Rockwell Automation

expanding **human possibility**™

VFD Installation Considerations

Thomas Svoren Sr Technical Consultant

Rockwell Automation Resources

- DRIVES-IN001 – Wiring and Grounding Guidelines for PWM AC Drives
- DRIVES-AT003 – Industry Installation Guidelines for PWM AC Drives
- 750-IN001 – PowerFlex 750 Drives Installation Instructions
- 520-UM001 – PowerFlex 520 Drives User Manual
- 750-IN100 – PowerFlex 750 Series Products with Total Force Control Installation instructions
- GMC-RM001 - System Design for Control of Electrical Noise
- Drives-AT001 - Drives Engineering Handbook
- Selecting the Best Option for Mounting Low-Voltage AC Drives
  - Jeff Raefield, Power Technical Consultant, Rockwell Automation
- EMI Emissions of Modern PWM AC Drives
  - IEEE Industry Applications Magazine, Vol. 5, No. 6, November/December 1999, pp. 47-81.
  - Gary L. Skibinski, Russel J. Kerkman, and Dave Schlegel

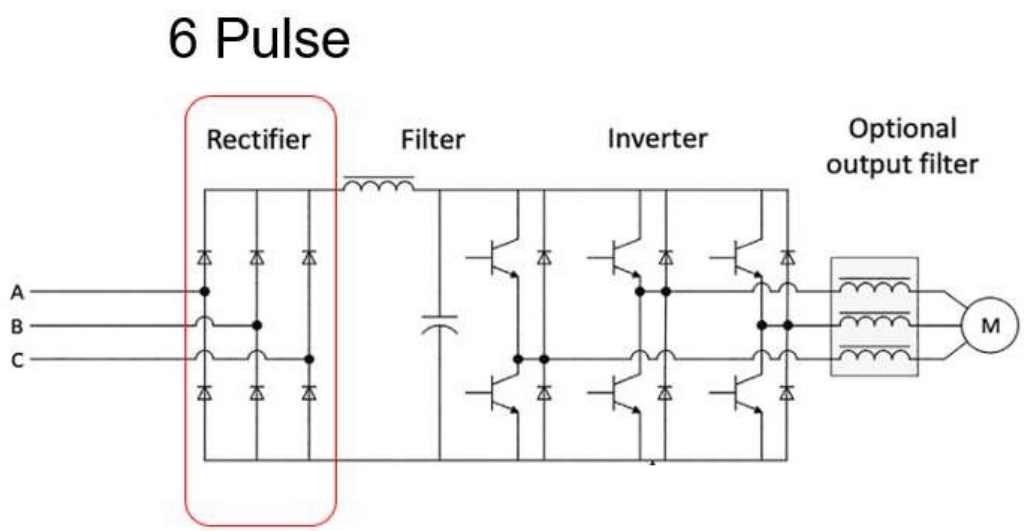
Compatible, Reliable, and Dependable to Keep Your Enterprise Operating

Rockwell Automation

Compatibility of an AC Drive System

Controlling Electro Magnetic Emissions (prevent interference)

Comparing a 6 pulse drive to an AFE drive



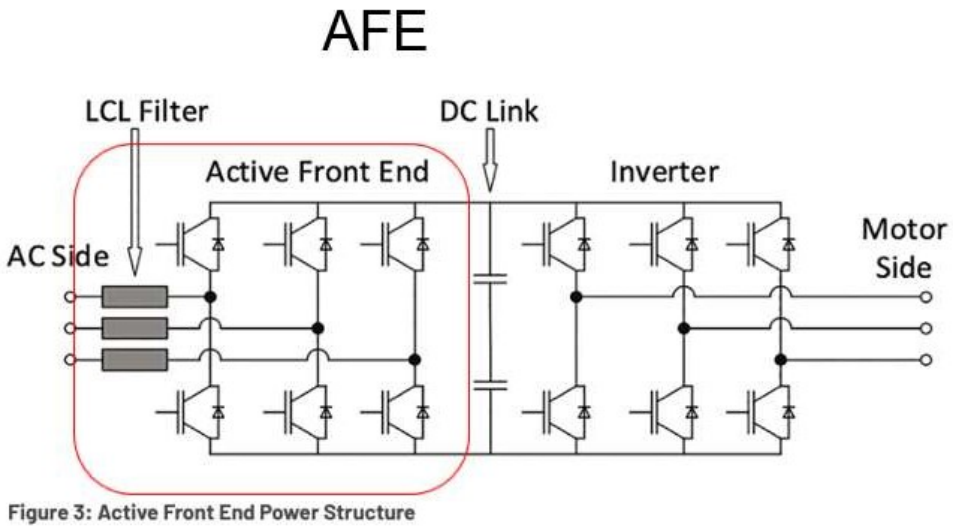
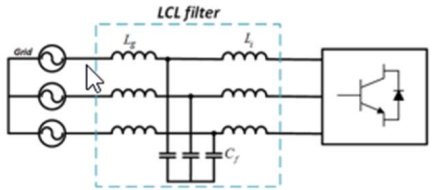
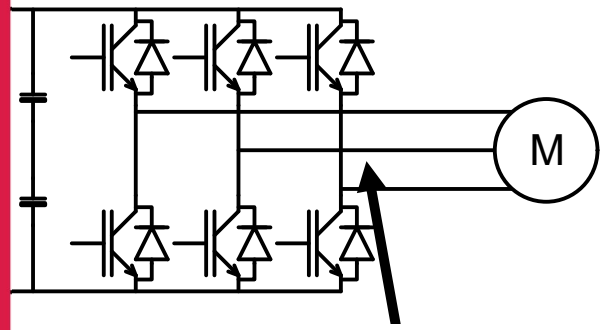


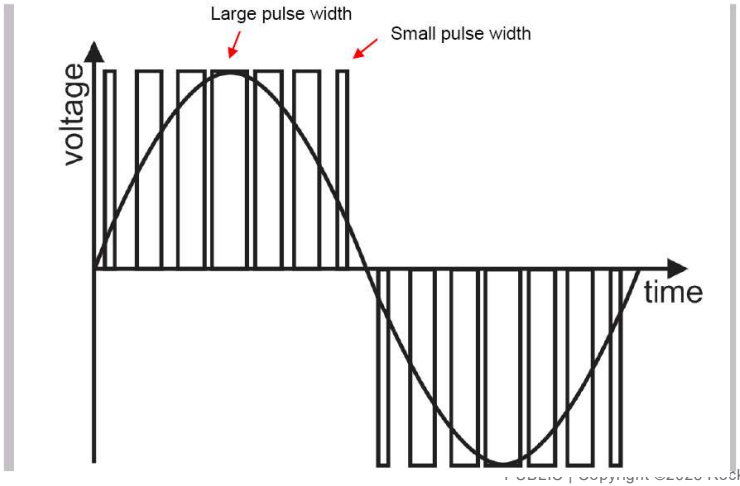
Figure 3: Active Front End Power Structure



What a VFD output voltage and current looks like

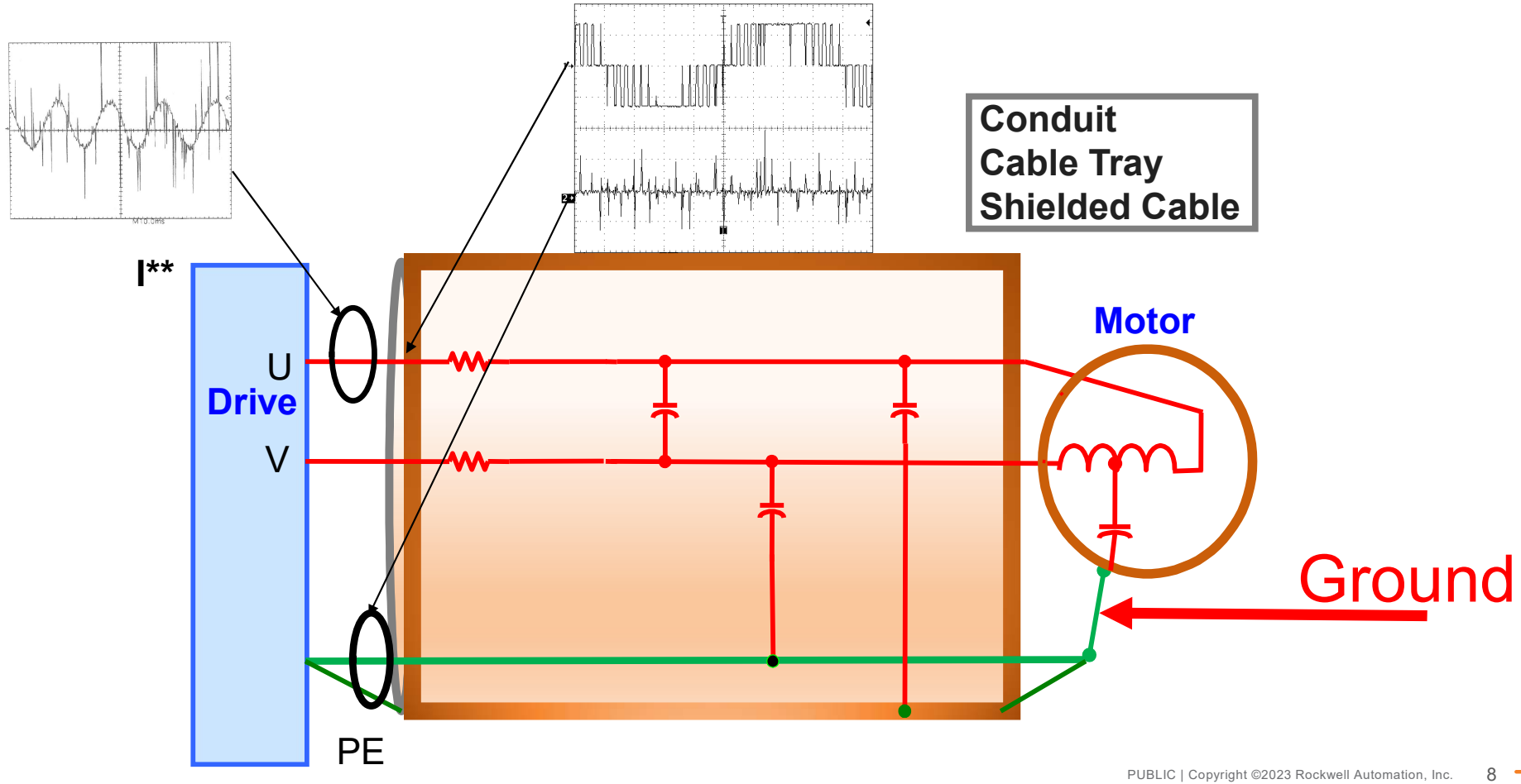
Converter



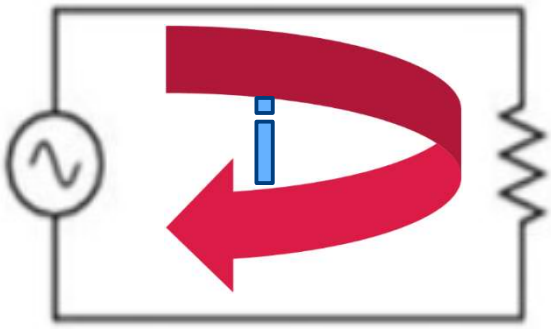


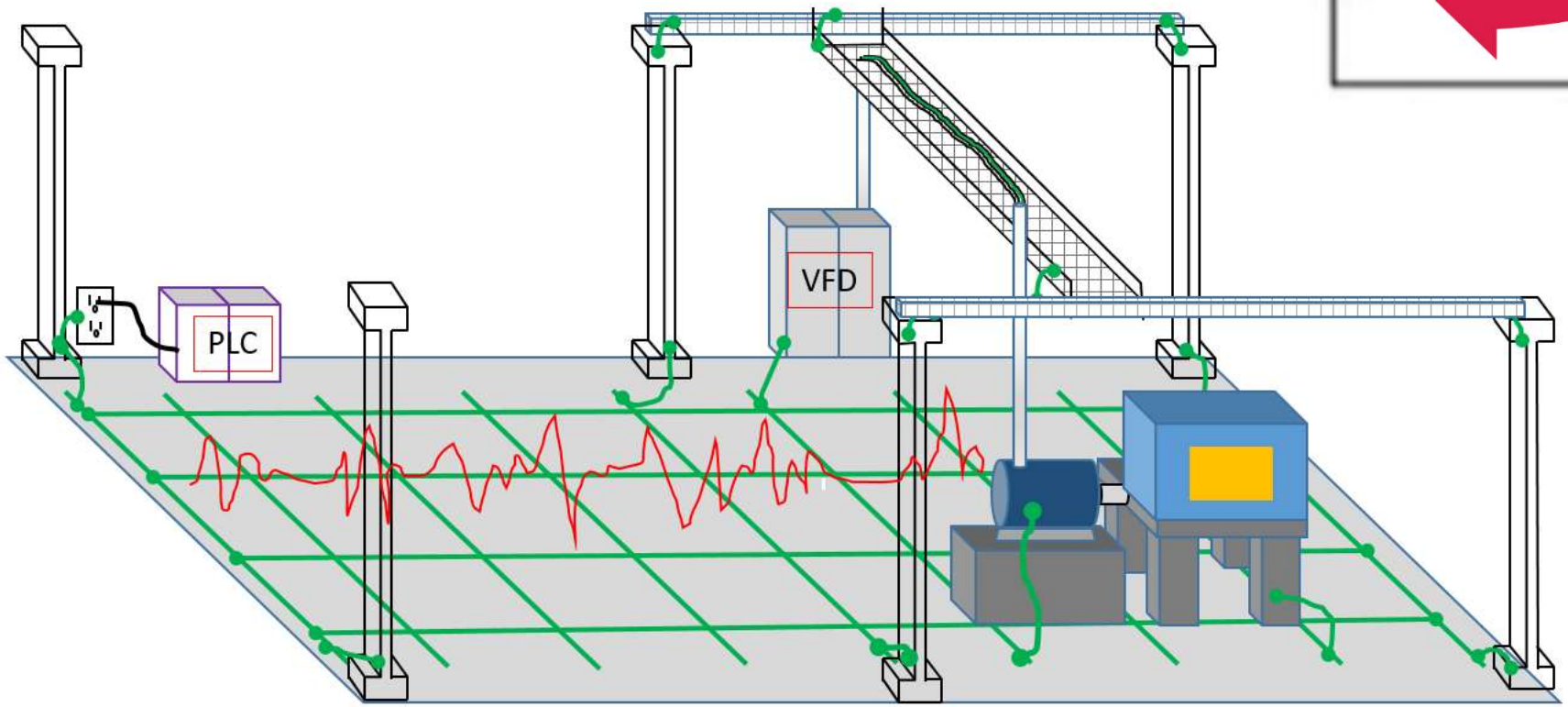
Electrical Characteristics of VFD output cable and motor showing

parasitic capacitance to ground and high frequency common mode current

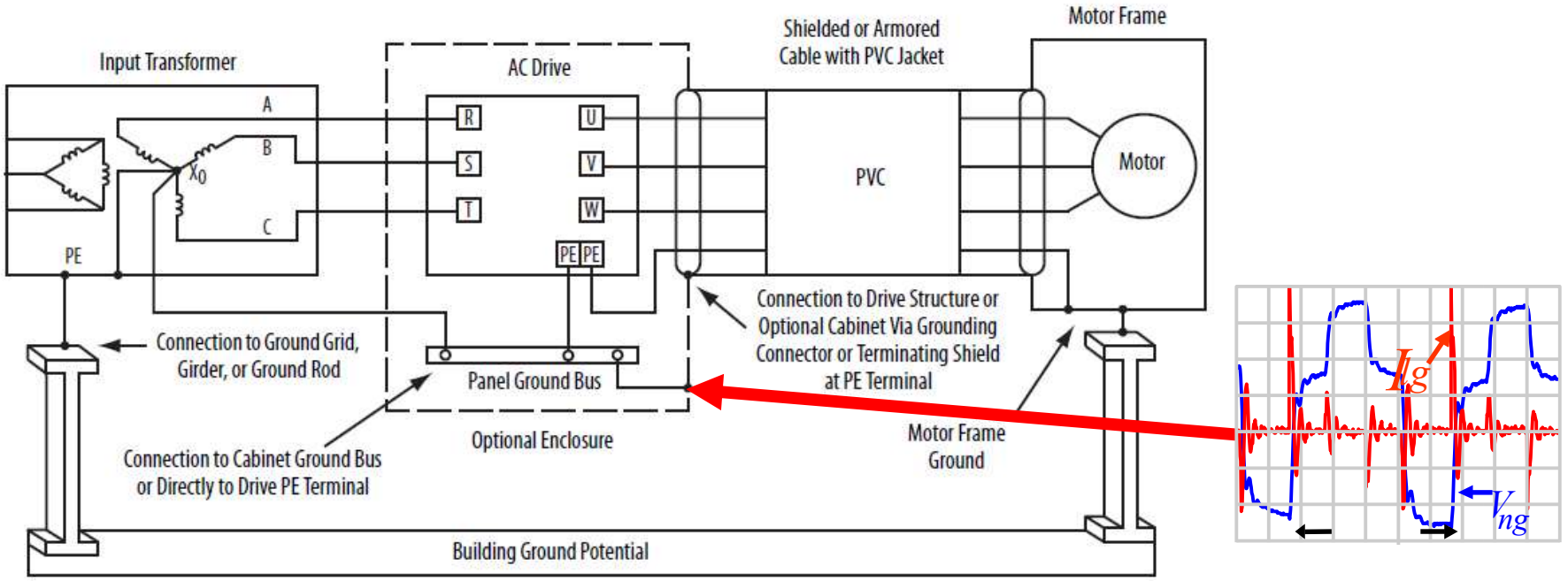


A better illustration

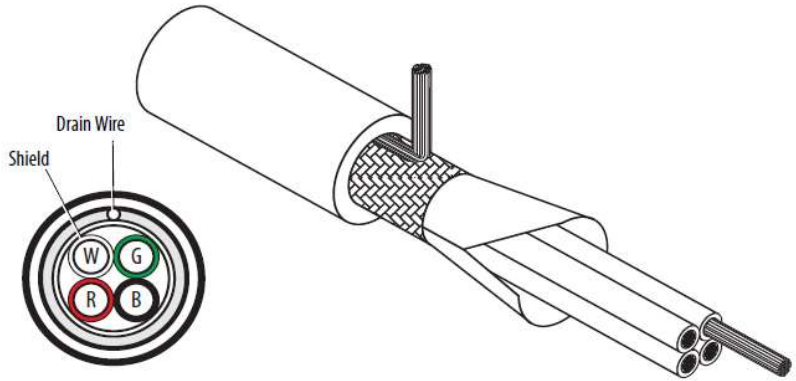




Containing Emissions Using Shield Cable

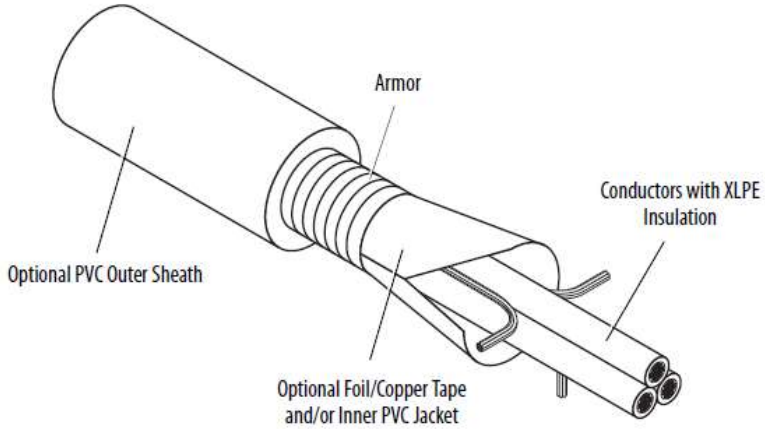


VFD Cable Selection



< 200HP

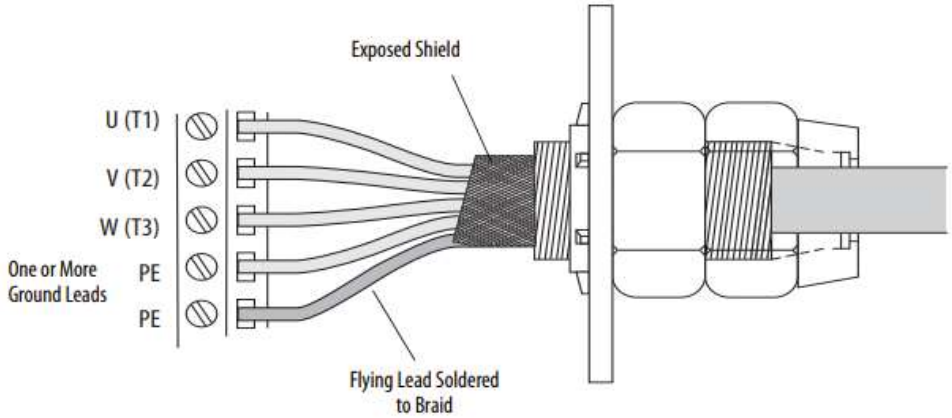
> 200HP



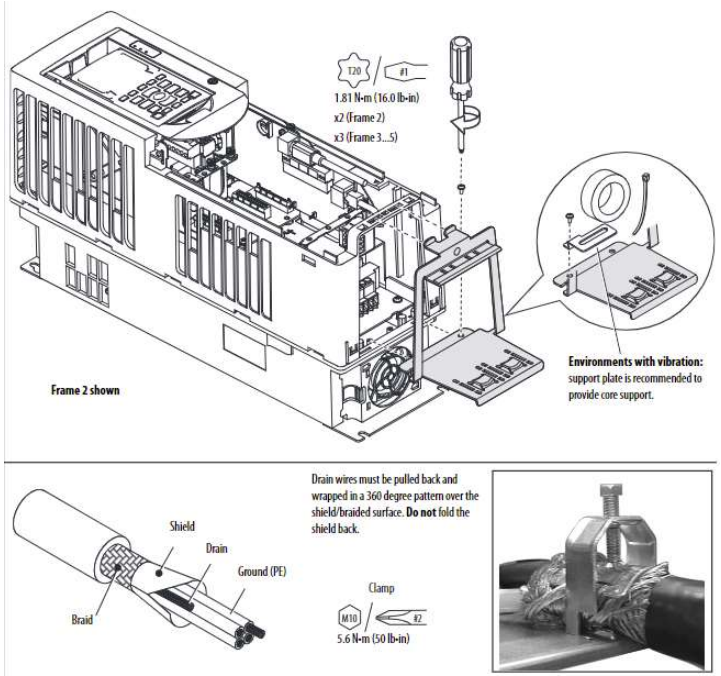
How do you get the shield connected to the drive?

Good

Figure 24 - Terminating the Shield with a Pigtail Lead

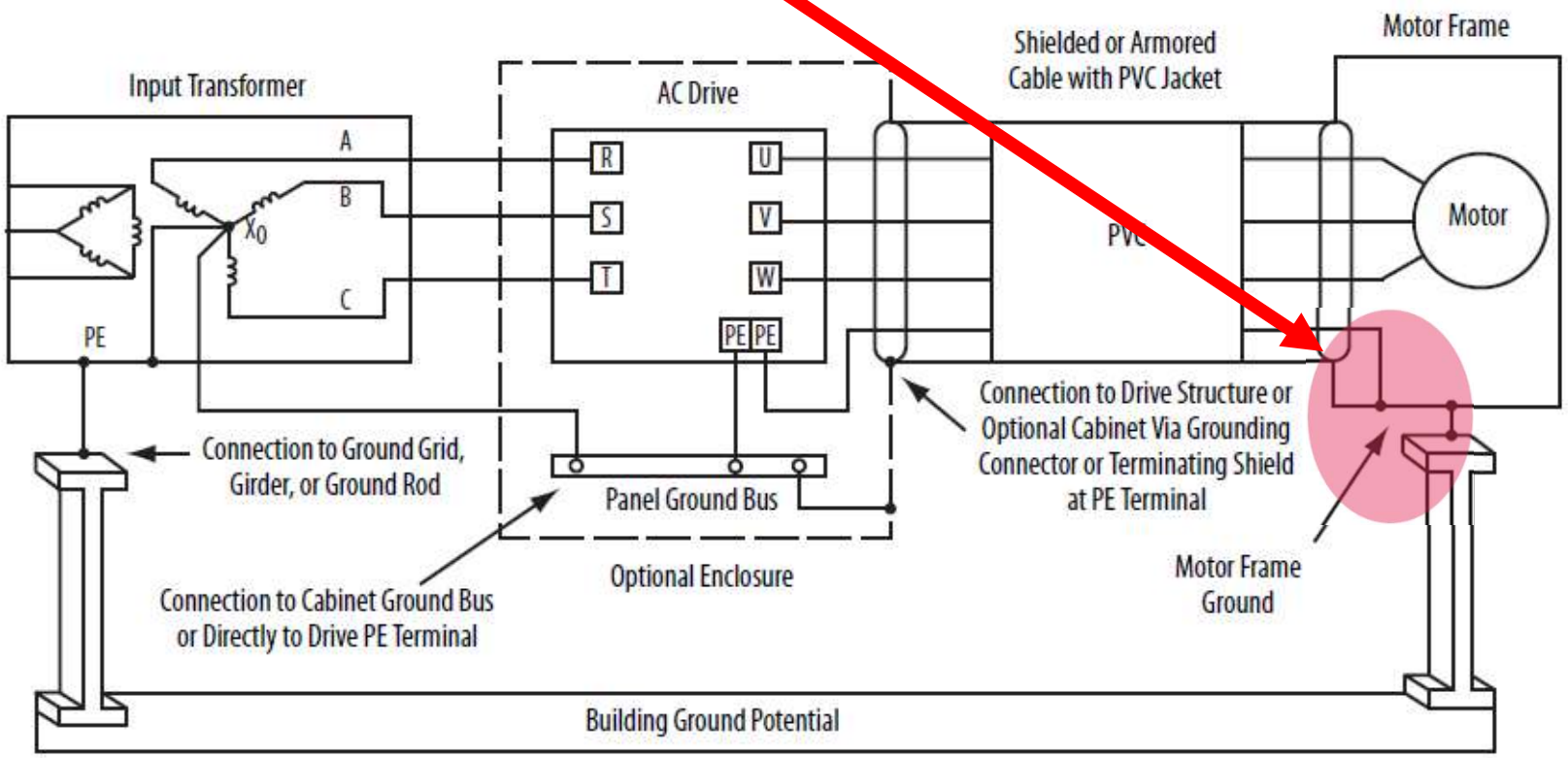


Better



How about on the motor side of the shield?

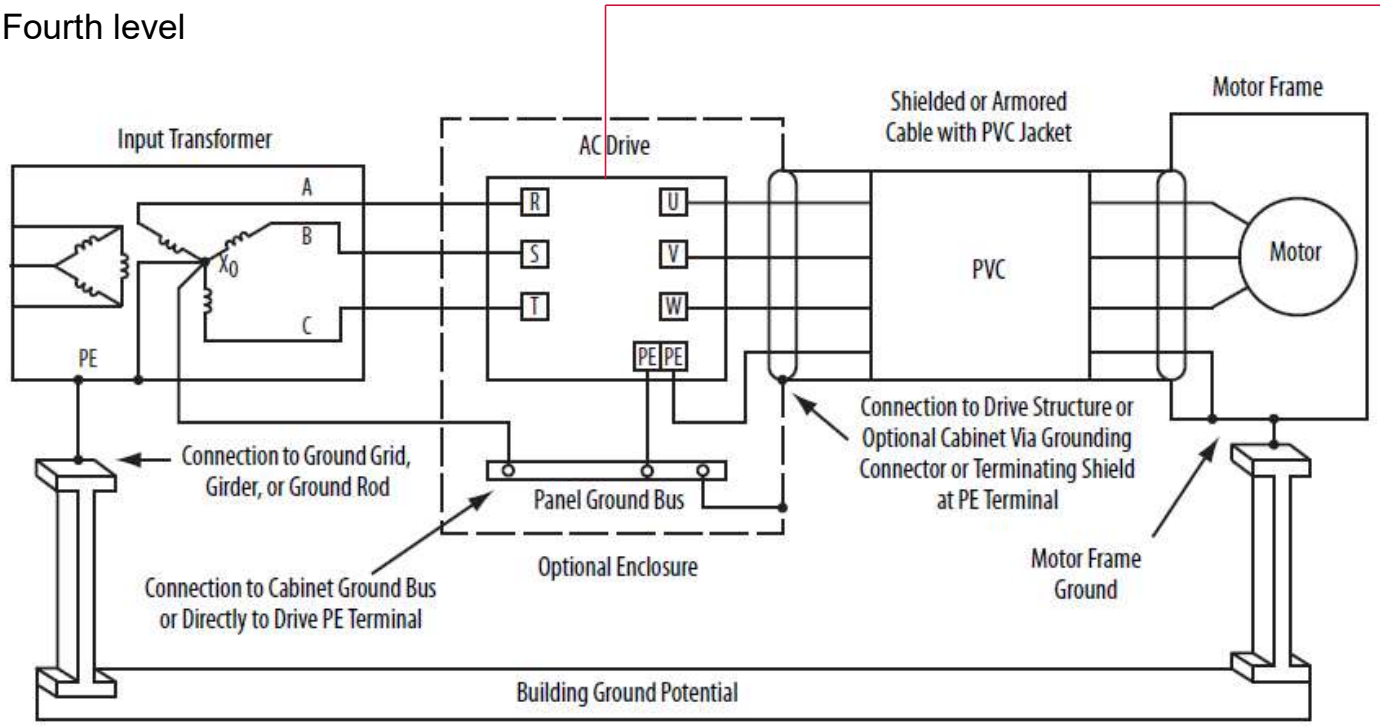
https://www.youtube.com/watch?v=MWwaK2ZVebY



Shield Termination

Containing Emissions Using Shield Cable

- Click to edit Master text
  - Second level
    - Third level
      - Fourth level

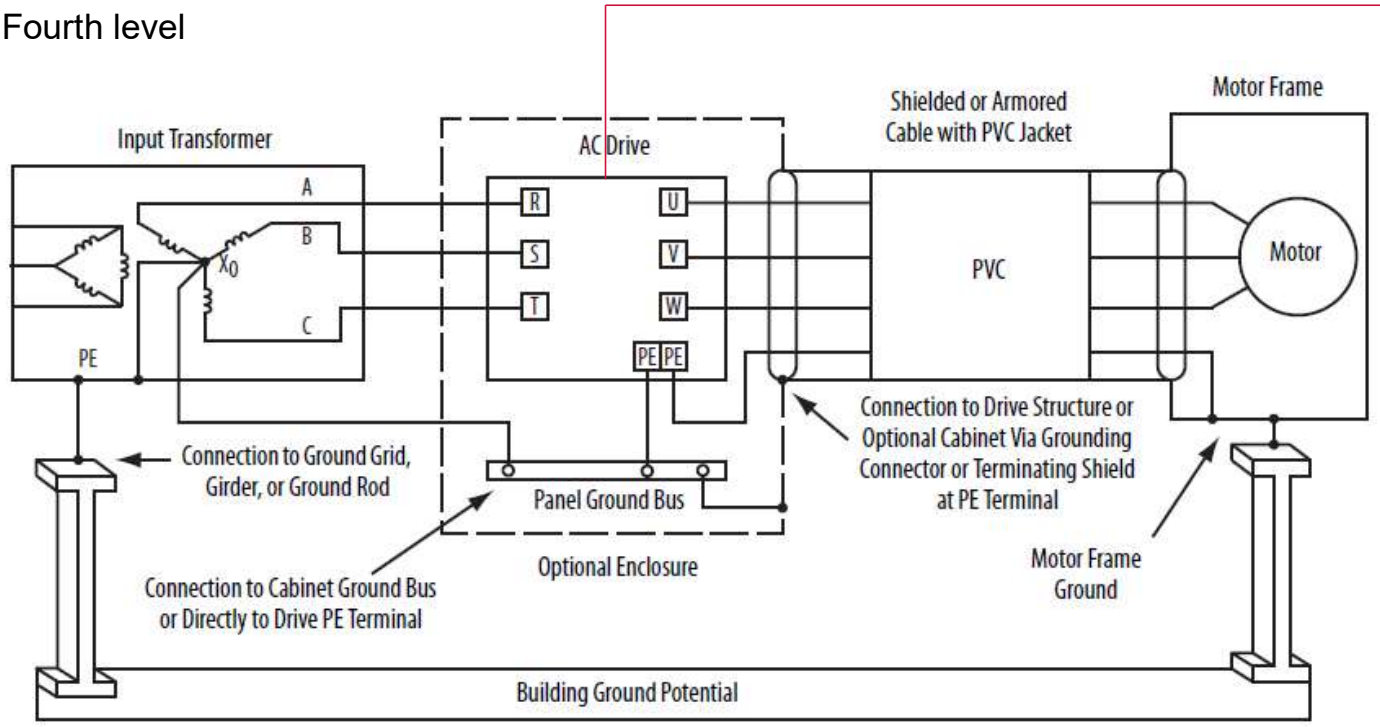


Shield Termination

Hubbell, grounding clamp

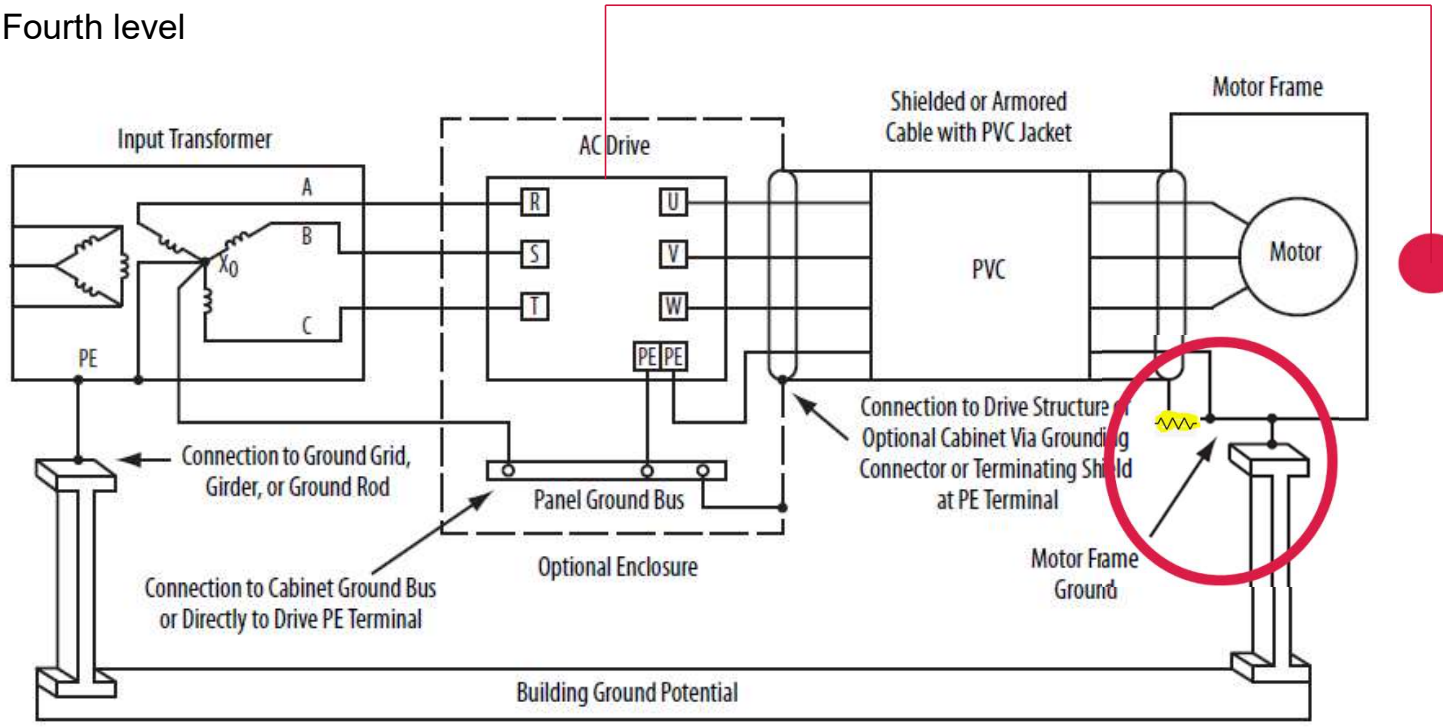
Containing Emissions Using Shield Cable

- Click to edit Master text
  - Second level
    - Third level
      - Fourth level



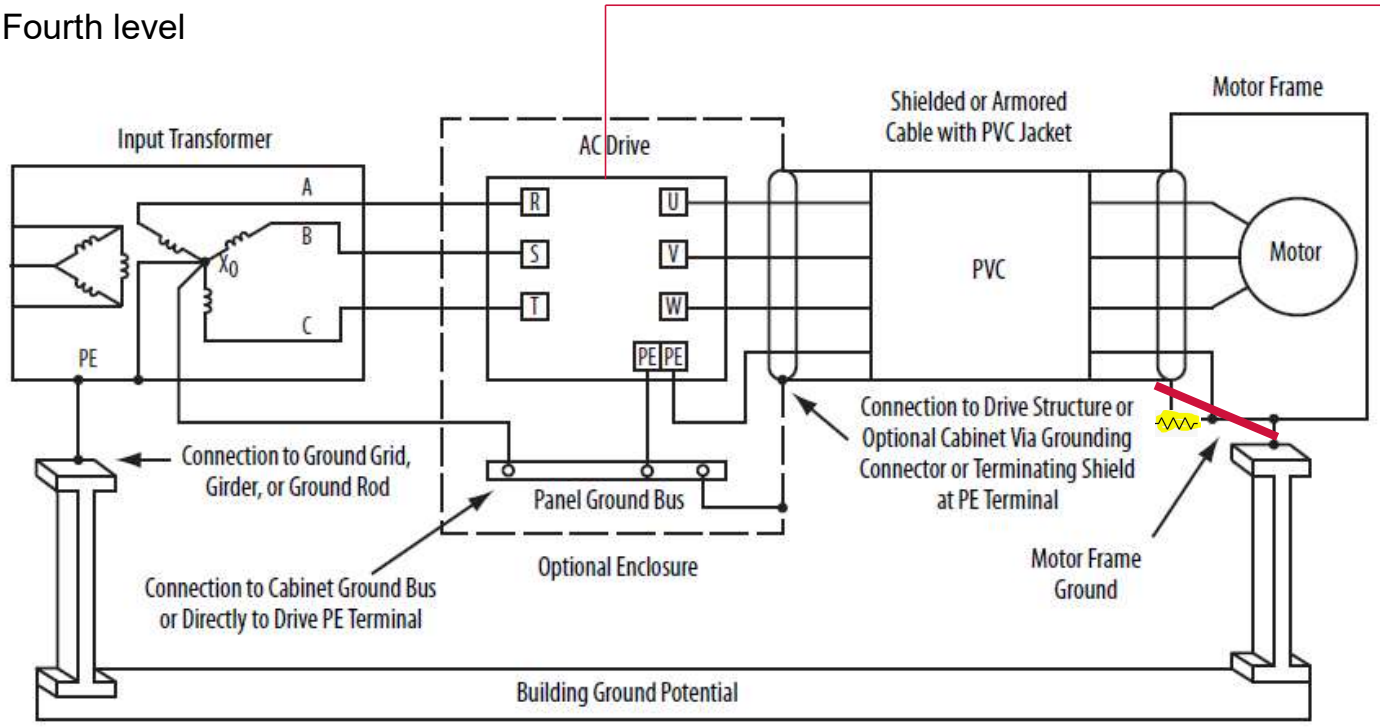
Containing Emissions Using Shield Cable

- Click to edit Master text
  - Second level
    - Third level
      - Fourth level

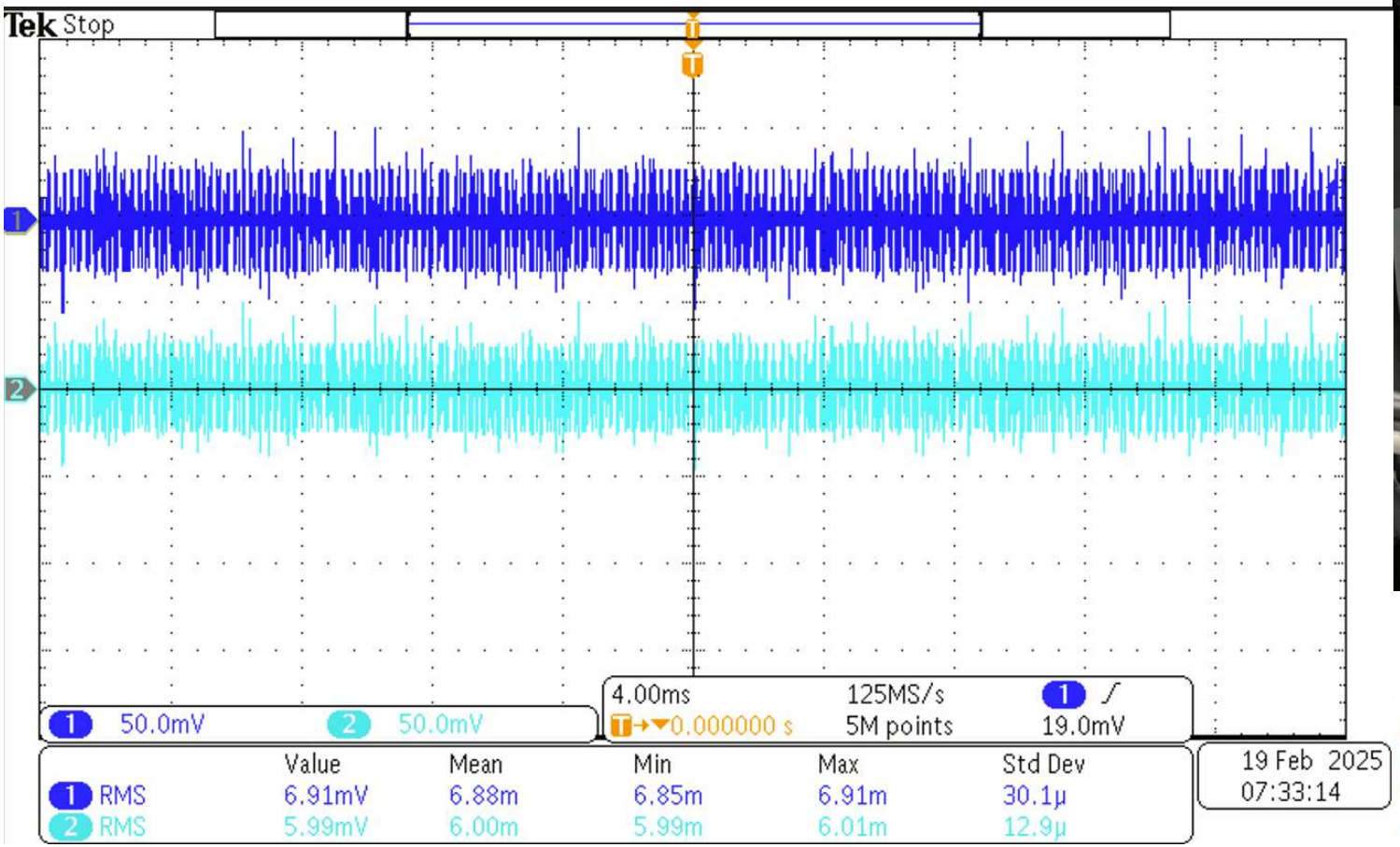


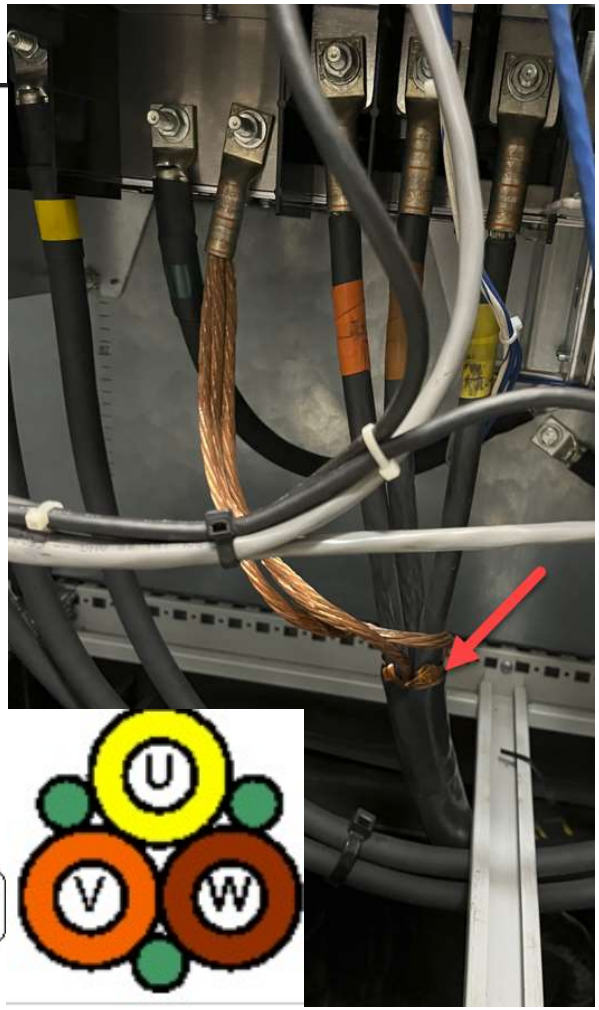
Containing Emissions Using Shield Cable

- Click to edit Master text
  - Second level
    - Third level
      - Fourth level



Connecting the shield





Redirecting Emissions with power jumpers

Table 29 - Recommended Power Jumper Configurations Wall Mount 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	UL compliance, 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 insure known and controlled voltages.
(2) Frame 5…7 Common DC Input drives do not have the PE-A jumper.

What about Active Front End Drives when it comes to power jumpers?

Table 69 - PowerFlex 755TL/TR Drive Jumpers

Grounding Scheme	EMC Option	PE-A	PE-A1	PE-A2	PE-B1	
		MOV on the AC Precharge Control Circuit Board	MOV in the TVSS Module	Common Mode Caps on All AC Common Mode Filter Circuit Boards	Y-Caps on Line Side Converter Power Interface Circuit Boards	Y-Caps on Motor Side Inverter Power Interface Circuit Boards
Factory Default	C3	Connected (In)	Connected (In)	Connected (In)	Disconnected (Out)	Disconnected (Out)
Grounded	C2 (1)	Connected (In)	Connected (In)	Connected (In)	Disconnected (Out)	Disconnected (Out)
	C3	Connected (In)	Connected (In)	Connected (In)	Disconnected (Out)	Disconnected (Out)
Ungrounded/High-resistance Ground (2) AC fed ungrounded Impedance grounded B phase ground	–	Disconnected (Out)	Disconnected (Out)	Disconnected (Out)	Disconnected (Out)	Disconnected (Out)
Marine Ungrounded / High Resistance Ground (1)	–	Disconnected (Out)	Disconnected (Out)	Disconnected (Out)	Disconnected (Out)	Disconnected (Out)

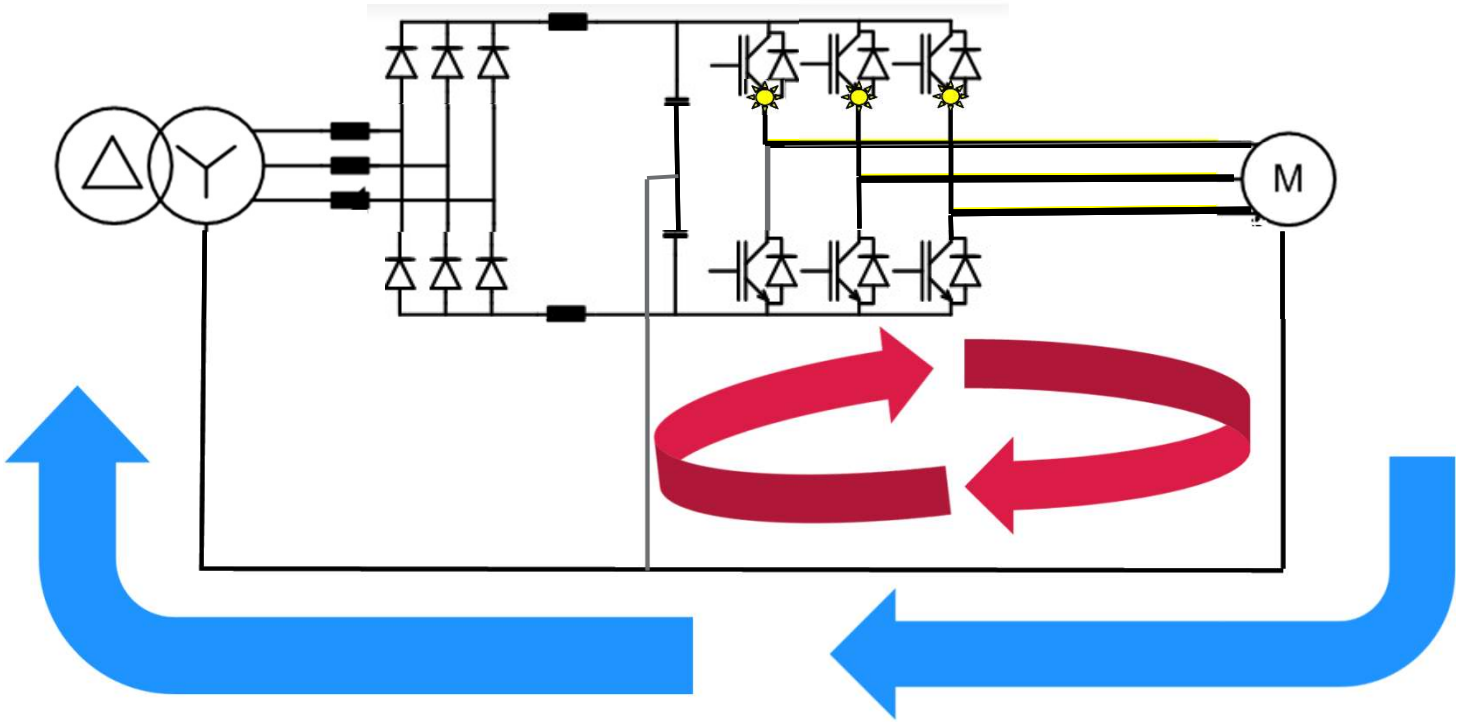
(1) Meets EN61800-3 Category C2 for conducted emissions.
(2) Ungrounded and high-resistance ground systems do not meet the EMC Directive due to the disconnected jumper positions.

Table 70 - PowerFlex 755TM Regenerative Bus Supplies Jumpers

Grounding Scheme	EMC Option	PE-A	PE-A1	PE-A2	PE-B1	
		MOV on the AC Precharge Control Circuit Board	MOV in the TVSS Module	Common Mode Caps on All AC Common Mode Filter Circuit Boards	Y-Caps on Line Side Converter Power Interface Circuit Boards	Y-Caps on Motor Side Inverter Power Interface Circuit Boards
Factory Default	C3	Connected (In)	Connected (In)	Connected (In)	Disconnected (Out)	–
Grounded	C2 (1)	Connected (In)	Connected (In)	Connected (In)	Disconnected (Out)	–
	C3	Connected (In)	Connected (In)	Connected (In)	Disconnected (Out)	–
Ungrounded/High-resistance Ground (2) AC fed ungrounded Impedance grounded B phase ground	–	Disconnected (Out)	Disconnected (Out)	Disconnected (Out)	Disconnected (Out)	–
Marine Ungrounded / High Resistance Ground (1)	–	Disconnected (Out)	Disconnected (Out)	Disconnected (Out)	Disconnected (Out)	–

(1) Meets EN61800-3 Category C2 for conducted emissions.
(2) Ungrounded and high-resistance ground systems do not meet the EMC Directive due to the disconnected jumper positions.

Path of common mode current with jumper



Attenuating Emissions with Common Mode Chokes/Ferrite Applied to Signal Cables i.e Encoders, Analog, Communication

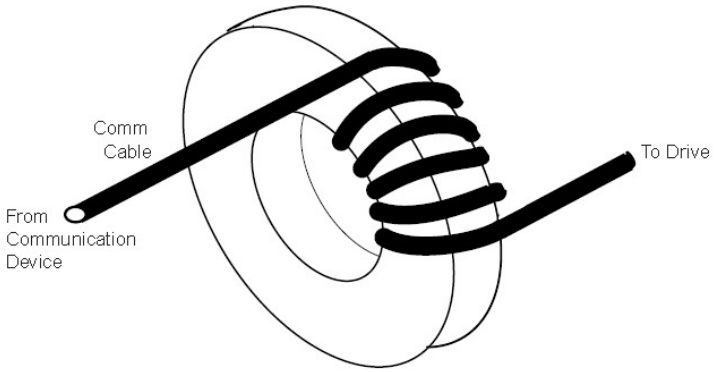
- Cabling – Chapter 6 of Drives-IN001
  - Other hardware
    - Common Mode Cores/Ferrite Chokes

Another effective method of reducing common mode noise is to attenuate the noise before it can reach the ground grid. Install a common mode ferrite core on the output cables to reduce the amplitude of the noise to a level that makes it relatively harmless to sensitive equipment or circuits. Common mode cores are most effective when multiple drives are in a relatively small area. For more information, refer to 1321-M Common Mode Chokes Instructions, publication 1321-5.0.

Follow these guideline as a general rule for installing common mode chokes:

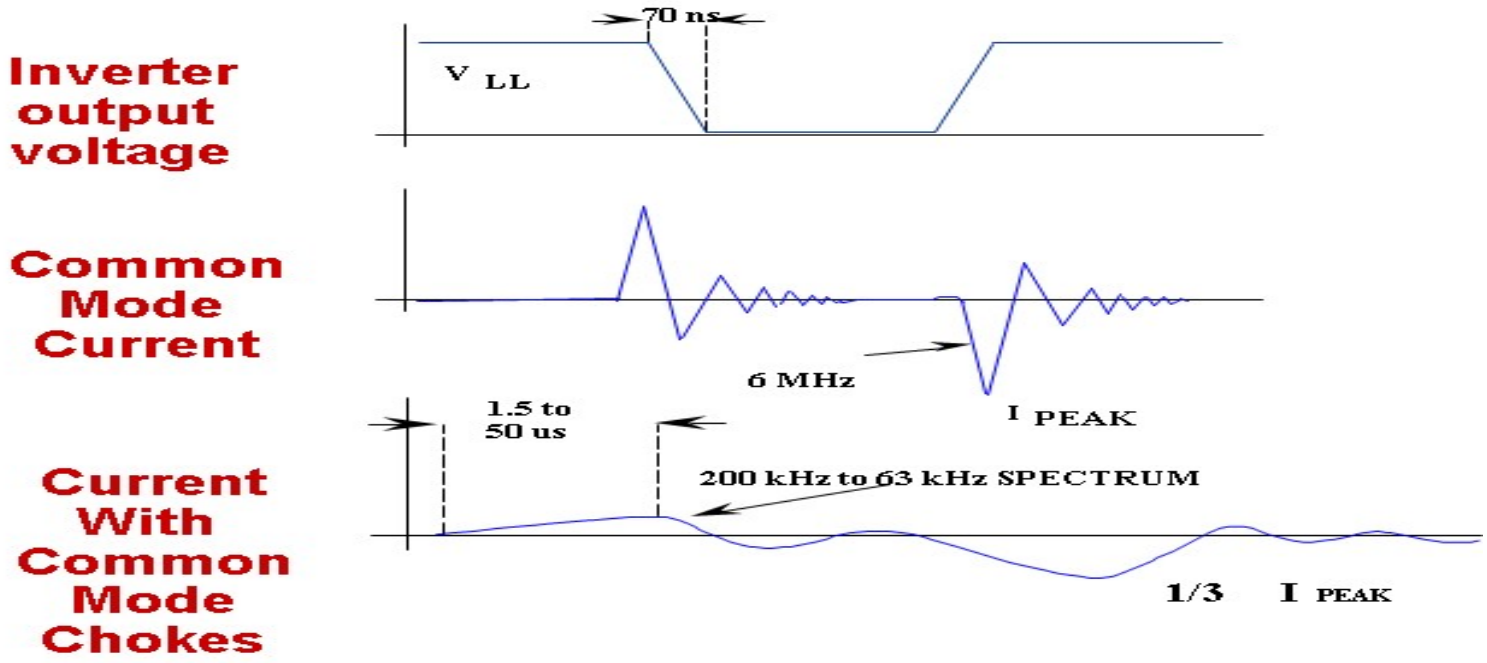
- If the distance between the drive and motor, or the drive and input transformer, is greater than 22.8 m (75 ft), and
- If sensitive circuits with leads greater then 22.8 m (75 ft), such as encoders, analog or capacitive sensors, are routed in or out of the cabinet near the drive or transformer, then

Install common mode chokes.

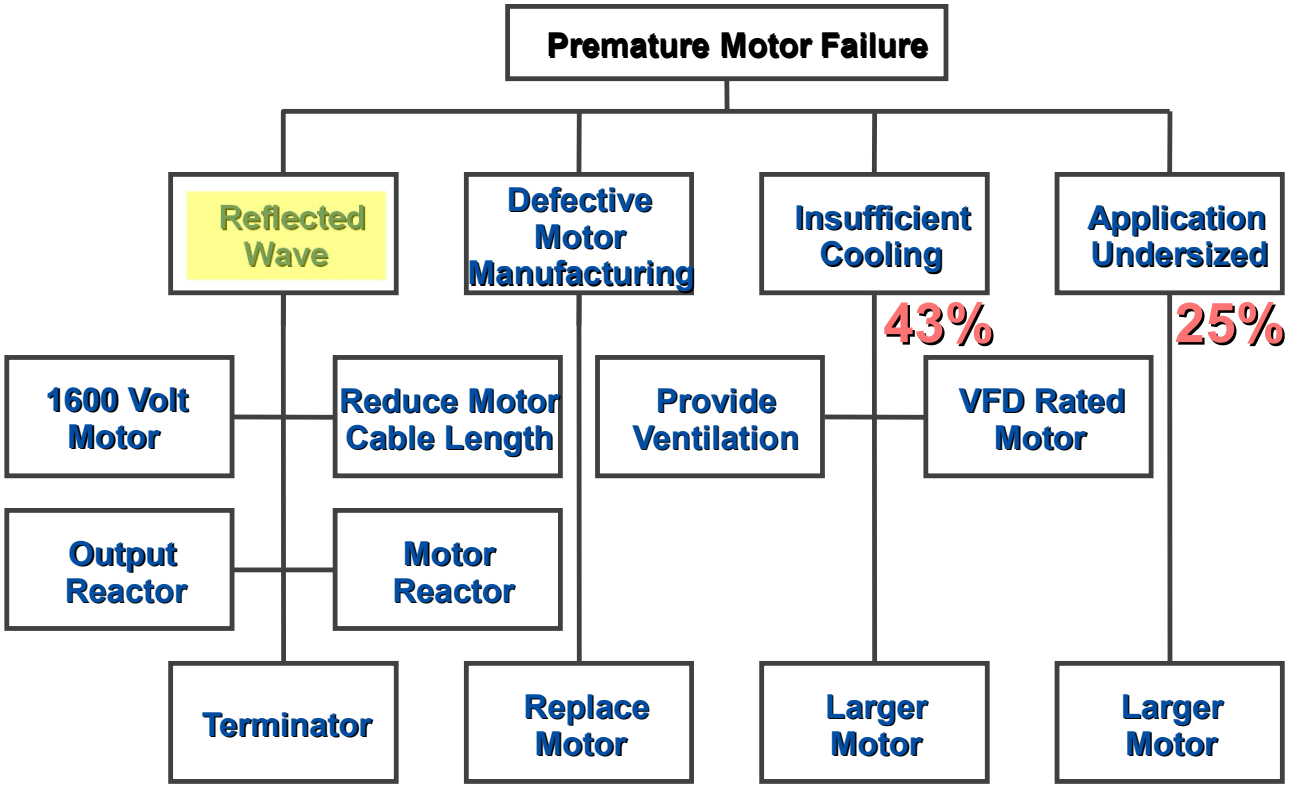


Common Mode Noise

What Do Common Mode Chokes Do?

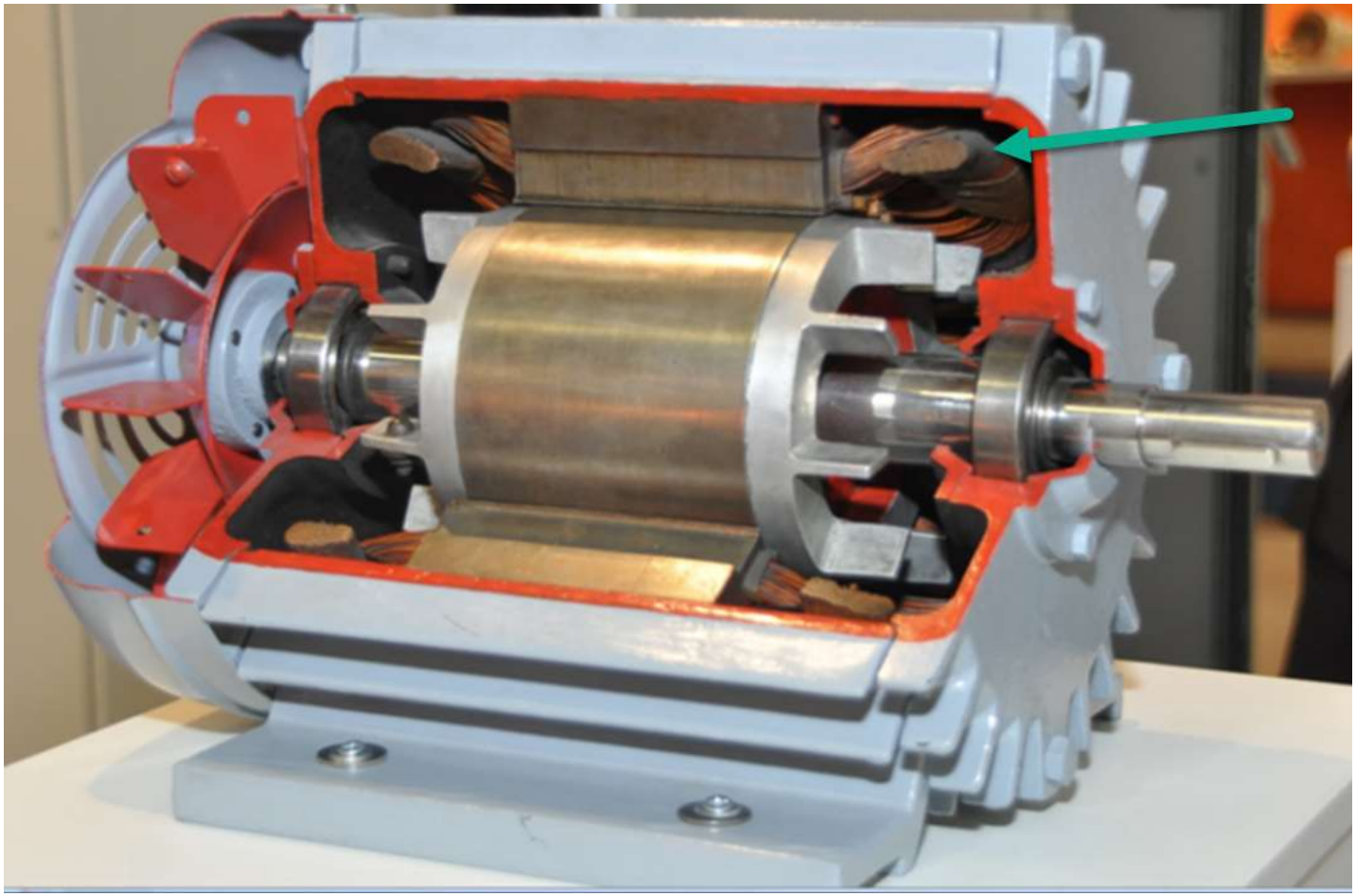


Reflected Wave and VFD appplications

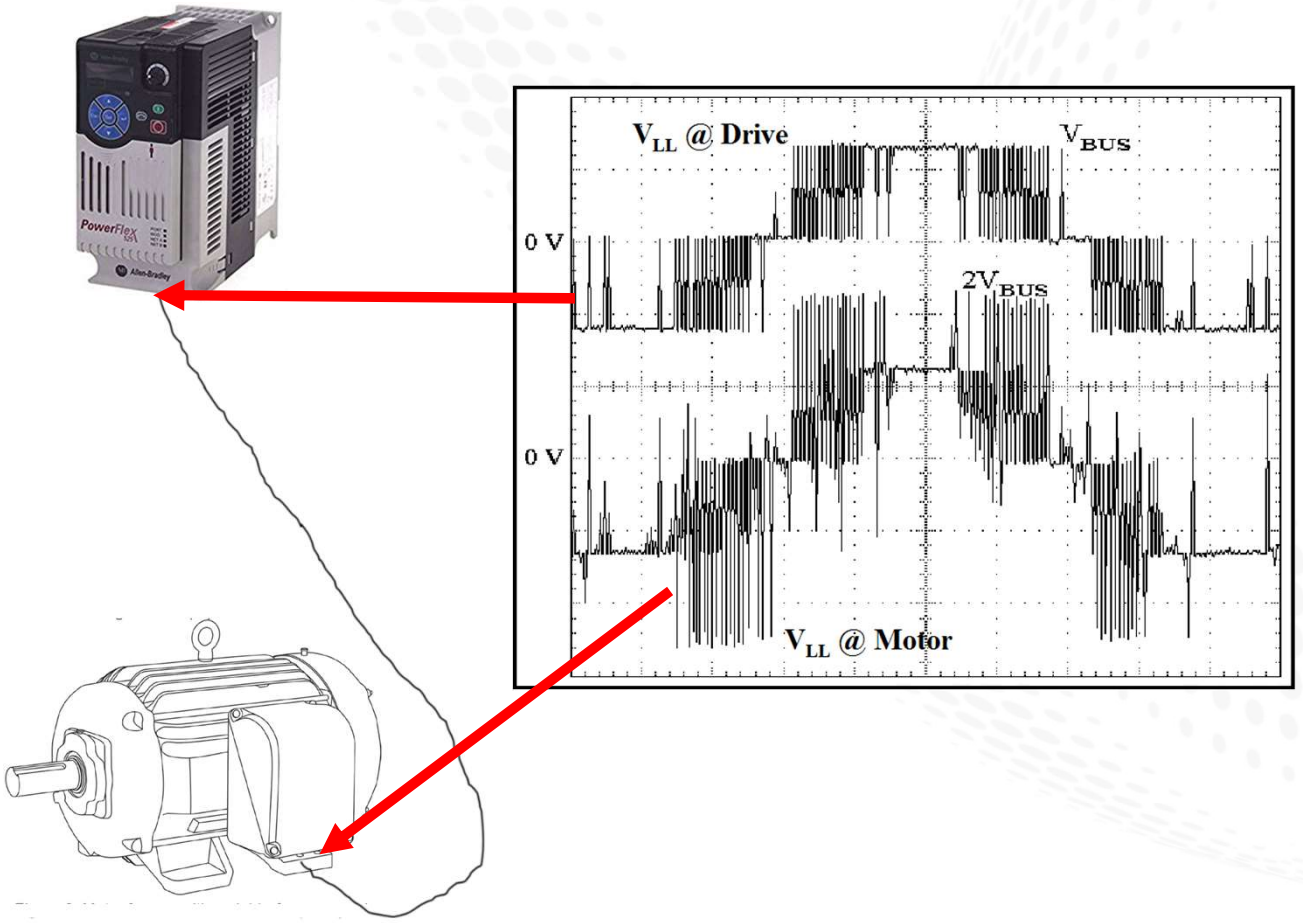


- Additional Failures
- 12% Bearings
- 10% Single phasing

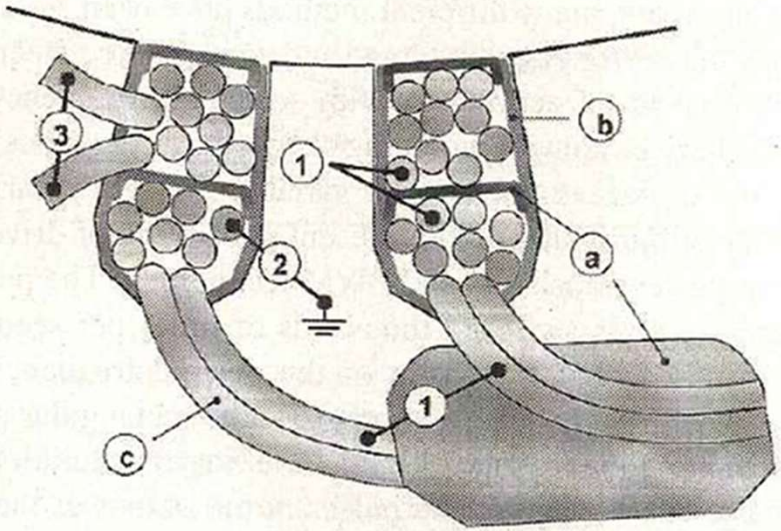
Motor Cutaway



Will Motor be Compatible with AC Drive?

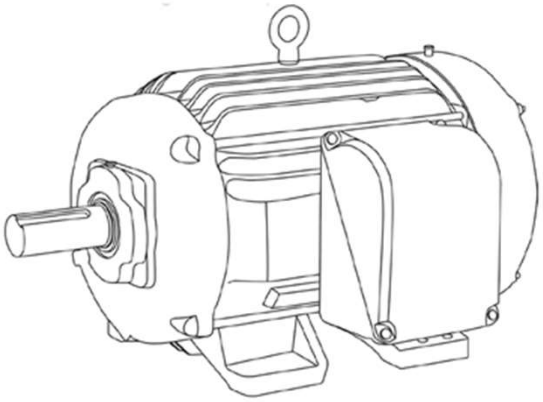


Will Motor be Compatible with AC Drive?



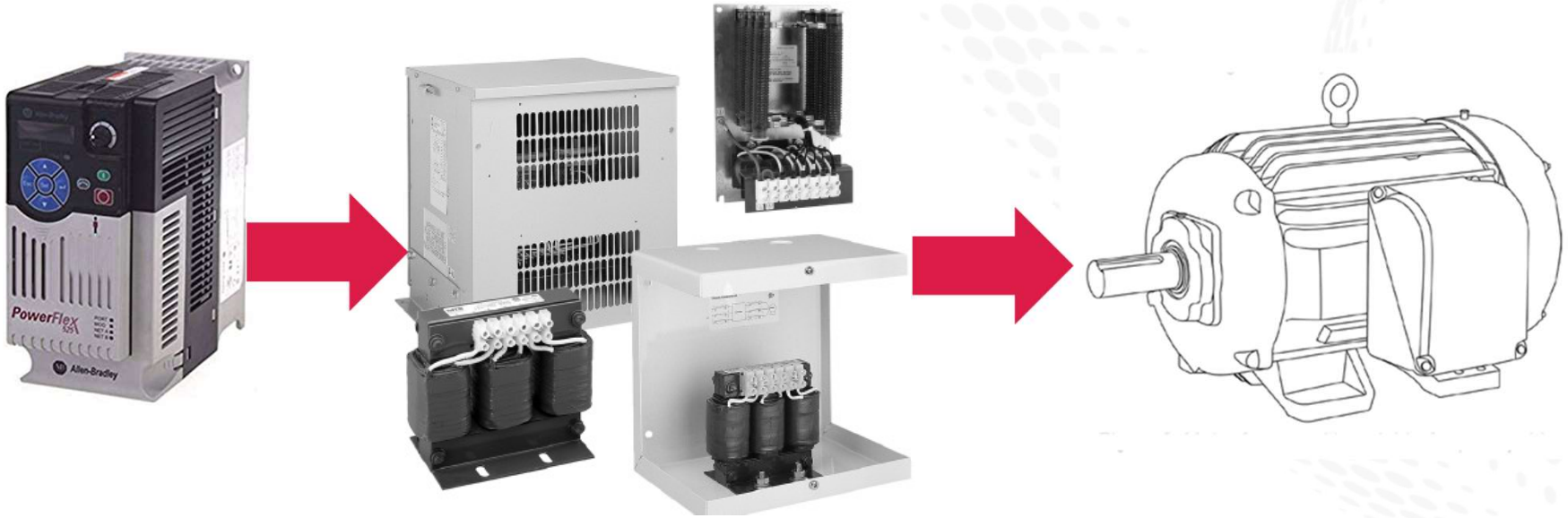
a	phase insulation / overhang insulation
b	ground insulation
c	turn insulation
1	phase to phase
2	phase to ground
3	turn to turn

Will Motor be Compatible with AC Drive?



Specify and buy Inverter Duty Insulated Motors (designed to NEMA motor standard MG1 part 31 1992 - 2021)

Will Motor be Compatible with AC Drive?



Will Motor be Compatible with AC Drive?

- Cabling – Appendix A of Drives-IN001
  - Length
    - Symptoms: Motor Failures, Overcurrent Faults

Type A Motor
- No phase paper or misplaced phase paper
- Lower quality insulation systems
- Corona inception voltages between 850…1000V

Type B Motor
- Properly placed phase paper
- Medium quality insulation systems
- Corona inception voltages between 1000…1200V

1488V Motor
- Meets NEMA MG 1-1998 section 31 standard
- Insulation can withstand voltage spikes of 3.1 times rated motor voltage due to inverter operation

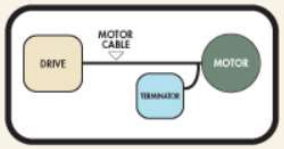
1329 R/L Motor
- AC variable speed motors are control-matched for use with Allen-Bradley drives
- Motor designed to meet or exceed the requirements of the Federal Energy Act of 1992
- Optimized for variable speed operation and include premium inverter grade insulation systems that meet or exceed NEMA MG1 (Part 31.40.4.2)

Table 47 - PowerFlex 753 and 755 Wall Mount Drives, 480V Shielded/Unshielded Cable – Meters (Feet) (continued)

Drive	Rating		No Solution				Reactor Only				Reactor and Damping Resistor or 1321-RWR				Reactor/RWR (see page 129)	Resistor		Available Optio		
Frame	Hp	kHz	1000V	1200V	1488V	1600V	1000V	1200V	1488V	1600V	1000V	1200V	1488V	1600V	Cat. No.	Ohms	Watts	TFA1	TFB2	RWR2
	1.0	2	7.6 (25)	12.2 (40)	83.8 (275)	83.8 (275)	7.6 (25)	91.4 (300)	152.4 (500)	152.4 (500)	152.4 (500)	152.4 (500)	152.4 (500)	152.4 (500)				●		●
		4	7.6 (25)	12.2 (40)	83.8 (275)	83.8 (275)	7.6 (25)	12.2 (40)	121.9 (400)	152.4 (500)	152.4 (500)	152.4 (500)	152.4 (500)	152.4 (500)				●		●
	2.0	2	7.6 (25)	12.2 (40)	83.8 (275)	83.8 (275)	7.6 (25)	91.4 (300)	182.9 (600)	182.9 (600)	152.4 (500)	182.9 (600)	182.9 (600)	182.9 (600)				●	●	●
		4	7.6 (25)	12.2 (40)	83.8 (275)	83.8 (275)	7.6 (25)	12.2 (40)	121.9 (400)	182.9 (600)	152.4 (500)	182.9 (600)	182.9 (600)	182.9 (600)				●		●
	3.0	2	7.6 (25)	12.2 (40)	106.7 (350)	152.4 (500)	7.6 (25)	91.4 (300)	182.9 (600)	182.9 (600)	152.4 (500)	182.9 (600)	182.9 (600)	182.9 (600)				●	●	●
		4	7.6 (25)	12.2 (40)	106.7 (350)	152.4 (500)	7.6 (25)	12.2 (40)	121.9 (400)	182.9 (600)	152.4 (500)	182.9 (600)	182.9 (600)	182.9 (600)				●		●

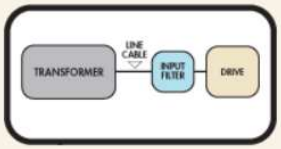
WEB-BASED SIMULATOR

REFLECTED WAVE



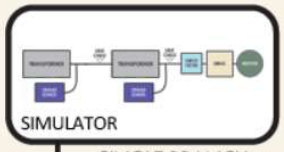
The reflected wave simulation tool models the high frequency characteristics of the inverter PWM voltage waveform , the cable connecting the drive to the motor and the motor itself, to predict the peak value and rise time of the voltage waveform at the motor

VOLTAGE DROP

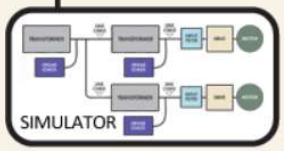


The voltage drop calculator estimates the voltage available at the load by computing the voltage drops through the source transformer, cables, line and load reactors, drive and output filters. A plot of available voltage as a function of cable length between

HARMONICS



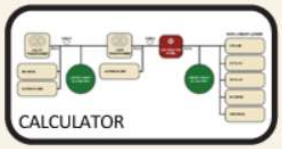
SINGLE BRANCH



DUAL BRANCH

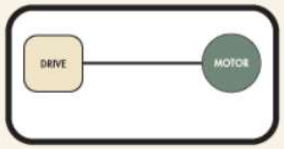
The harmonics simulator is a circuit simulation program with one or two load branches. Each of the loads can be set to be of a specific type. Waveforms of voltage and current at different points of common coupling are generated along with numerical values for voltage and current THD

HARMONICS



The harmonics calculator is a spreadsheet based tool which uses look-up tables to estimate the voltage and current harmonics at different points of common coupling in a network consisting of multiple loads. Only numerical outputs are provided including checks for

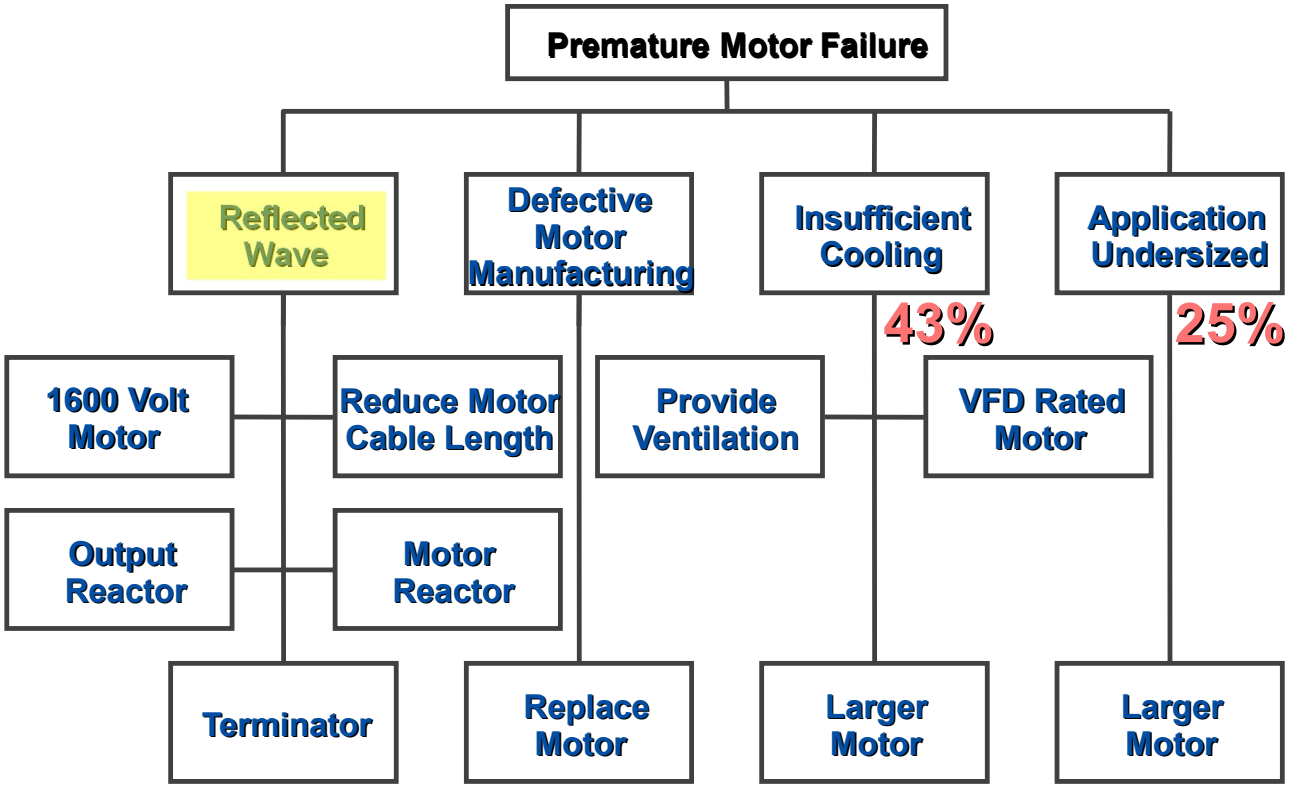
TORQUE HARMONICS



The torque harmonics calculator estimates the harmonics in the electromagnetic motor torque for the drive and motor parameters provided by the user. The model does not include the dynamics of the driven load.

ttps://rockwell.transim.com/ReflectedWave

Bearing Current and VFD appplications



- Additional Failures
- 12% Bearings
- 10% Single phasing

Bearing failures caused by current is not a new phenomenon.

1. Alger , P. L. and Samson , H. W. , " Shaft Currents in Electric Machines ", *Trans. A.I.E.E.* , February 1924 , v. 43 , pp. 235 – 245 . [Crossref], [Google Scholar]

2. Pearce , C. T. , " Bearing Currents—Their Origin and Prevention ", *Electric J.* , August 1927 , v. 24 , pp. 372 – 376 . [Google Scholar]

3. Riggs , L. W. , " How Much Shaft Current Can a Bearing Carry Safely? " *Power* , February 1944 , pp. 103 – 105 . [Google Scholar]

4. Hoover , D. B. , " Heating and Failure of Bearings Due to Little Appreciated Causes ", *Water Works and Sewerage* , October 1945 , v. 92 , n. 10 , pp. 297 – 299 . [Google Scholar]

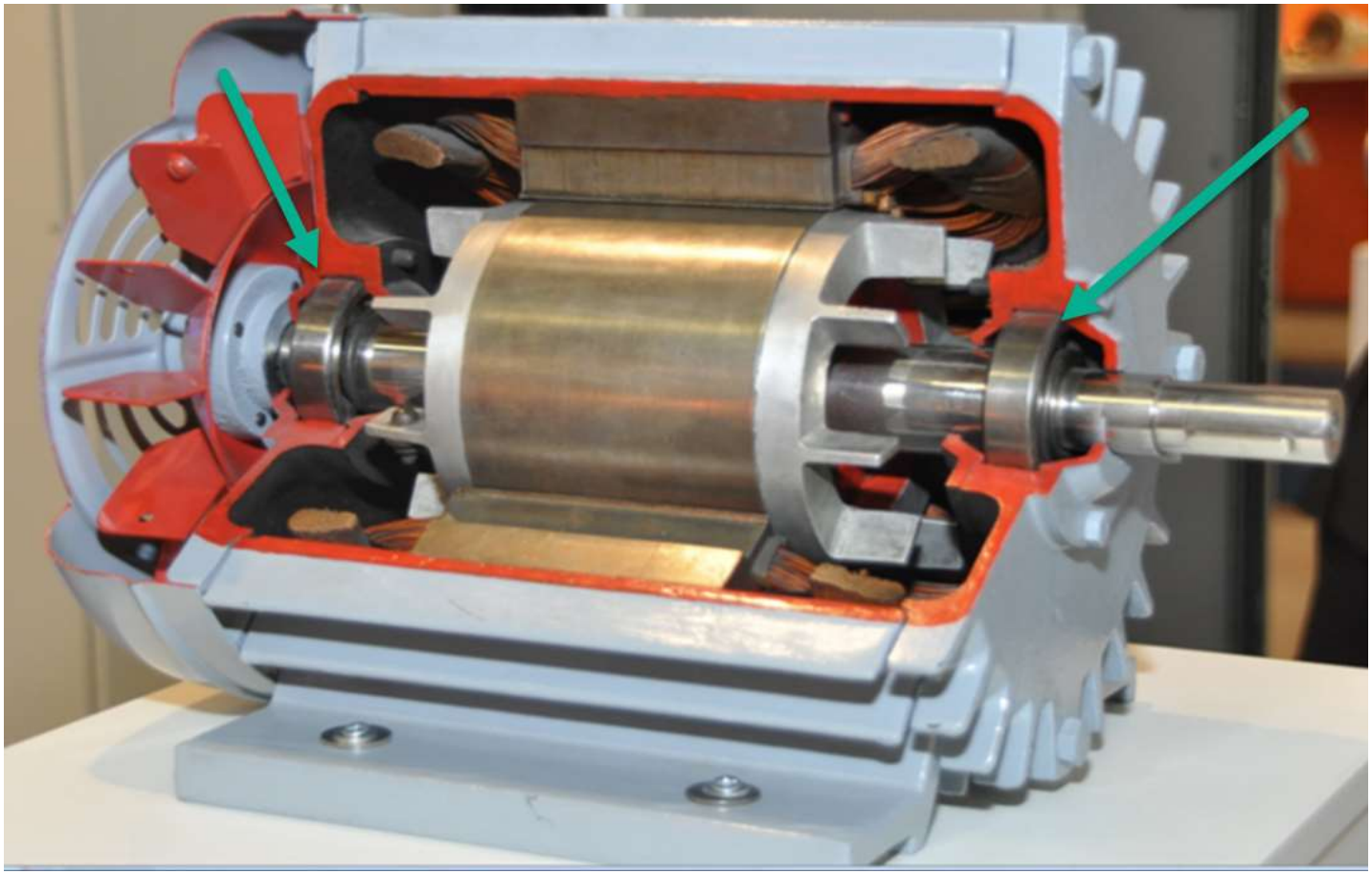
5. Wilcock , D. F. , " Bearing Wear Caused by Electric Current ," *Electrical Manufacturing* , February 1949 , pp. 108 – 111 . [Google Scholar]

6. " Static Charges Might Cause Turbine Bearing Failures ," *Power Engineering* , May 1954 , v. 58 , pp. 73 – 74 . [Google Scholar]

7. Rudorff , D. W. , " Principles and Applications of Spark Machining ", *Proc. Inst. Mech. Engrs.* , 1957 , v. 171 , n. 14 , pp. 495 – 512 . [Crossref], [Google Scholar]

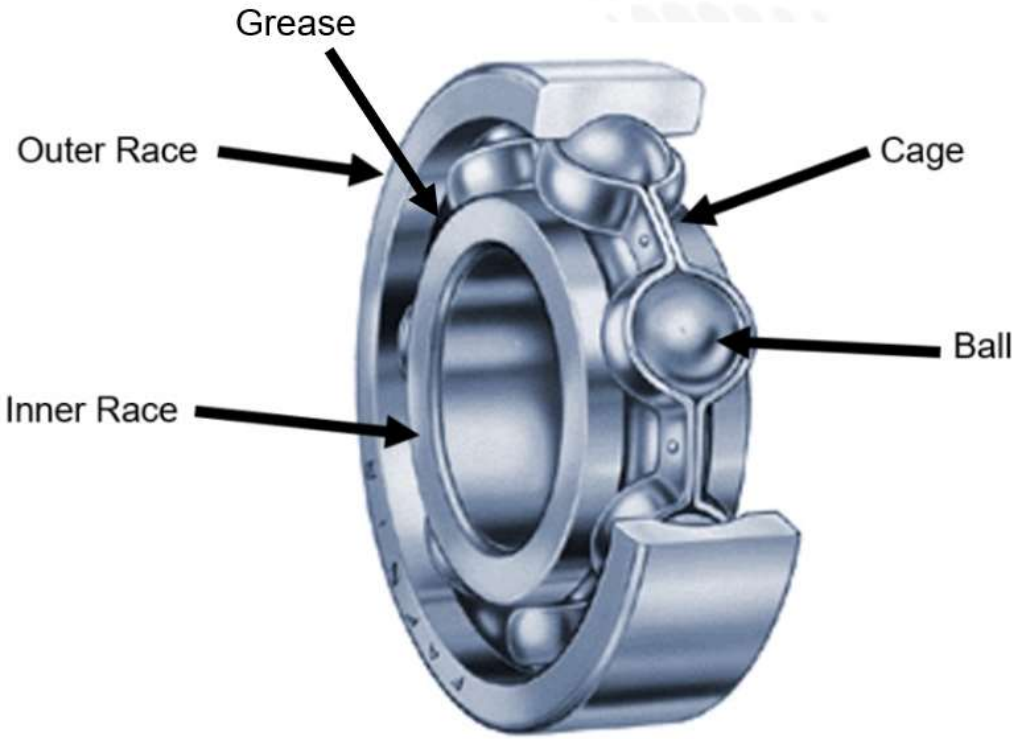
Motor Cutaway

Non Drive End (NDE)



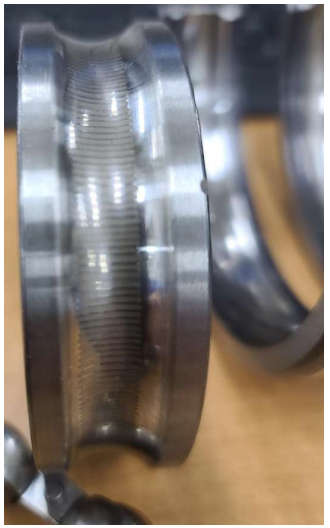
Drive End (DE)

Parts of the bearing



Outer Raceway

Inner Raceway

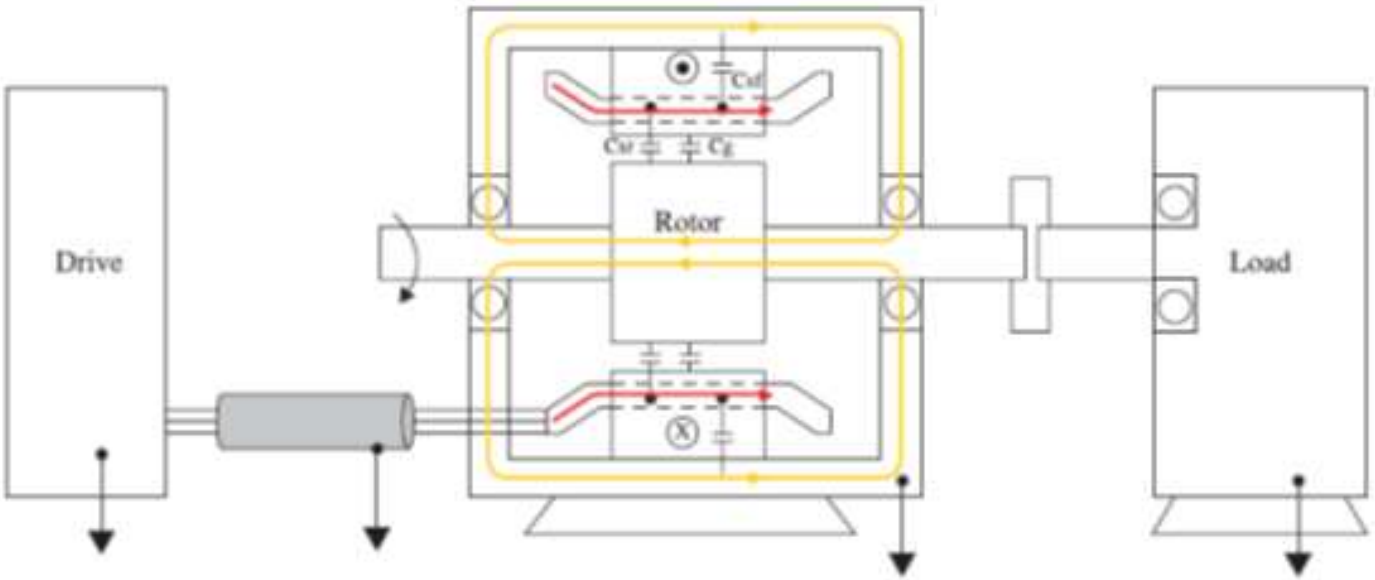


Bearing Current Sources and Mechanisms

- Three sources of bearing current
  - Electro magnetically induced (circulating current)
  - Electrostatic coupled (electrical or mechanical (ESD))
  - Ground source current (back feeding)

Circulating Current

Magnetically Induced Voltage developed from DE to NDE



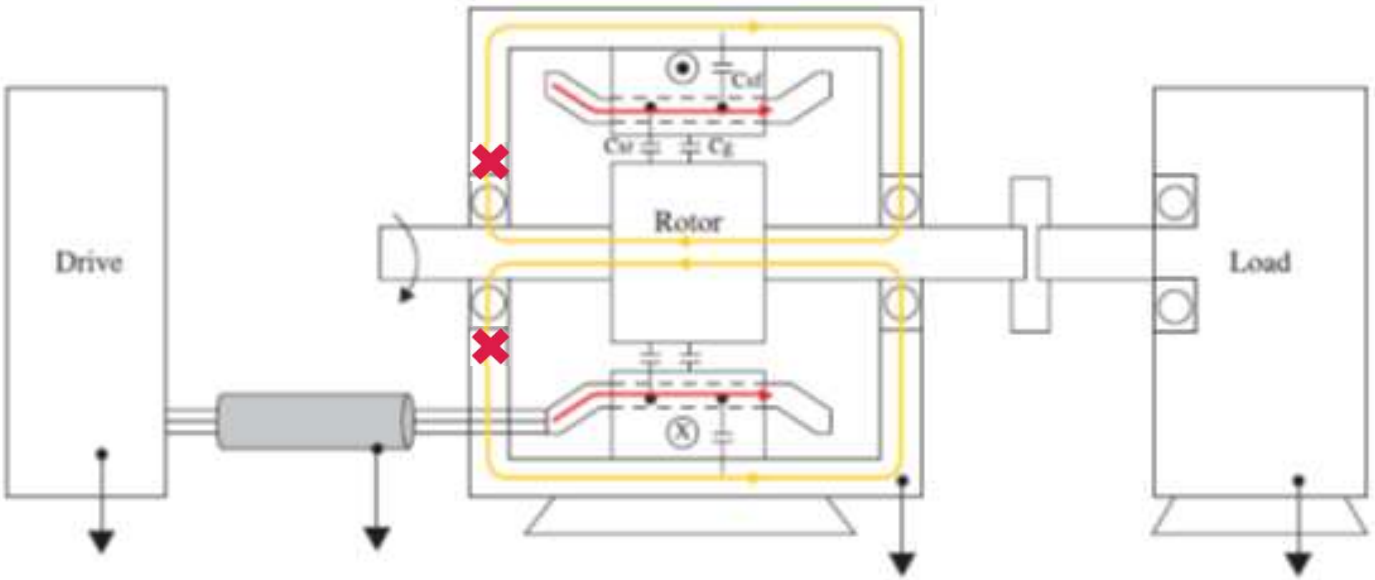
Solution: Insulated bearing on the Non Drive End

INSULATED

NON-INSULATED

Circulating Current

Insulated Bearing on NDE bearing prevents circulating current

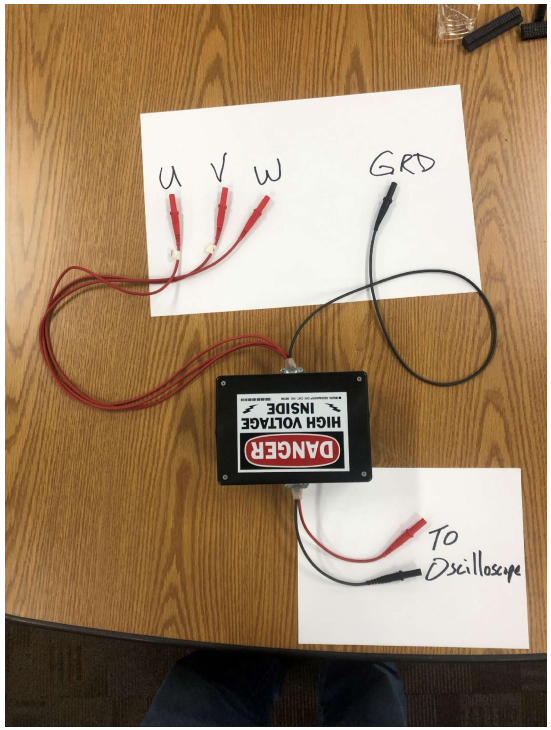


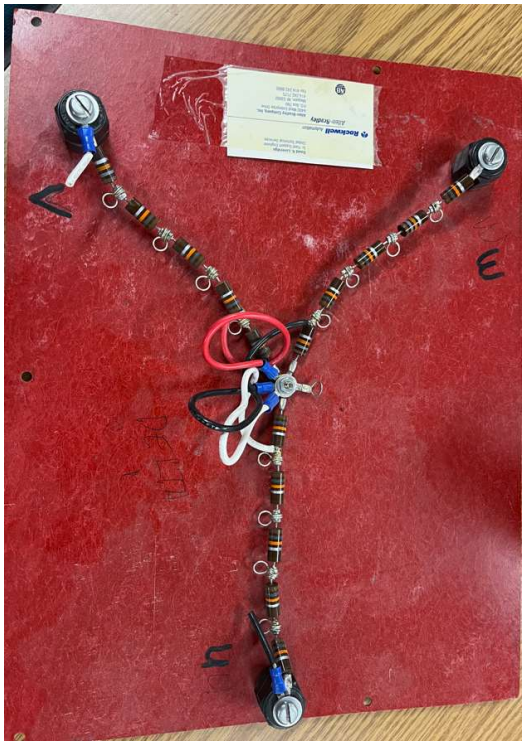
Electro Static Coupled

What is Shaft Voltage?

To Oscilloscope

What is Stator to Neutral Voltage?



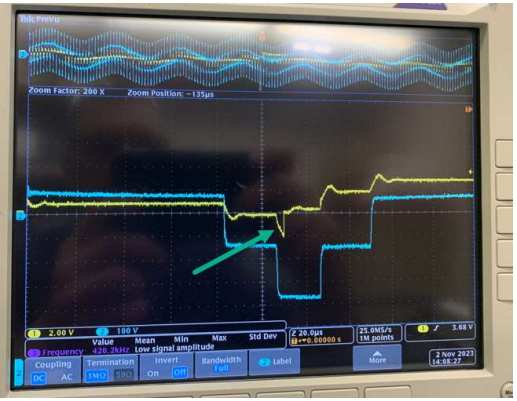


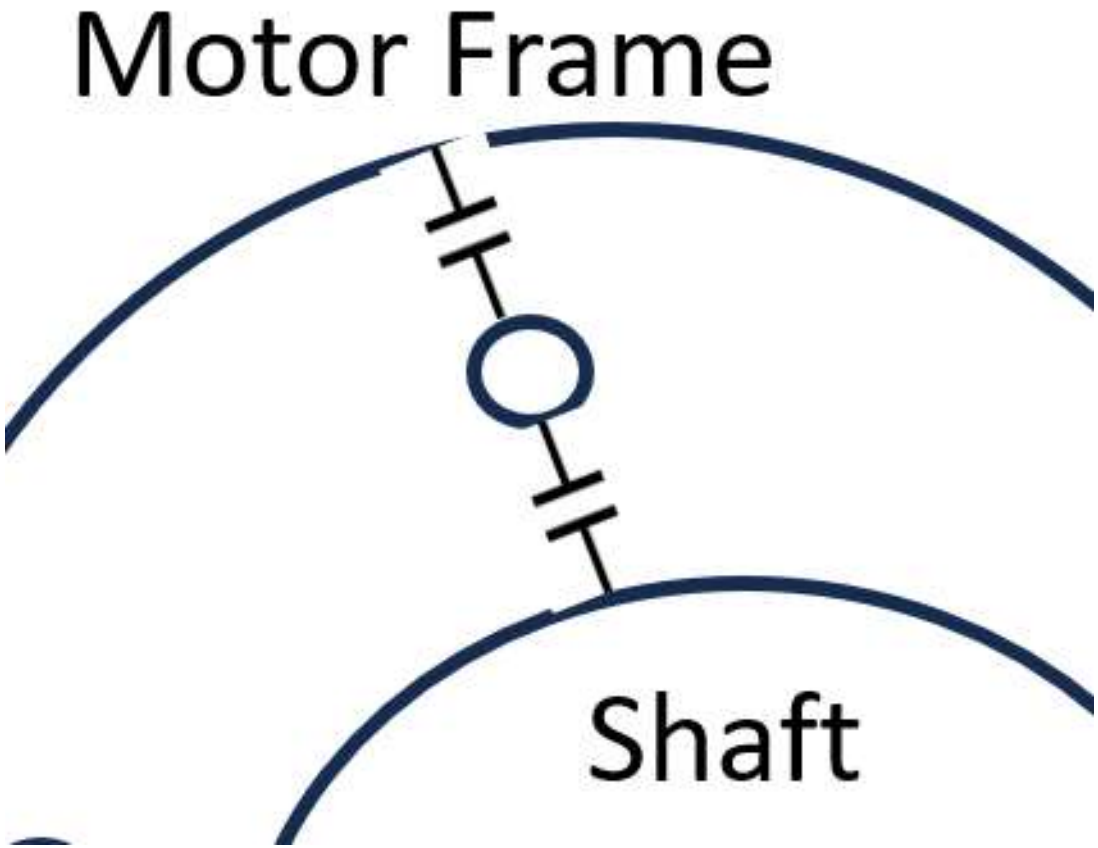
Yellow is Shaft Voltage. Teal is Stator Neutral to Ground

Normal

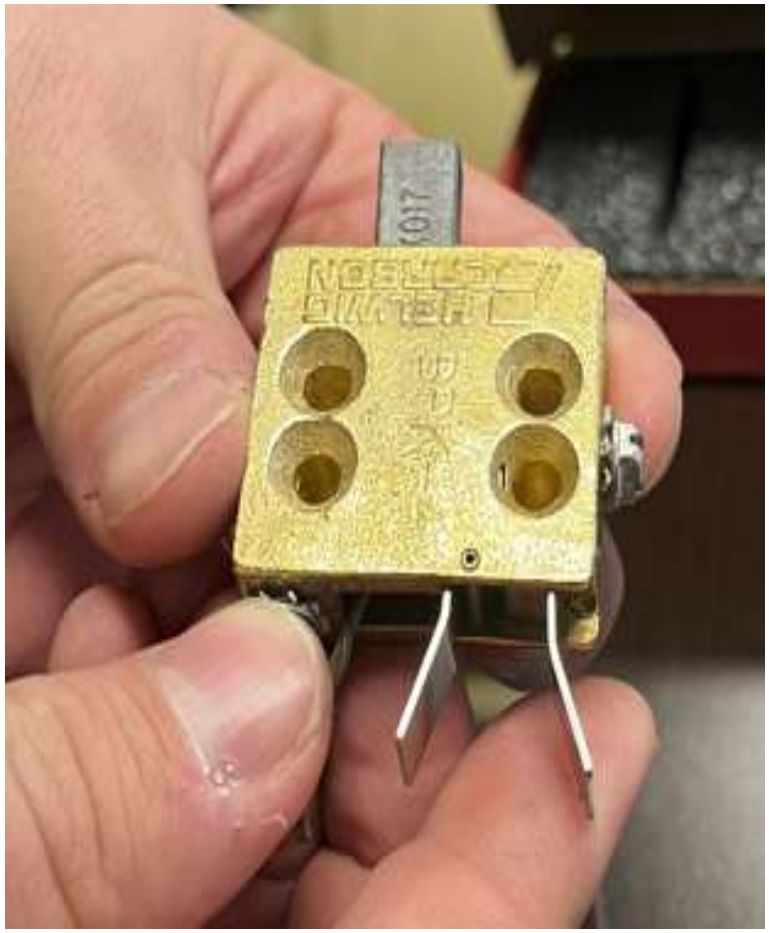
Shaft Voltage Discharge

Electrostatic Coupled





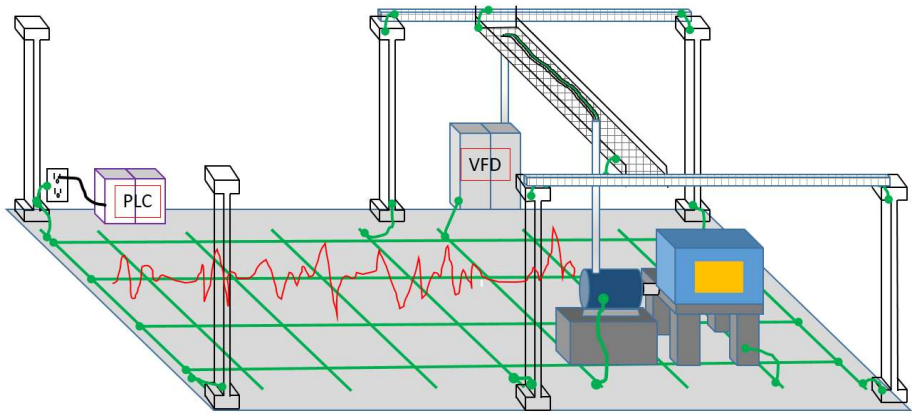
Solution: Shaft Brush

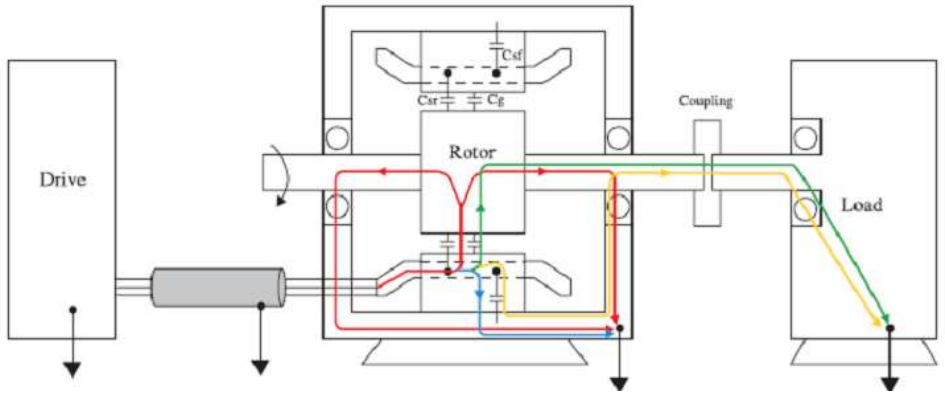


Backfeeding Current

Common Mode Current Finds Path Through

1. Motor Bearings
2. Machine (gear box, pillow bearings)





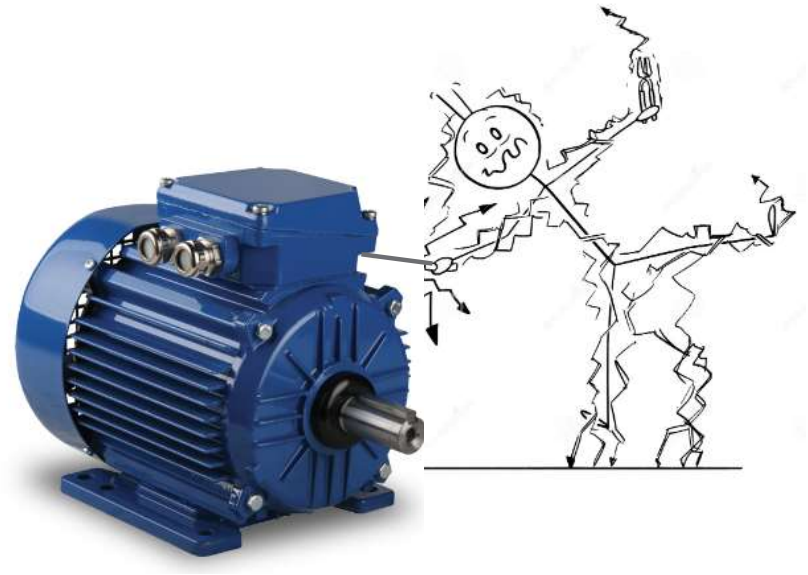
Solution: CM core or reactor on output of drive

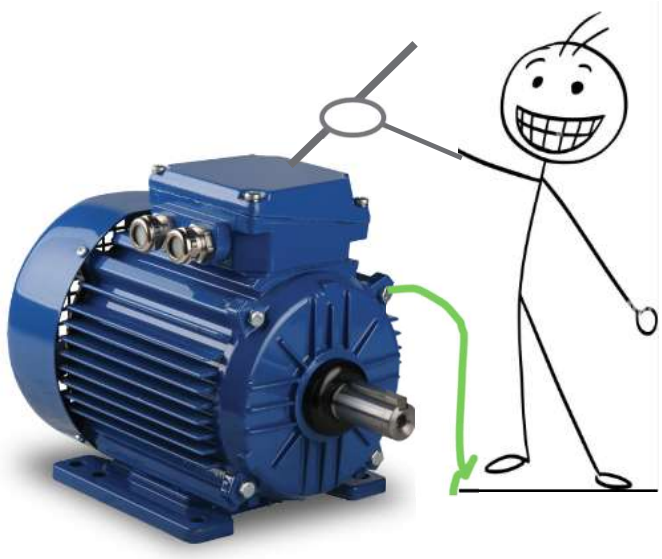
Solution to Bearing Current Mechanisms.

- Insulated Bearing.
- Shaft Ground Brush.
- Grounding and Bonding of Motor Cables.
- ASD Output LR Filter, especially for AFE Drives.
- For AFE: DC Bus Conditioner.
- Common Mode Choke.
- Conductive Lubricants.
- ASD Output Load Reactor.
- Ceramic Bearing.
- Insulated Coupling between Motor and Encoder.
- ASD Carrier Frequency Setting.
- ASD Common Mode Voltage Reduction Feature.

What is ground anyway????!!!???

Safety Ground

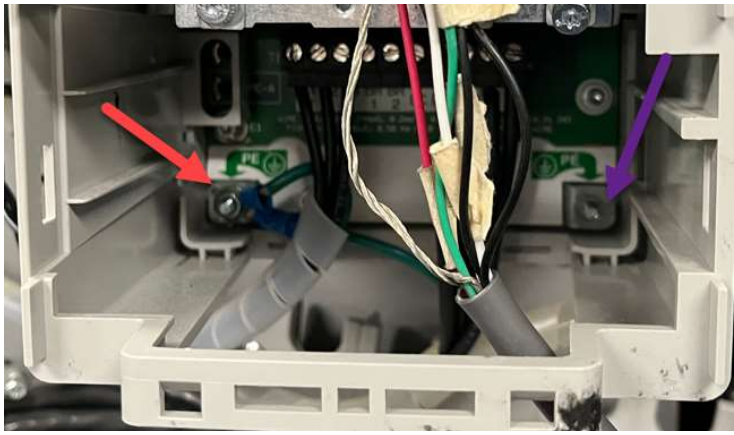


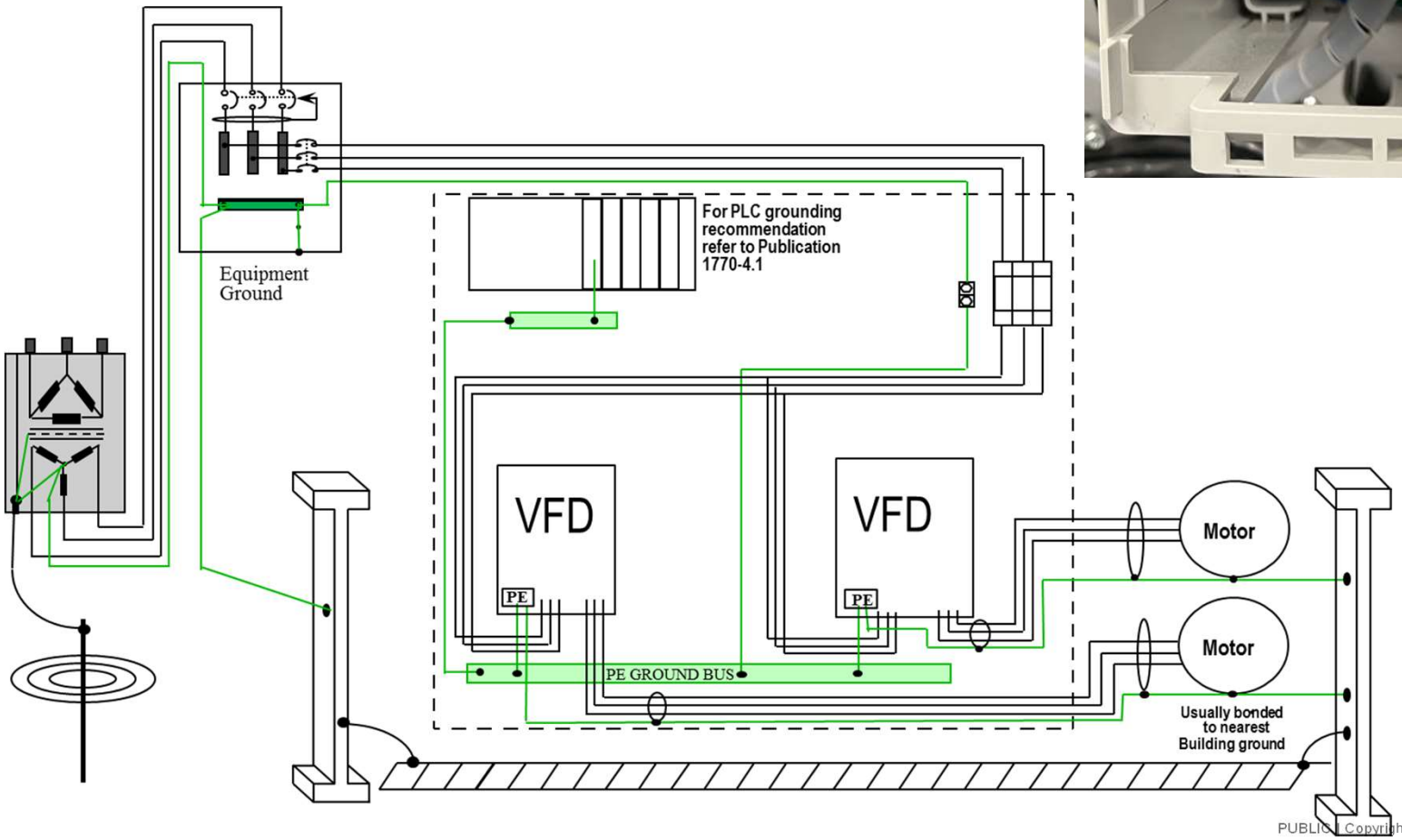


Purpose of Ground

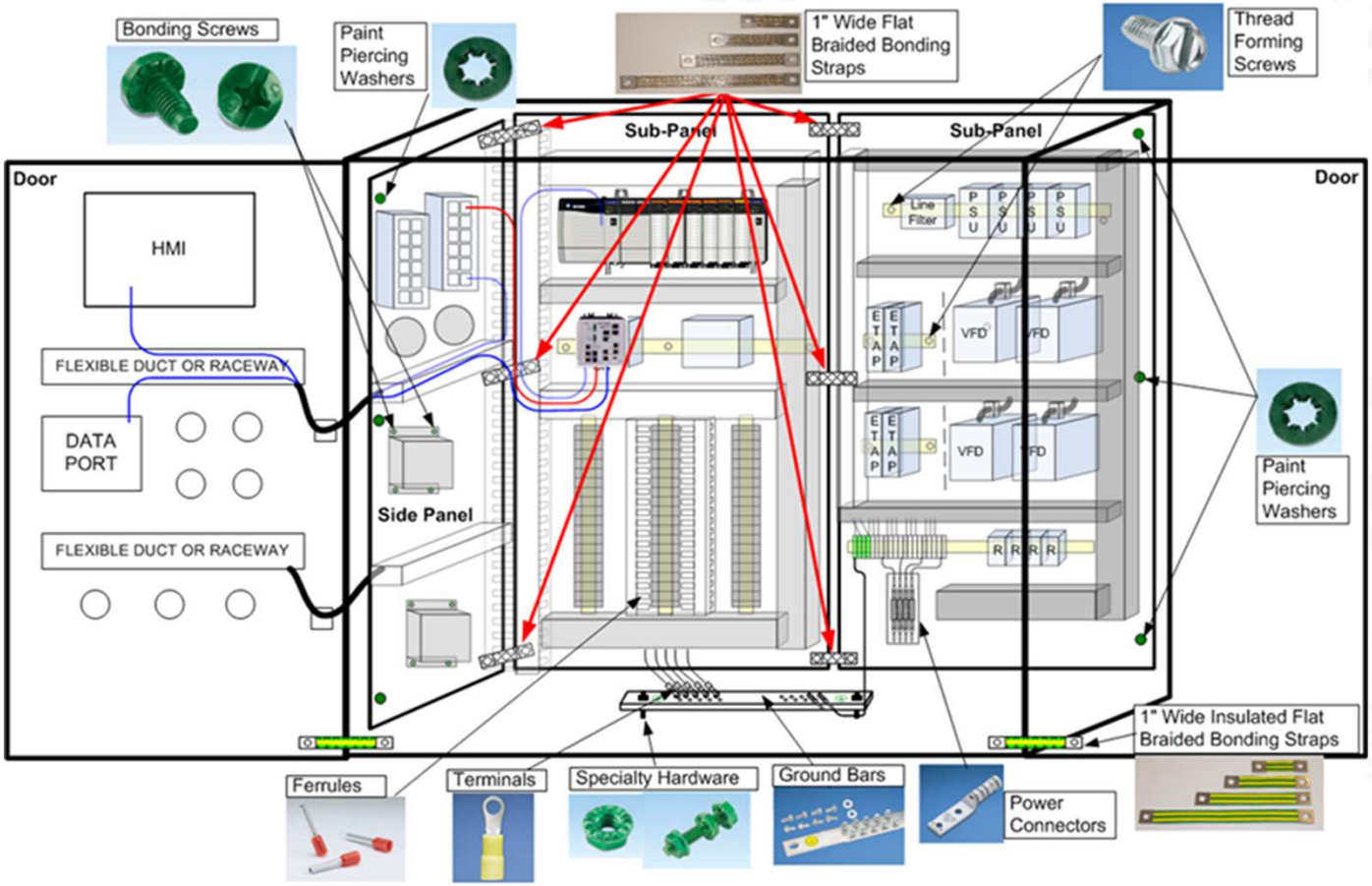
- Low resistance to ground or earth to provide a fault return path between the fault and the source to lessen a voltage hazard until a breaker or fuse opens that disconnects the power source from the fault
- Low resistance path between equipment metal chassis and nearby metal structures to minimize personal danger in the event of an electrical fault within the equipment.
- Provide the preferred path for a lightning stroke
- Provide a path for Electro Static Discharge
- Common, low impedance reference plane between electronic devices, circuits, and systems
- Reference plane for radio frequency antenna systems

Grounding and Bonding to Panel





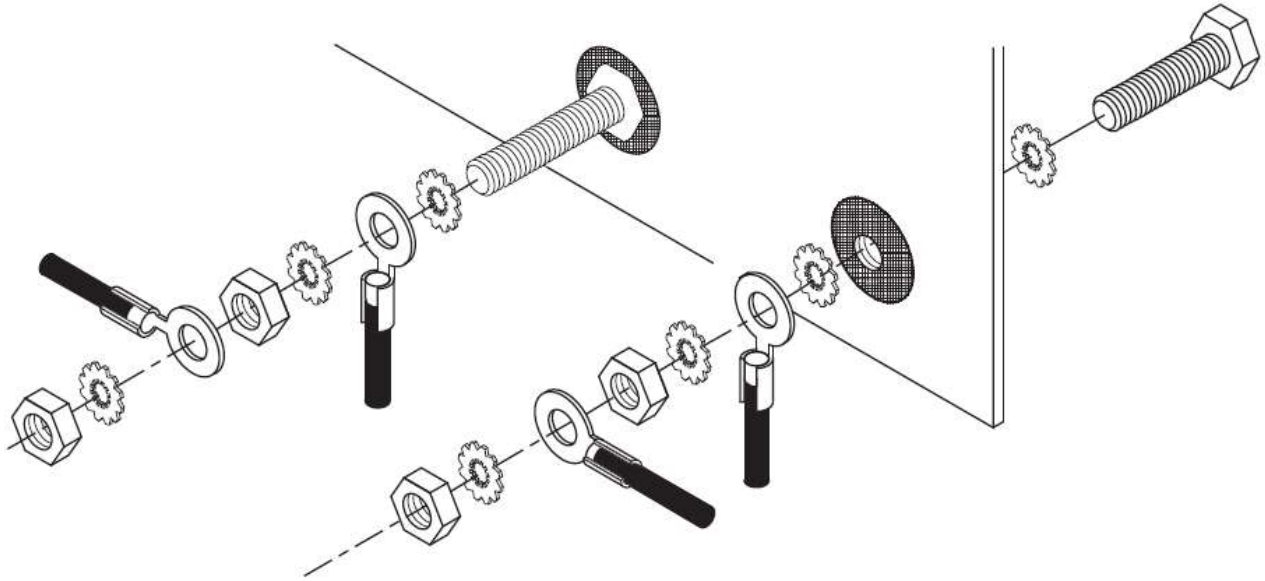
AC Drive Panel Layout and Bonding



Grounding and Bonding for the Industrial Plant Floor"Why it's Important and How to Accomplish it"
David Dohm, RCDD-Technical Systems Engineering Program Manager
Panduit Corporation

Grounding & Bonding Inside the panel

Remove Paint



Can you see whats wrong?

Input Cabling Recommendations

*Not the same recommendation as motor cables. Motor cables must handle PWM signals.

In general, the selection of cable for AC input power to a drive has no special requirements. Some installations may suggest shielded cable to prevent coupling of noise onto the cable.

Type – Copper Only

Size – differs per drive. See VFD User Manual for each specific VFD size.

Shielded or Unshielded - Shielded provides noise immunity to EMC standards (CE, C-Tick, FCC, etc). If shielded cable is used the shields must be bonded at both ends to provide a continuous path for common mode noise current.

Industries - Individual industries may have required standards due to environment or experience

Input Protection Recommendations

Thermal Magnetic Breaker (Acceptable**)

Bussmann DFJ Drive Fuse (Recommended)

Ferraz Shawmut HSJ Fuse (Recommended)

Fuse and Circuit Breaker Ratings

The tables in this section provide recommended AC line input fuse and circuit breaker information. See the following Fuses and Circuit Breakers sections for CE and UL requirements. The size recommendations are based on 40 °C (104 °F) and the U.S. NEC. Other country, state, or local codes can require different ratings. DC link fuse recommendations for DC input drives are also provided.

Fuses

The recommended fuse types are listed here. Select a fuse rating within the range that is specified in the tables starting on page 76.

- CE – Type gG fuses
- UL – Fast-acting Class J, T

IMPORTANT For maximum protection of the drive and its internal components, we recommend the use of fuses over other methods of circuit protection. Fuses reduce the risk of drive damage from power quality events and improves machine and process utilization.

Circuit Breakers

The non-fuse listings in the following tables include inverse time circuit breakers, and 140M/140MT self-protected combination motor controllers. If one of these methods is chosen for protection, the following requirements apply, for both UL and CE installations:

- 140M/140MT self-protected combination motor controllers are acceptable if the installation conforms with the requirements that are specified in the tables.
- Inverse time circuit breakers can only be used with a fuse that is specified in the tables.

**See Slide 13 for details

Input Protection Sizing

Are Circuit Breakers an Option?

- Circuit Breakers **must** be used with the **specified fuses** to be compliant with the UL61800-5-1 (2nd ed.) and EN61800-5-1:2007 specifications
- All drives designed after 2/1/2020 must comply (e.g., 755TS/R/L/M)

The UL 61800-5-1 Specification [Link Here]

UL 61800-5-1 harmonizes the requirements for the safety and design of low-voltage drives and replaces the UL 508C specification. The incentives for development of the new UL specification include:

- Creates a unified global requirement for the safety and design of low-voltage (LV) drive products.
- Design, testing and certification of new drive products is simplified, which previously mandated compliance with requirements based on geography:
  - Marking UL 508C for UL for drive applications in North America
  - Marking EN / IEC 61800-5-1 for CE typically for drive applications in Europe and the rest of the world, since both these UL and IEC standards were vastly different
- And ultimately, to help create a single design of low-voltage drive products that can be used globally without additionally requiring another certification based upon the geographic location where the drive is installed and used.
- All PowerFlex 755T drives are designed and built to meet these new requirements

From 750-TD104

400V AC and 540V DC Input Protection Devices—Drive Frames 1...7, and 7A (Continued)

Applied Rating (1)	Frame (2)	Cont. Output Amps	Sized For Normal Duty			Sized For Heavy Duty			Input Qty.		AC Input Protection Devices								Input Qty.	DC Input Protection (12)	
			Cat. No.	Output Overload Amps		Cat. No.	Output Overload Amps		Cont. AC Input		Fuse		Circuit Breaker (6)				140M/140MT Type E Combination Motor Controller with Adjustable Current Range (7) (8)		Cont. DC Input	Fuse Cat. No. 20-750-...	Fuse Holder Cat. No. 20-750-...
kW				1 Min	3 s		1 Min	3 s	kVA	Amps	Min [A] (4)	Max [A] (5)	Max/140G Part No.	Max I^2t [kA^2s]	I_{peak} [kA]	Min. Encl. Vol. [$in.^3$] (11)	Cat. No.	Min. Encl. Vol. [$in.^3$] (11)	Amps		
400V AC Input																			**540V DC Input**		
55	5	104	20G...C104	114.4	156	20G...C140 (3)	156	210	64.5	93.1	125	200	175/140G-JC6F3-D17	980	30	29291	–	–	109.9	DCFUSE3S-200A	DCFH-NH1
75	6	140	20G...C140	154	210	20G...C170	210	255	88.9	128.3	175	300	250/140G-JC6F3-D25	980	30	43937	–	–	151.4	DCFUSE3S-315A	DCFH-NH1
90	6	170	20G...C170	187	255	20G...C205	255	307.5	107.9	155.8	200	300	250/140G-JC6F3-D25	980	30	43937	–	–	183.9	DCFUSE3S-315A	DCFH-NH1
110	6	205	20G...C205	225.5	307.5	20G...C260	307.5	390	130.1	187.8	250	400	300/140G-KC6F3-D30	4200	47.9	43937	–	–	221.7	DCFUSE3S-400A	DCFH-NH1
132	6	260	20G...C260	286	390				165	238.2	300	500	400/140G-KC6F3-D40	4200	47.9	43937	–	–	281.2	DCFUSE5S-500A	DCFH-NH2
	7					20G...C302	390	468	165	238.2	300	500	400/140G-KC6F3-D40	4200	47.9	43937	–	–	281.2	DCFUSE6S-500A	DCFH-NH3
160	7	302	20G...C302	332.2	453	20G...C367	453	550.5	191.7	276.7	350	600	800/140G-M6F3-D80	17000	65	43937	–	–	326.7	DCFUSE6S-550A	DCFH-NH3
200	7	367	20G...C367	403.5	550.5	20G...C456	550.5	684	232.9	336.2	450	700	800/140G-M6F3-D80	17000	65	43937	–	–	397	DCFUSE6S-700A	DCFH-NH3
						20G...C477	550.5	684	232.9	336.2	450	700	800/140G-M6F3-D80	17000	65	43937	–	–	397	DCFUSE6S-700A	DCFH-NH3
250	7	456	20G...C456	501.6	684				289.5	417.8	600	800	800/140G-M6F3-D80	17000	65	43937	–	–	493.2	DCFUSE6S-900A	DCFH-NH3
	7A	472				20G...C567	708	849.6	299.6	432.4	1100 (Bussmann 170M6xx5)		1300	–	–	–	–	–	–	–	–
270	7	477	20G...C477	524.7	715.5				302.8	437	600	800	800/140G-M6F3-D80	17000	65	43937	–	–	516	DCFUSE6S-900A	DCFH-NH3
315	7A	540				20G...C650	810	972	342.7	494.7	1100 (Bussmann 170M6xx5)		1500	–	–	–	–	–	–	–	–
315	7A	567	20G...C567	623.7	850.5				359.9	519.5	1100 (Bussmann 170M6xx5)		1600	–	–	–	–	–	–	–	–
355	7A	650	20G...C650	715	975				412.6	595.5	1100 (Bussmann 170M6xx5)		1800	–	–	–	–	–	–	–	–

(1) Applied rating refers to the motor that is connected to the drive. For example, a C022 drive can be used in Normal Duty mode on an 11 kW motor, or in Heavy Duty mode on a 7.5 kW motor. A C015 drive can be used in Heavy Duty mode on a 5.5 kW motor with the same ratings as a C011 drive. The drive can be programmed for either mode. For any given drive catalog number, Normal Duty mode provides higher continuous current but smaller overload current when compared to Heavy Duty mode. See parameter 0:35 [Duty Rating Cfg].

(2) Only enclosure codes F, N, and R. See the explanation of catalog number positions 8...10 for 400V drives on page 5 for frame sizes of other enclosure types.

(3) This drive is the next larger frame size.

(4) For UL compliance - fast-acting class J (Bussmann DFJ) or fast-acting class T (Bussmann JJS) fuses only. Equivalent fuses of class J, T may be used if they have lower I_{peak} and I^2t ratings than the Bussmann JJS fuse. For CE compliance - type gR fuses (Bussmann 170M - size 00 to 3, IEC 60269 or DIN 43620, or FWP-_G10F, _G14F, _G22F) only. Minimum protection device size is the lowest rated device that supplies maximum protection without nuisance tripping. Max. source SCCR = 100 kA. For Frame 7A, only the specified fuse (Bussmann 170M6615, 170M6665, 170M6715 or 170M6765) shall be used. The drive and the overcurrent protection devices must be integrated within the same overall assembly. Max. source SCCR = 100 kA.

(5) For UL compliance - fast-acting class J (Bussmann DFJ) or fast-acting class T (Bussmann JJS) fuses only. Equivalent fuses of class J, T may be used if they have lower I_{peak} and I^2t ratings than the Bussmann JJS fuse. For CE compliance - type gR fuses (Bussmann 170M - size 00 to 3, IEC 60269 or DIN 43620, or FWP-_G10F, _G14F, _G22F) only. Maximum protection device size is the highest rated device that supplies drive protection. Max. source SCCR = 100 kA. For Frame 7A, only the specified fuse (Bussmann 170M6615, 170M6665, 170M6715 or 170M6765) shall be used. The drive and the overcurrent protection devices must be integrated within the same overall assembly. Max. source SCCR = 100 kA.

(6) Circuit breaker - inverse time breaker - unless a specific Bulletin 140G part number and min. enclosure volume are specified, must be used with a fuse specified in the table. For US NEC, minimum circuit breaker size is 125% of motor FLA. Ratings that are shown are maximum values.
Bulletin 140G circuit breakers rated ≤400A are UL489 listed current-limiting type with SCCR of 65 kA, and can be used without fuses when the drive is installed in an enclosure with minimum volume as specified. Equivalent UL489 listed current-limiting circuit breakers may be used if they have SCCR of 65 kA, and lower I_{peak} and I^2t ratings.
Bulletin 140G circuit breaker rated at 800A is UL489 listed with SCCR of 65 kA, and can be used without fuses when the drive is installed in an enclosure with minimum volume as specified. Equivalent UL489 listed circuit breakers may be used if they have SCCR of 65 kA, and lower I_{peak} and I^2t ratings.

(7) Bulletin 140M/140MT with adjustable current range must have the current trip set to the minimum range so that the device does not trip.

(8) Bulletin 140M/140MT is UL Listed for 480Y/277V. Not UL Listed for use on 400V or 480V Delta/Delta, corner ground, or high-resistance ground systems.

(9) Bulletin 140M/140MT must be Frame C (140M-C2E-xxx or 140MT-C3E-xxx) or Frame D (140M-D8E-xxx or 140MT-D9E-xxx). Max. source SCCR = 65 kA.

(10) Bulletin 140M/140MT must be Frame D (140M-D8E-xxx or 140MT-D9E-xxx) or Frame F (140M-F8E-xxx). Max. source SCCR = 65 kA.

(11) When using the Bulletin 140M/140MT or a circuit breaker, the drive must be installed in a ventilated or non-ventilated enclosure with the minimum volume that is specified in this column. Application-specific thermal considerations can require a larger enclosure.

(12) DC fuses specified are UL recognized and CE compliant.

Rockwell Automation Publication 750-TD104F-EN-P - January 2025

400V AC and 540V DC Input Protection Devices—Drive Frames 1...7, and 7A

Applied Rating (1)		Cont. Output Amps	Sized For Normal Duty			Sized For Heavy Duty			Input Qty.		AC Input Protection Devices									Input Qty.	DC Input Protection (12)	
			Cat. No.	Output Overload Amps		Cat. No.	Output Overload Amps		Cont. AC Input		Fuse		Circuit Breaker (6)				140M/140MT Type E Combination Motor Controller with Adjustable Current Range (7) (8)			Cont. DC Input	Fuse Cat. No. 20-750-...	Fuse Holder Cat. No. 20-750-...
kW	Frame (2)			1 Min	3 s		1 Min	3 s	kVA	Amps	Min [A] (4)	Max [A] (5)	Max/140G Part No.	Max I^2t [kA^2s]	I_{peak} [kA]	Min. Encl. Vol. [$in.^3$] (11)	Cat. No.	Min. Encl. Vol. [$in.^3$] (11)	Amps		
400V AC Input																				**540V DC Input**		
0.37	1	1.3				20G...C2P1	2.3	3.2	0.8	1.2	2	4	15/140G-HC6C3-C15	510	23.2	29291	140x-xxx-B25 (9)	3242	1.4	DCFUSE1-10A	DCFH-51
0.75	1	2.1	20G...C2P1	2.3	3.2	20G...C3P5	3.9	5.3	1.3	1.9	3	6	15/140G-HC6C3-C15	510	23.2	29291	140x-xxx-B25 (9)	3242	2.2	DCFUSE1-10A	DCFH-51
1.5	1	3.5	20G...C3P5	3.9	5.3	20G...C5P0	5.5	7.5	2.1	3.1	4	10	15/140G-HC6C3-C15	510	23.2	29291	140x-xxx-B40 (9)	3242	3.7	DCFUSE1-10A	DCFH-51
2.2	1	5	20G...C5P0	5.5	7.5				3.1	4.5	6	10	30/140G-HC6C3-C30	510	23.2	29291	140x-xxx-B63 (9)	3242	5.3	DCFUSE1-10A	DCFH-51
						20G...C8P7	9.6	13.1	3.1	4.5	6	15	30/140G-HC6C3-C30	510	23.2	29291	140x-xxx-B63 (9)	3242	5.3	DCFUSE1-10A	DCFH-51
4	1	8.7	20G...C8P7	9.6	13.1	20G...C011	13.1	17.3	5.4	7.8	10	20	30/140G-HC6C3-C30	510	23.2	29291	140x-xxx-C10 (9)	3242	9.2	DCFUSE1-16A	DCFH-51
5.5	1	11.5	20G...C011	12.7	17.3	20G...C015	17.3	23.1	7.1	10.3	15	25	30/140G-HC6C3-C30	510	23.2	29291	140x-xxx-C16 (10)	3242	12.2	DCFUSE1-20A	DCFH-51
7.5	1	15.4	20G...C015	16.9	23.1				9.6	13.8	20	30	30/140G-HC6C3-C30	510	23.2	29291	140x-xxx-C20 (10)	3242	16.3	DCFUSE1-25A	DCFH-51
0.75	2	2.1	20G...C2P1	3.1	3.7	20G...C2P1	3.1	3.7	1.3	1.9	3	4	15/140G-HC6C3-C15	510	23.2	29291	140x-xxx-B25 (9)	3242	2.2	DCFUSE1-10A	DCFH-51
1.5	2	3.5	20G...C3P5	5.2	6.3	20G...C3P5	5.2	6.3	2.1	3.1	4	7	15/140G-HC6C3-C15	510	23.2	29291	140x-xxx-B40 (9)	3242	3.7	DCFUSE1-10A	DCFH-51
2.2	2	5	20G...C5P0	7.5	9	20G...C5P0	7.5	9	3.1	4.5	6	10	30/140G-HC6C3-C30	510	23.2	29291	140x-xxx-B63 (9)	3242	5.3	DCFUSE1-10A	DCFH-51
4	2	8.7	20G...C8P7	13	15.6	20G...C8P7	13	15.6	5.4	7.8	10	15	30/140G-HC6C3-C30	510	23.2	29291	140x-xxx-C10 (10)	3242	9.2	DCFUSE1-16A	DCFH-51
5.5	2	11.5	20G...C011	17.2	20.7	20G...C011	17.2	20.7	7.1	10.3	15	20	30/140G-HC6C3-C30	510	23.2	29291	140x-xxx-C16 (10)	3242	12.2	DCFUSE1-20A	DCFH-51
						20G...C015	17.3	23.1	7.1	10.3	15	20	30/140G-HC6C3-C30	510	23.2	29291	140x-xxx-C16 (10)	3242	12.2	DCFUSE1-20A	DCFH-51
7.5	2	15.4	20G...C015	16.9	23.1	20G...C022	24.2	33	9.6	13.8	20	30	30/140G-HC6C3-C30	510	23.2	29291	140x-xxx-C20 (10)	3242	16.3	DCFUSE1-25A	DCFH-51
11	2	22	20G...C022	24.2	33				13.6	19.7	25	45	30/140G-HC6C3-C30	510	23.2	29291	140x-F8E-C25	3242	23.2	DCFUSE1-40A	DCFH-NH1
	3					20G...C030	33	45	13.6	19.7	25	45	30/140G-HC6C3-C30	510	23.2	29291	140x-F8E-C25	4052	23.2	DCFUSE1-40A	DCFH-NH1
15	3	30	20G...C030	33	45	20G...C037	45	55.5	18.6	26.9	35	60	90/140G-HC6F3-C90	510	23.2	29291	140x-F8E-C32	4052	31.7	DCFUSE3-63A	DCFH-NH1
18.5	3	37	20G...C037	40.7	55.5	20G...C043	55.5	66.6	22.9	33.1	45	70	90/140G-HC6F3-C90	510	23.2	29291	140x-F8E-C45	4052	38.1	DCFUSE3-63A	DCFH-NH1
22	3	43	20G...C043	47.3	64.5	20G...C060 (13)	66	90	26.7	38.5	50	90	90/140G-HC6F3-C90	510	23.2	29291	–	–	45.4	DCFUSE3-80A	DCFH-NH1
						20G...C061	66	90	26.7	38.5	50	90	90/140G-HC6F3-C90	510	23.2	29291	–	–	45.4	DCFUSE3-125A	DCFH-NH1
30	4	60	20G...C060	66	90	20G...C072	90	108	37.2	53.7	70	100	90/140G-HC6F3-C90	510	23.2	29291	–	–	63.4	DCFUSE3-125A	DCFH-NH1
						20G...C073	90	108	37.2	53.7	70	100	90/140G-HC6F3-C90	510	23.2	29291	–	–	63.4	DCFUSE3-125A	DCFH-NH1
	3	61	20G...C061	67.1	91.5				37.8	54.6	70	100	90/140G-HC6F3-C90	510	23.2	29291	–	–	64.5	DCFUSE3-125A	DCFH-NH1
37	4	72	20G...C072	79.2	108	20G...C086	108	129.6	44.6	64.4	80	125	100/140G-HC6F3-D10	510	23.2	29291	–	–	76.1	DCFUSE3-125A	DCFH-NH1
	5					20G...C085	108	129.6	44.6	64.4	80	125	100/140G-HC6F3-D10	510	23.2	29291	–	–	76.1	DCFUSE3S-160A	DCFH-NH1
	4	73	20G...C073	80.3	109.5				45.2	65.3	80	125	100/140G-HC6F3-D10	510	23.2	29291	–	–	77.1	DCFUSE3-125A	DCFH-NH1
45	5	85	20G...C085	93.5	127.5	20G...C104	127.5	156	52.7	76.1	100	150	125/140G-HC6F3-D12	510	23.2	29291	–	–	89.8	DCFUSE3S-160A	DCFH-NH1
	4	86	20G...C086	94.6	129				53.3	77	100	150	125/140G-HC6F3-D12	510	23.2	29291	–	–	90.9	DCFUSE3-160A	DCFH-NH1

How do I know if I need Impedance (add a line reactor)? (non regen drives)

1

Installation site has switched power factor correction capacitors.

2

Installation site has reoccurring lightning strikes or voltage spikes in excess of 6000V Peak.

3

Installation site has power interruptions or voltage dips in excess of 200VAC.

4

Voltage unbalance trips

5

The transformer is too large in comparison to the drive. General rule is if the transformer is more than 10x the capacity of the VFD. See calculation:

Sample Calculation of Impedance From DRIVES-IN001

EXAMPLE The drive is rated 1 Hp, 480V, 2.7A input.
The supply transformer is rated 50,000 VA (50 kVA), 5% impedance.

$$Z_{drive} = \frac{V_{line\text{-}line}}{\sqrt{3} * I_{input\text{-}rating}} = \frac{480V}{\sqrt{3} * 2.7} = 102.6 \text{ Ohms}$$

$$Z_{xfmr} = \frac{(V_{line\text{-}line})^2}{VA} * \% \text{ Impedance} = \frac{480^2}{50{,}000} * 0.05 = 0.2304 \text{ Ohms}$$

Note that the percent (%) impedance has to be in per unit (5% becomes 0.05) for the formula.

$$\frac{Z_{xfmr}}{Z_{drive}} = \frac{0.2304}{102.6} = 0.00224 = 0.22\%$$

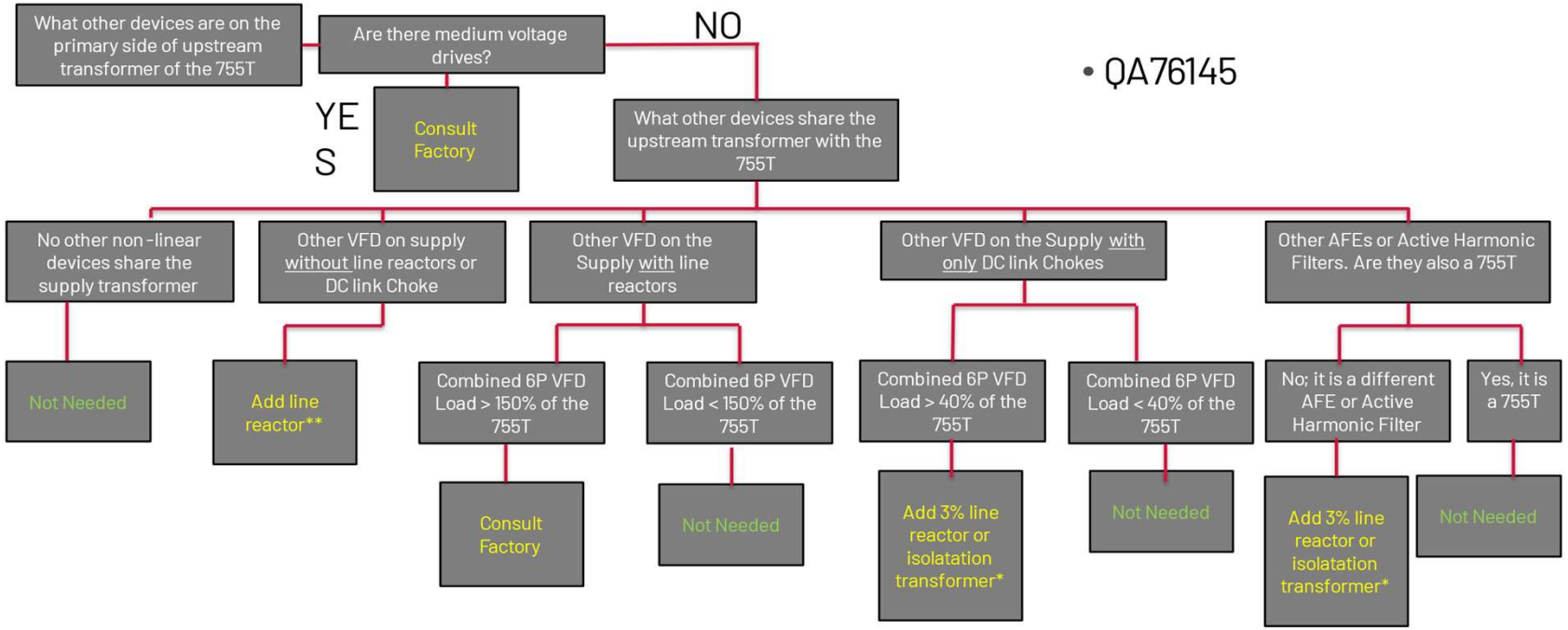
0.22% is less than 0.5%. Therefore, this transformer is too big for the drive and a line reactor should be added.

For a more accurate portrayal of impedance

You can add the impedance of the cable from the transformer to the drive. It can add another 5-20 ohms to the transformer.

PowerFlex 755T (L/R/M) – Line Reactor Required? (AFE drives)

For more information, reference Knowledgebase ID QA76145



*If line reactor is required, add no higher than 3% or may be too much voltage drop, size line reactor like you would for the equivalent 755 drive

**Line reactors are preferred in front of the non 755T drive. In this case add the line reactor in front of the non 755T drive first and follow remaining guidance.

Treat drives with passive harmonic filters as drives with line reactors, unless they are larger than 1.5 times the 755T. If this is the case, consult factory

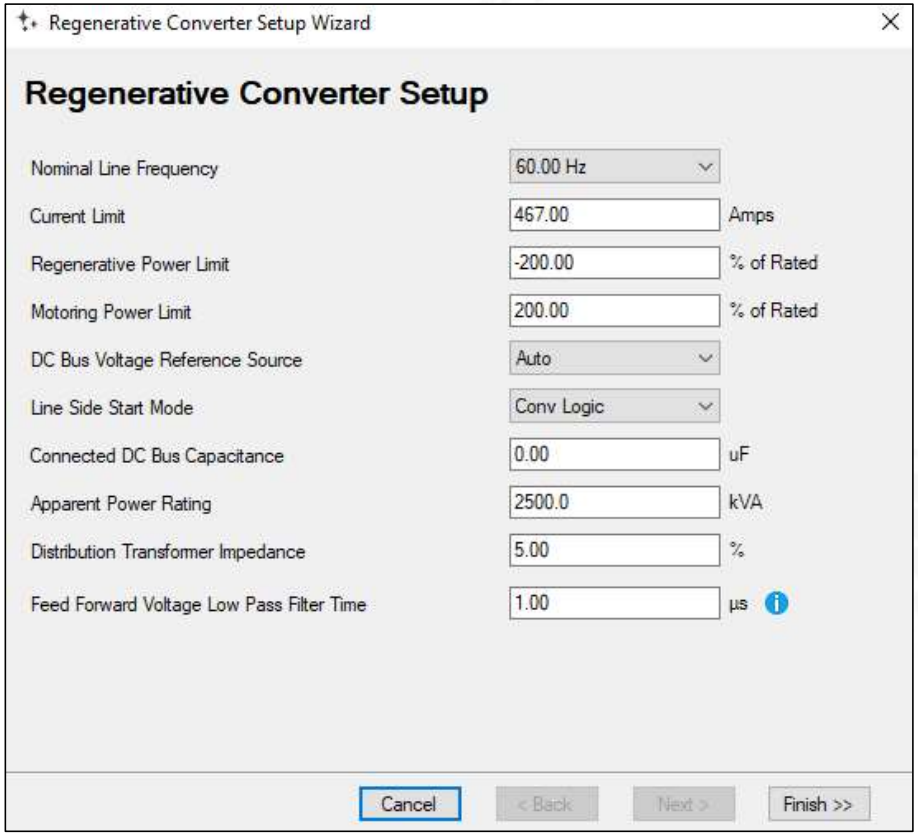
What to do if a line reactor is added in front of an AFE

How do you account for a line reactor when entering the AC Line Parameters into a PF755T

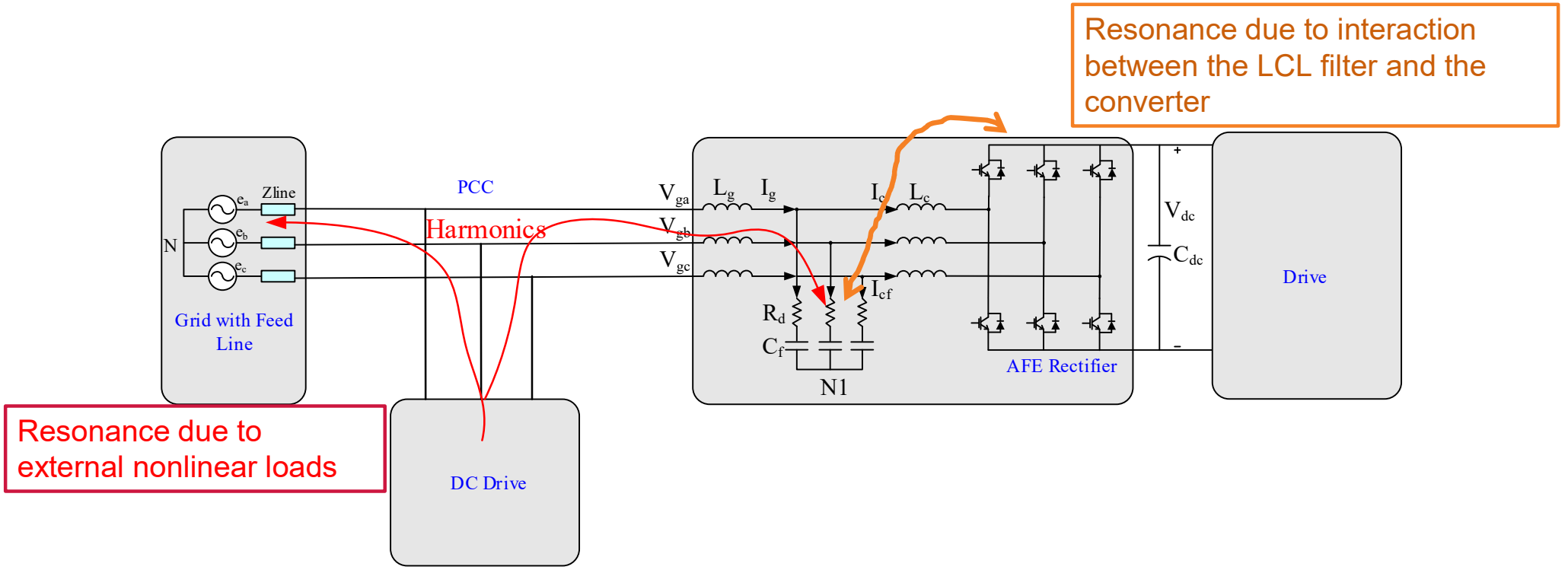
Doc ID:	QA45323	**Version:**	4.0
Status:	Published	**Author:**	KA Rest User
Published Date:	10/17/2022	**Owner:**	KA Rest User
Answer ID:	1088022	**Last Modified:**	9/2/2023
Last Modifier:	Lei Ma		

Power Source Considerations with 755T – Setup

- KVA: must be equal to or greater than drive KW rating
- Primary Voltage
- Secondary Voltage
- % Impedance
- Grounding (SOLIDLY GROUNDED PREFERRED!)



What is Capacitor Resonance?



External Non-Linnear Loads:
DC Drive, AC Drive, other AFE, MV drives, etc.

Why is it a Problem?

- If filter capacitors get hot it reduces their useful life could lead to unplanned down time (early failure).
- Typically, an AFE drive is part of a lineup or a critical system. Unplanned down time… not good.
- We protect the LCL filter capacitors:
  - To ensure product longevity
  - To prevent catastrophic failure

Configurable LCL Filter Capacitor Over Resonance Response

Review the Attention statement that follows if you intend to configure the line side converter to produce an alarm instead of a fault when the LCL Capacitor Over Resonance event occurs.

ATTENTION: You must read the following information before you can enable the Line Side Converter to produce an alarm instead of a fault when the **LCL Filter Capacitor Over Resonance** event occurs.
Operating the product (drive or bus supply) during the LCL Capacitor Over Resonance event may damage the LCL filter. This damage may lead to catastrophic product failure and collateral damages.
It is your responsibility to configure drive parameters, understand the causes and consequences of LCL capacitor over resonance, and meet safety requirements in accordance with all applicable codes and standards. If enabling the Line Side Converter to produce an alarm instead of a fault when the LCL Capacitor Over Resonance event occurs is desired, you must certify the safety of the application. To acknowledge that you have read this 'Attention' and properly certified the application, set bit 5 'CapORsncAlrm' of parameter 13:40 [Conv Options Cfg]. This action removes Fault 56, 'CapOvrRsncCfg'. It allows parameter 0:453 [CapOvrRsncActn] to be set to 0 'Alarm', enabling an alarm instead of a fault.

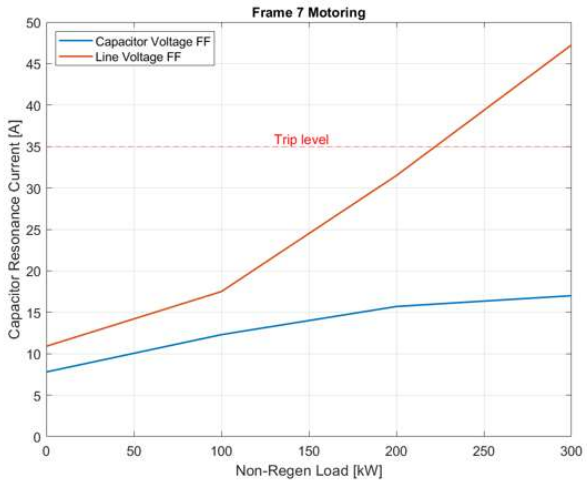
What if I follow guidance and there is still cap resonance?

When drive is running

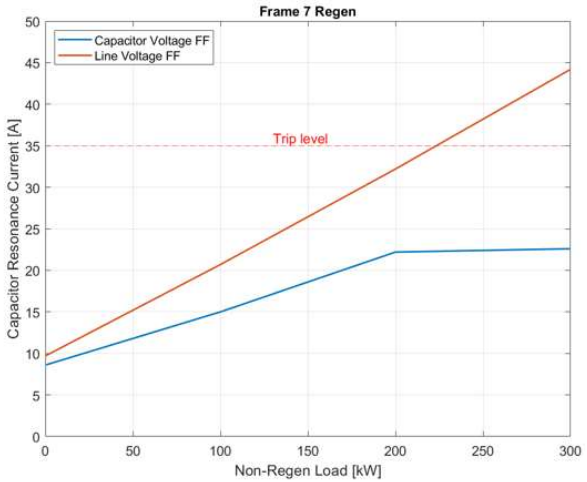
- Firmware 13 – new parameter for “impedance shaping” of LCL filter.

13 - Line Sid...	365	FFVltgSource Sel	Cap Voltage		1

- When drive is running this allows for **significant reduction** in BPF currents (cap resonance).
- Investigation required to see how this could affect installation guidance! There is significant improvement in BPF currents which has been confirmed in the field.



Motoring 100% load of the AFE*

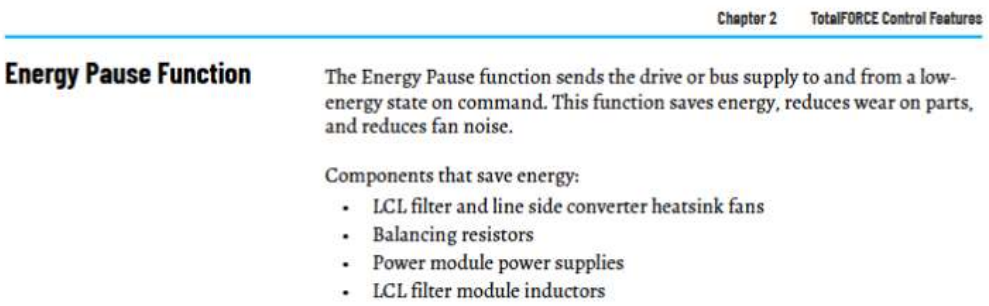


Regen 100% load of the AFE*

What if I follow guidance and there is still cap resonance?

When drive is not running

- Use energy pause to remove the LCL filter from the power circuit when the drive is idle.
  - Requires Auxiliary power – see 750-RM100 chapter 2 for more information.



Chapter 2 TotalFORCE Control Features

Energy Pause Function

The Energy Pause function sends the drive or bus supply to and from a low-energy state on command. This function saves energy, reduces wear on parts, and reduces fan noise.

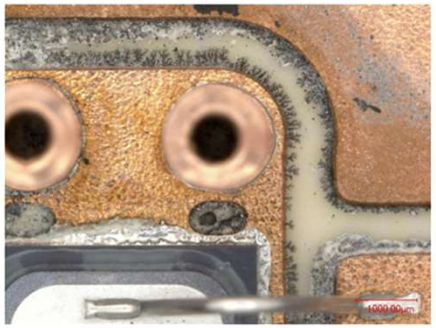
Components that save energy:

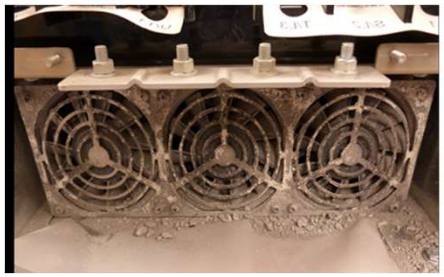
- LCL filter and line side converter heatsink fans
- Balancing resistors
- Power module power supplies
- LCL filter module inductors

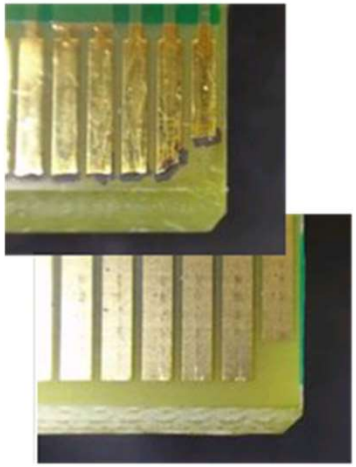
- Or Run the active converter whenever the AFE is powered.
- Remember, the drive will counteract harmonics when running.

AC Drive is Reliable and Dependable When Protected.

Protect AC Drive From the Atmosphere/Climate Conditions:

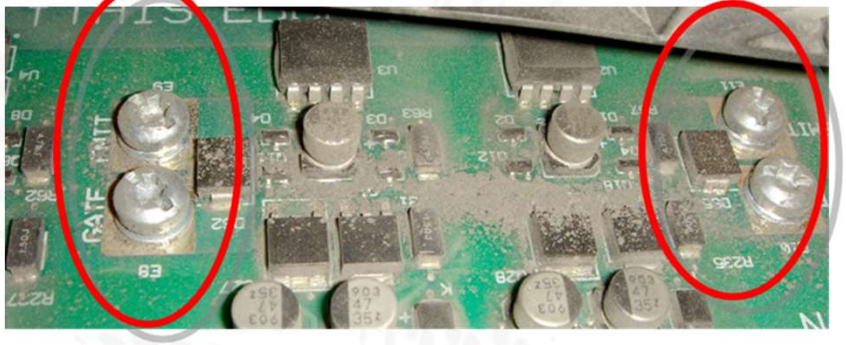






Magnetic dust found

inside drive enclosure

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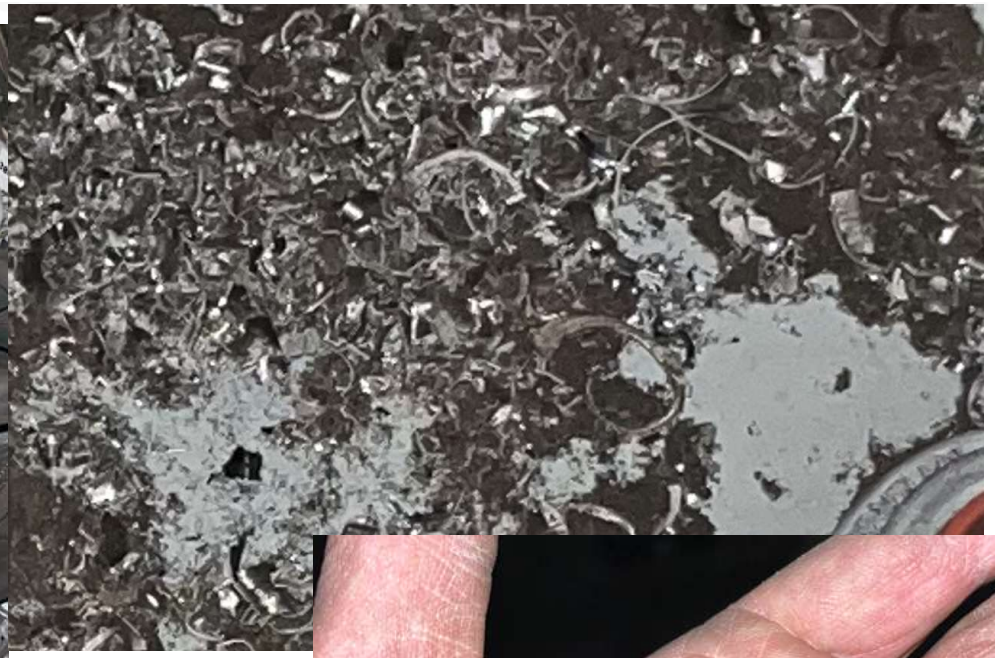



What is
he talking
about ?

497AJH

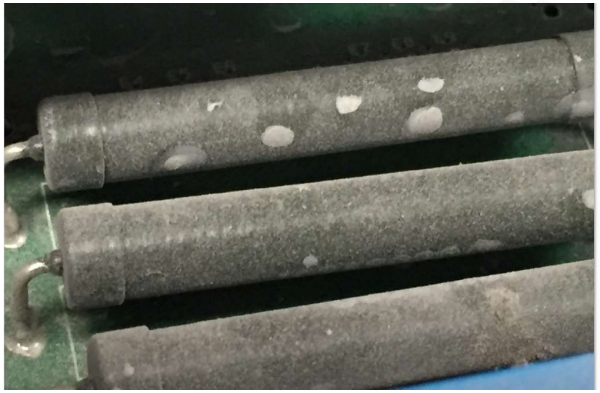
Image shown is a representation only. Exact specifications should be obtained from the product data sheet.

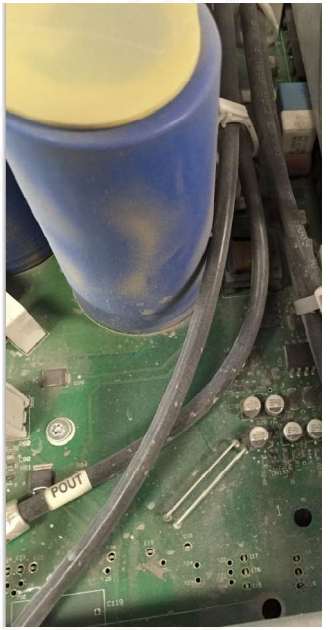
DigiKey Part Number	SCP760-ND
Manufacturer	SCS
Manufacturer Product Number	497AJH
Description	VACUUM HEPA 120VAC ESD SAFE
Manufacturer Standard Lead Time	2 Weeks
Customer Reference	
Detailed Description	Electronics Vacuum 120VAC With 7 ft Hose, 8 ft Cord, HEPA Filter, Nozzle, Strap ESD Safe
Datasheet	Datasheet

Figure 25: ESD safe vacuum for vacuuming boards and cabinet
https://www.digikey.com/en/products/detail/scs/497AJH/9169375

Air Handling Units and Air Conditioners

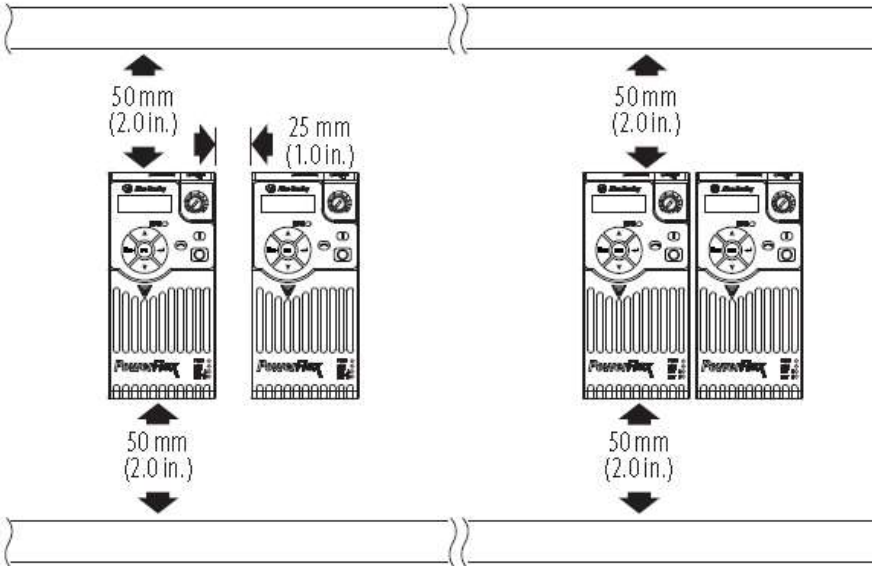
Pictures from Customer Sites

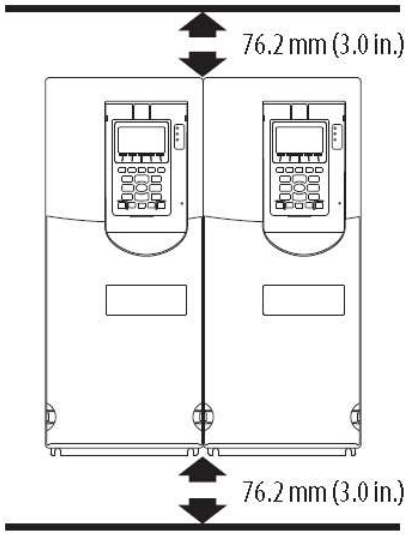


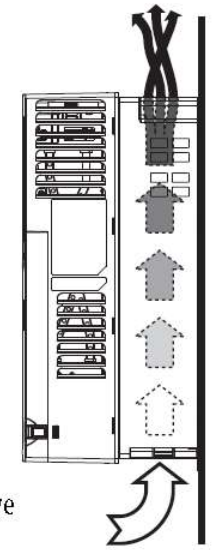


AC Drive is Reliable and Dependable When Protected.

Protect AC Drive From the Atmosphere/Climate Conditions:







Airflow through the drive must not be impeded.

Pictures from a customer site

AC Drive is Reliable and Dependable When Protected.

Protect AC Drive From the Atmosphere/Climate Conditions:

Pollution Degree Ratings According to EN 61800-5-1

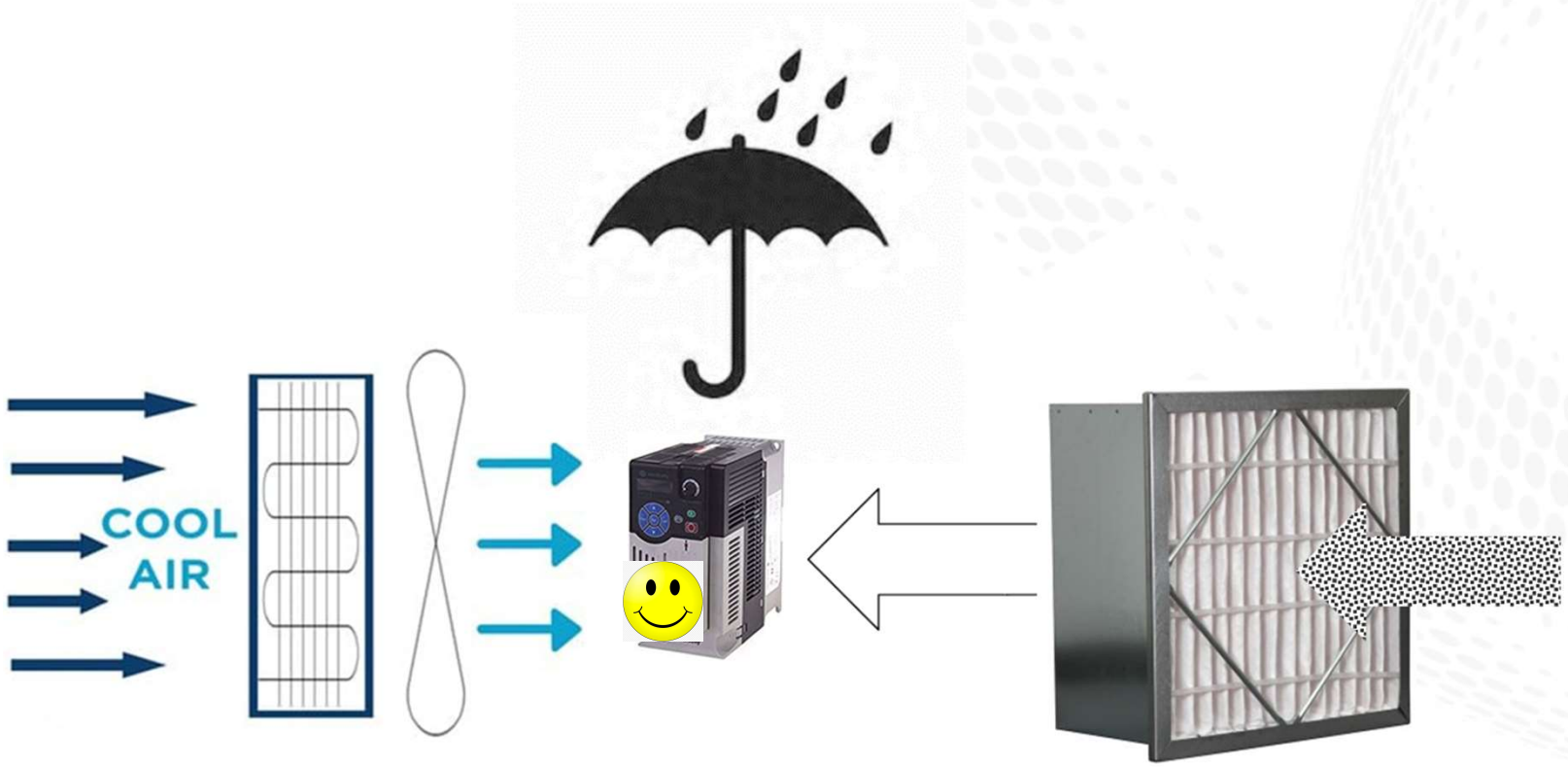
Pollution Degree	Description
1	No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.
2	Normally, only non-conductive pollution occurs. Occasionally, a temporary conductivity that is caused by condensation is to be expected, when the drive is out of operation.
3	Conductive pollution or dry non-conductive pollution occurs, which becomes conductive due to condensation, which is to be expected.
4	The pollution generates persistent conductivity that is caused, for example, by conductive dust or rain or snow.

Surrounding environment pollution degree

Pollution Degree1and 2	All enclosures acceptable
Pollution Degree 3 and 4	Enclosure that meets IP54, NEMA/UL Type 12 required

AC Drive is Reliable and Dependable When Protected.

Protect AC Drive From the Atmosphere/Climate Conditions:



Thank You