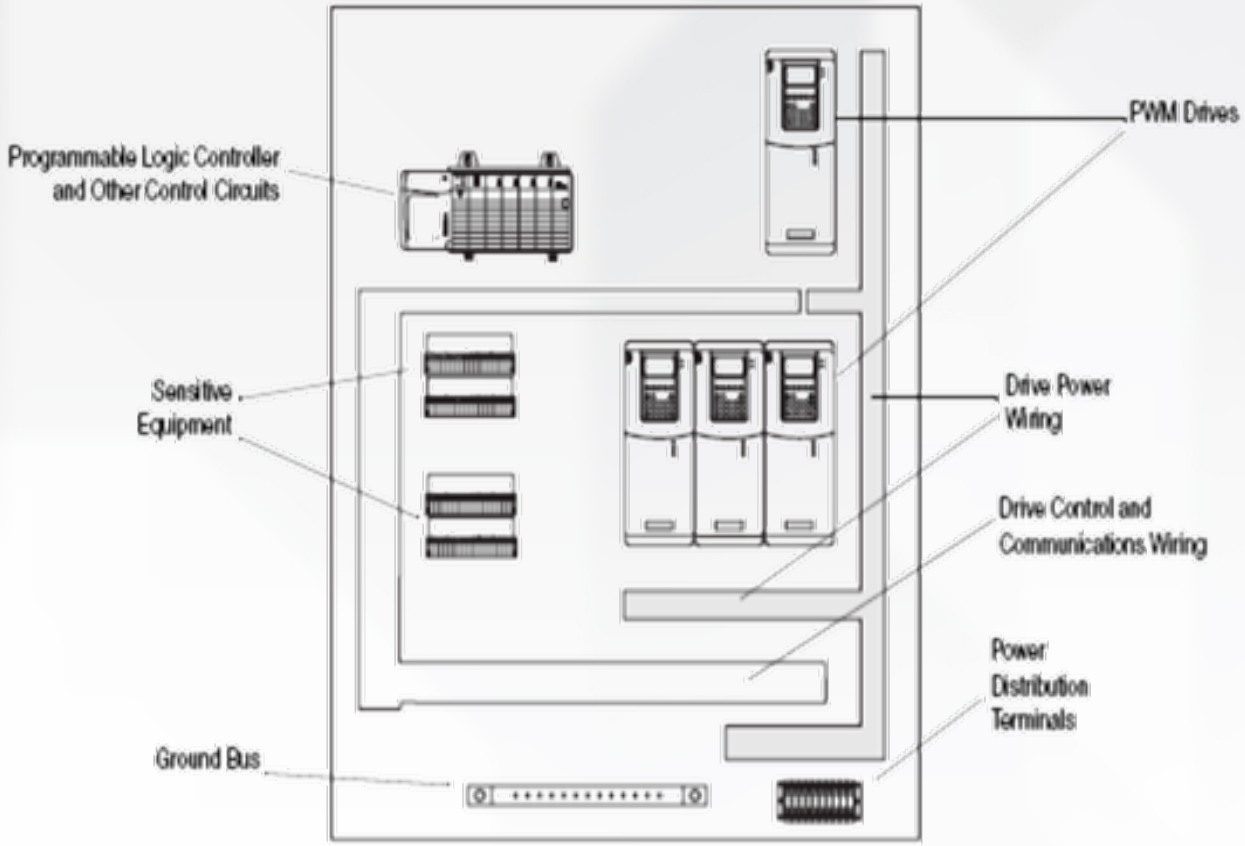
Wiring Segregation

- Thoughtful layout of enclosures can eliminate many noise related issues down the road
- Create noise “zones” within your enclosure
- Segregate low voltage sensitive signals (encoders, registration sensors, communication, etc.) from dirty signals (VFD PWM motor outputs, incoming utility power, shunt resistor wiring, etc.)
- Refer to drive User Manual or Installation Manual for layout guidance



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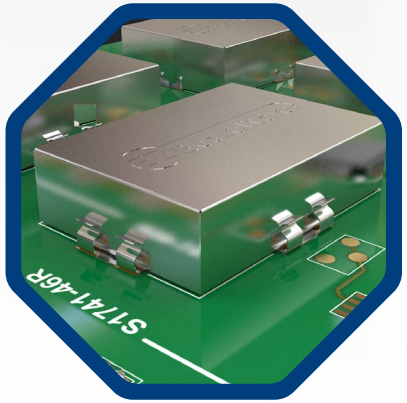
EMI Mitigation

What is EMI?

- Electro-Magnetic Interference (EMI) is unwanted electrical currents and voltages induced onto sensitive equipment
- May cause faults or undesirable operation
- May be difficult to troubleshoot or resolve
- Often causes difficult to explain faults or behavior in affected equipment

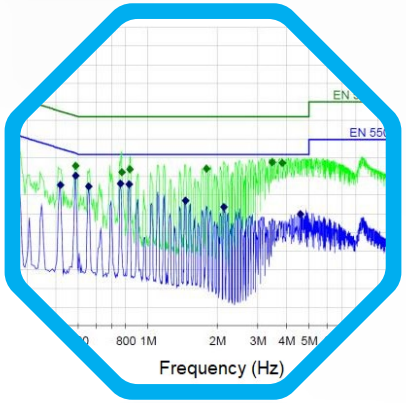
Intra-System EMI

- Expected by the product manufacturer
- Well controlled
- Stays within product and does not affect external equipment



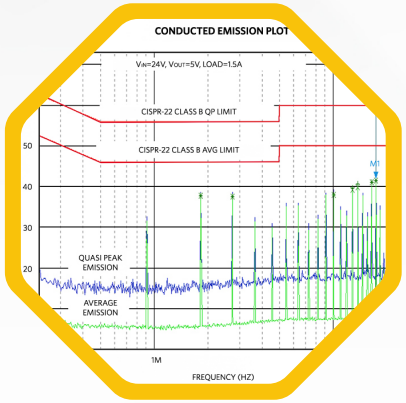
Radiated EMI

- Unintentional Interference
- Radiated through air as EM Waves
- Picked up by sensitive equipment, wires, enclosures, etc.
- Induces unwanted currents and voltages on receiving equipment



Conducted EMI

- Unintentional Interference
- Conducted through wires and cables
- Affects equipment with wired connections (including ground) to the EMI producing equipment



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EMI Mitigation Priority

1. **Reduce or shield EMI source**
   - Proper grounding and bonding of VFD and shielded motor cable
   - EMC Ferrite cores on VFD outputs
2. **Segregate conductors by noise zones**
   - Run dirty power separately from sensitive encoder, comms, or analog signals
3. **Limit received EMI on sensitive signals**
   - Shield and bond low voltage cables
   - Employ differential pair signaling or 4-20mA analog where possible
4. **Filter out received EMI on sensitive signals**
   - Ferrite beads on signal cables

Temperature, Environment, and Installation

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Equipment Longevity

- Drives lifetime is heavily influenced by the environment in which it is installed
- Most important factors are:
  - Temperature
  - Humidity
  - Dust and Corrosive gasses
- Excessive heat stresses IGBTs in the drive and eventually causes failure
- Thoughtful design can prevent early wear and tear on your equipment

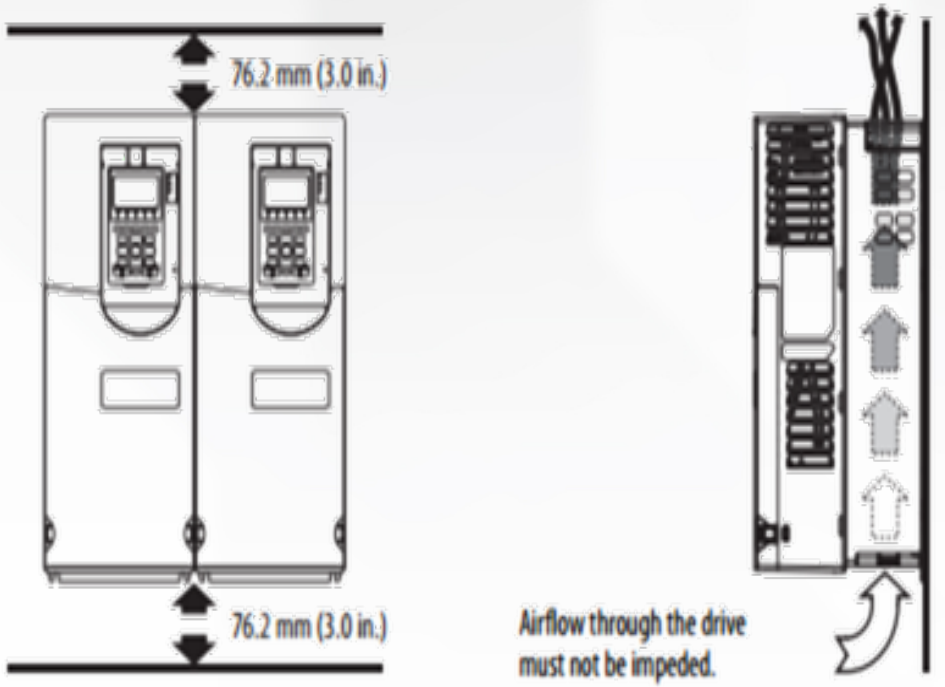
Humidity and Ingress Protection

- VFDs and other control equipment must be protected from condensing humidity and external sources of water spray
- Condensation and power electronics do not mix!
- Thoughtful enclosure design can prevent condensation even in humid environments
- **Externally mounted VFDs** can be purchased up to IP66/NEMA 4X, or VFDs can be packaged in sealed enclosures
- Conformal coating on PCBs provides added protection against moisture and corrosion

Drive Installation and Clearances

- Drive installation manuals (e.g., 750-IN001) will provide guidance on clearance between and above/below drives
- Clearance is necessary for proper cooling without derating
- Some drives allow zero-stacking to increase panel density
- Airflow must not be obstructed

Figure 11 - Minimum Mounting Clearances – Wall Mount Frames 1...7



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Corrosive Gases

Solution: XT for Extreme Environments

Introducing additional protection against ***GX level corrosive gas environments***

Standard offering on PowerFlex 755TL/TR/TM (Optional PF755TS)

Validated to operate in environments rated **GX** per ISA 71.03-2013 and **CX** per IEC 60721-3-3:2019

XT IGBTs

Enhanced conformal coating

Critical connection protection

Protected fans

Environment-resistant packaging

Plugs and Covers

PowerFlex architecture-class AC drives portfolio w/ XT Features

Optional Frame 8 & 9

PowerFlex 753 & 755

1...1800 Hp / 0.75...1400 kW

- Speed, Torque & Position Control
- XT Option (Frame 8 & 9)
- 6-pulse Drive
- **FORCE Technology**

Optional

PowerFlex 755TS

1...400 Hp / 0.75... 270 kW

- Speed, Torque & Position Control
- XT Option
- CIP Security
- 6-Pulse Drive
- **TotalFORCE Technology**

PowerFlex 755TL/TR

10...6000 Hp / 7.5...4500 kW

- Speed, Torque & Position Control
- XT Standard
- Liquid Cooled Option
- Regeneration & Low Harmonic
- **TotalFORCE Technology**

PowerFlex 755TM

250...6000Hp/160...4500kW (AC)
70...4800 kW (DC)

- Speed, Torque & Position Control
- XT Standard
- Common Bus Drive System
- AFE or 6-pulse supply
- Non-regen bus supply
- **TotalFORCE Technology**

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CIP Security

- Provides a secure transport layer in an EtherNet/IP™ network which
- Allows the drive to help protect itself from malicious communications
- Configured using FactoryTalk® Policy Manager

Identity, authentication which helps prevent unauthorized devices from establishing communications.

Integrity that helps prevent tampering or modification of communications.

Confidentiality that helps prevent snooping or disclosure of data

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