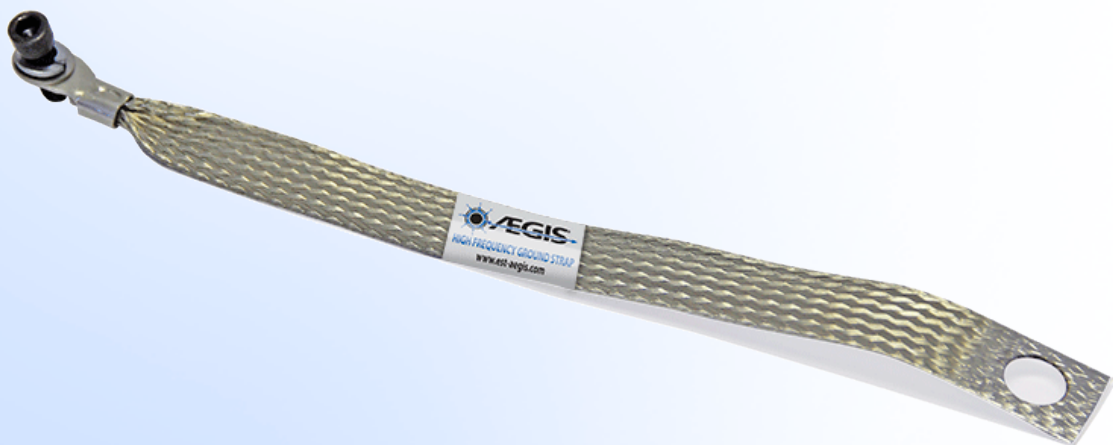
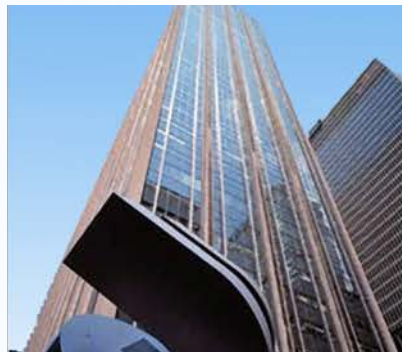


Best Practices for High Frequency Grounding with AEGIS® HFGS (High-Frequency Ground Straps)



High-Frequency Ground Strap Is Recommended for use by...



ABB in Technical Guide #5:



Allen-Bradley

Allen Bradley in Publication
1770-4.1



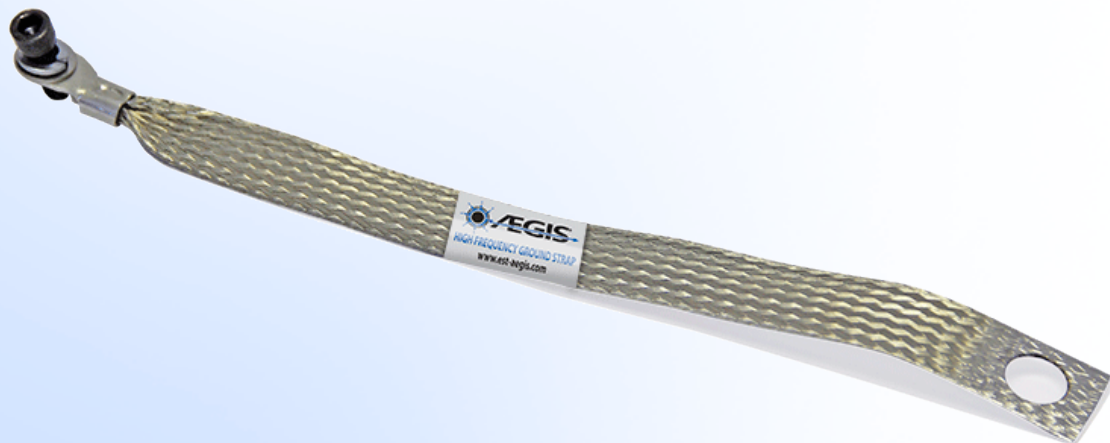
Nidec Motor Corporation in
their Technical White Paper



Danfoss in their Engineering
Guide



Baldor in their INDUSTRY
WHITE PAPER



**AEGIS® HF Ground Straps**
Ensure Effective Grounding of
High-Frequency Currents

Best Practices by Motor and Drive Manufacturers
what the experts say...

ABB Technical Guide No. 5
"Add high frequency bonding connections between the installations and known earth reference points to equalize the potential of affected items, using braided straps of copper..."
"This must be made at the points where discontinuity between the earth level of the inverter and that of the motor is suspected. Additionally it may be necessary to equalize the potential between the frames of the motor and the driven machinery to short the current path through the motor and the driven machine bearings."

Allen Bradley Publication 1770-4.1, Application Data, Industrial Automation Wiring and Grounding Guidelines
"In addition to making good connections through each bolt or stud, use either 1-inch copper braid... to connect each chassis, enclosure and central ground bus mounted on the back-panel"

Nidec Motor Corporation Technical White Paper: Increased Reports of Bearing Damage in AC Motors Operating from Modern PWM VFD's
"One approach that simplifies the solution is to utilize the following components: Proper grounding connection points, proper grounding cables and bonding straps for high frequency conditions and proper termination devices for high frequencies..."

Danfoss Engineering Guide – HVAC & Refrigeration applications – Facility services design and project engineering of electrical drives
"A large conductor surface area for draining high-frequency currents can be obtained by using fine stranded wire, such as ... using special earthing straps or cables."
"Braided earthing straps are often used nowadays in practice..."
"Note: System earthing has a substantial effect on smooth, trouble-free facility operation. Ground loops must be avoided. Good potential equalization is essential!"

Baldor INDUSTRY WHITE PAPER Inverter-Driven Induction Motors Shaft and Bearing Current Solutions
"Proper grounding of the motor frame is also important. ... ground straps should also be connected between the motor frame and the driven load equipment frame to allow a low impedance, alternate path for shaft currents."
"High frequency ground strap impedance is lowest for straps with fine conductors and the largest width to length ratio."
"In all cases, ground straps should be connected directly metal to metal (not through a painted surface) to provide the lowest impedance path for high frequency currents."

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Conveniently packaged in 12" and 24" lengths for any NEMA or IEC Motor...





AEGIS® HF Ground Straps Ensure Effective Grounding of High-Frequency Currents

The Need for Proper Earth Grounding of VFD-Driven Motor Systems

Proper high-frequency (HF) grounding of VFD-driven motor systems is vital to prevent earth-level discontinuities between system components. It is especially critical in applications involving a motor and coupled equipment that are not mounted to a common baseplate. In such cases, effective HF grounding of all system components is necessary to equalize the potential between equipment frames and to prevent ground loops between the motor and coupled equipment.

Widely recognized as the most efficient path to ground for high-frequency currents, grounding straps are recommended by major motor and drive manufacturers.



AEGIS® HF Ground Straps... Specially Designed for High-Frequency Currents

Made of flat-braided, tinned copper, AEGIS® HF Ground Straps are specially engineered for the lowest possible impedance to the damaging high-frequency currents generated by variable frequency drives (VFDs or inverters). With a circular hole on one end for easy installation around the foot mounting screw of NEMA- or IEC-frame motors, they are equipped with a ring terminal on the opposite end. Custom lengths are available upon request.



Complete the Path from Motor Shaft to Earth Ground

VFDs can save 30% or more in energy costs, but they can also damage motors. VFDs induce high-frequency voltages on the shafts of the motors they control — voltages that can discharge through motor bearings, destroying them in as little as 3 months and damaging coupled equipment.

AEGIS® Shaft Grounding Rings provide effective long-term protection of bearings against damaging VFD-induced currents. By channeling these currents away from bearings and safely to ground through the motor frame, they mitigate frosting and fluting damage, premature bearing failure, and costly motor system downtime.

When used with AEGIS® Shaft Grounding Rings, AEGIS® HF Ground Straps provide a continuous low-resistance path for damaging high-frequency currents — from motor shaft to earth ground.

Fits NEMA Frame Sizes	Fits IEC Sizes
48, 48H, 56, 56H, 143T, 145T, 182T, 184T, 213T, 215T	80M, 90S, 90L
254T, 256T, 284T, 284TS, 286T, 286TS, 324T, 324TS, 326T, 326TS, 364T, 364TS, 365T, 365TS	100S, 100L, 112S, 112M, 132S, 132M, 160S, 160M, 160L, 180S, 180M, 180L
404T, 404TS, 405T, 405TS, 444T, 444TS, 445T, 445TS, 447T, 447TS, 449T, 449TS	200S, 200M, 200L, 225S, 225M, 250S, 250M, 280S, 280M

* Standard length: 12"
Custom lengths and terminations available on request.
Complete, copy, and fax form below: 207-998-5143

For more options, visit www.est-aegis.com/HFGS

Size	☐ Ring terminal	Bolt size:
Size	☐ Ring terminal	Bolt size:

Electro Static Technology
An ITW Company
31 Winterbrook Road
Mechanic Falls, ME, USA 04256
207-998-5143 • 800-738-1957
sales@est-aegis.com
www.est-aegis.com/HFGS



For custom lengths contact
sales@est-aegis.com

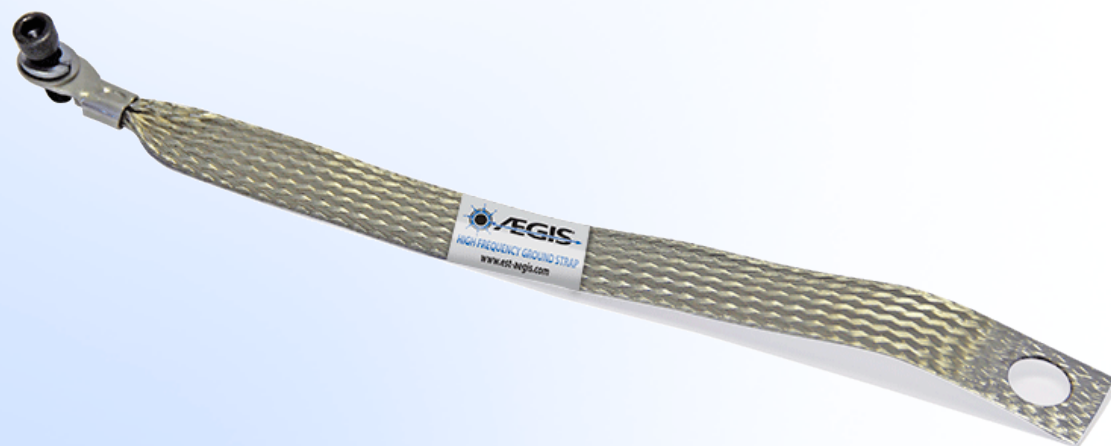


Part List...

AEGIS® HFGS High-Frequency Ground Strap Length: 12" and 24" Screws included			
12" Strap Catalog Number	24" Strap Catalog Number	Terminations	Fits Frame Sizes:
HFGS-T0410-R0312-12	HFGS-T0410-R0312-24	Term1: Punched hole 0.41" (10mm) Term 2: Ring terminal for 5/16" or 8 mm screws	<u>NEMA</u> : 48, 48H, 56, 56H, 143T, 145T, 182T, 184T, 213T, 215T <u>IEC</u> : 80M, 90S, 90L
HFGS-T0660-R0312-12	HFGS-T0660-R0312-24	Term1: Punched hole 0.66" (17mm) Term 2: Ring terminal for 5/16" or 8 mm screws	<u>NEMA</u> : 254T, 256T, 284T, 284TS, 286T, 286TS, 324T, 324TS, 326T, 326TS, 364T, 364TS, 365T, 365TS <u>IEC</u> : 100S, 100L, 112S, 112M, 132S, 132M, 160S, 160M, 160L, 180S, 180M, 180L
HFGS-T0940-R0312-12	HFGS-T0940-R0312-24	Term1: Punched hole 0.94" (24mm) Term 2: Ring terminal for 5/16" or 8 mm screws	<u>NEMA</u> : 404T, 404TS, 405T, 405TS, 444T, 444TS, 445T, 445TS, 447T, 447TS, 449T, 449TS <u>IEC</u> : 200S, 200M, 200L, 225S, 225M, 250S, 250M, 280S, 280M
HFGS-R0312-R0312-12	HFGS-R0312-R0312-24	Term 1: Ring terminal for 5/16" or 8 mm screws Term 2: Ring terminal for 5/16" or 8 mm screws	NEMA/IEC: universal terminations
Custom lengths and terminations available on request			

AEGIS® High-Frequency Ground Strap Ensures Reliable Bond Between Motor Frame and System Ground

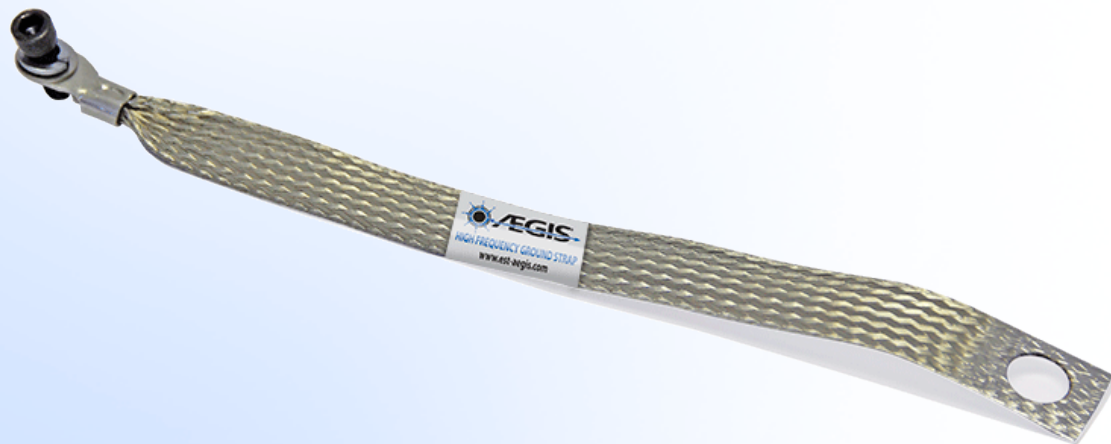
- Reliable-low impedance path to ground for high-frequency currents from the motor frame to drive/facility ground.
- Improve the grounding system of VFD driven systems plus any attached or coupled equipment.
- Focus on NEMA and IEC frame motors for off-the-shelf selection in 12" and 24" lengths
- Custom engineered high-frequency ground straps for longer lengths.



What can cause Impedance to High Frequency Currents?

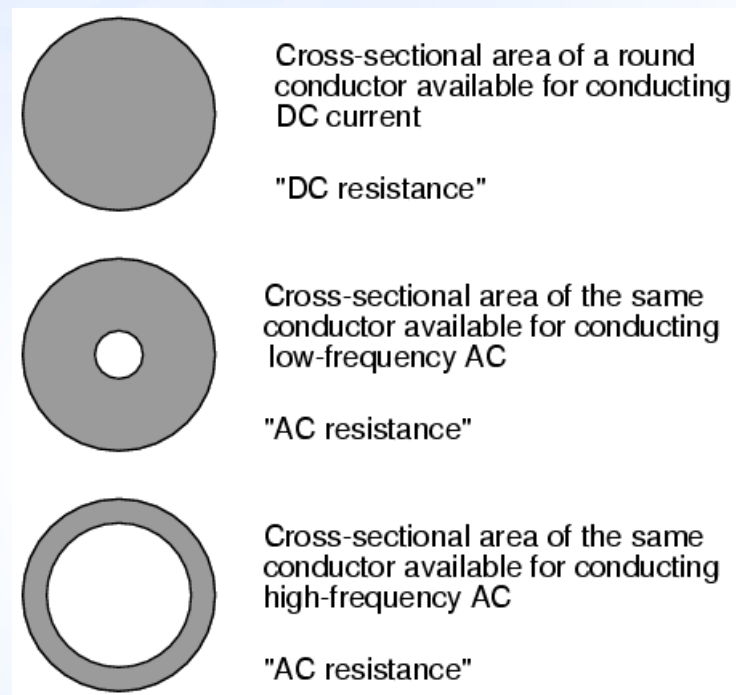
Note: Impedance is the “resistance” to high frequencies

- Long electrical wire lengths used in electrical connections can have a significant impedance to the high frequency currents
- Paint, corrosion, dissimilar metals, and multiple connection points can create impedances between surfaces
- Unshielded wire can induce electrical EMI and RFI across wires especially when multiple unshielded wires are all running in the same conduit



High Frequency Review

Grey is part of wire that actually carries current



Current travels through whole wire

DC

60 Hz

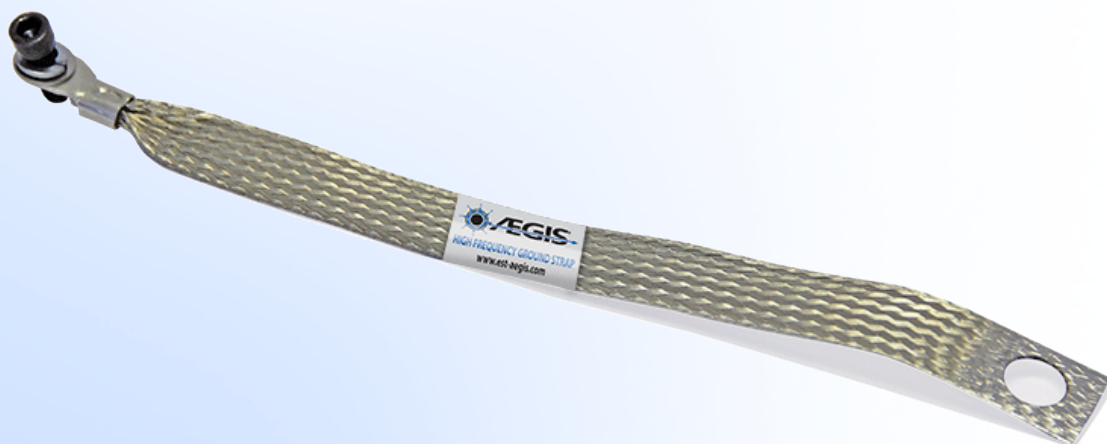


HF

50 MHz

Current travels on outside skin of wire

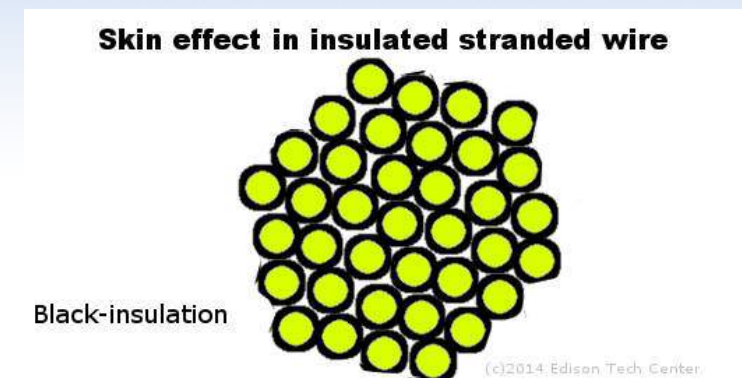
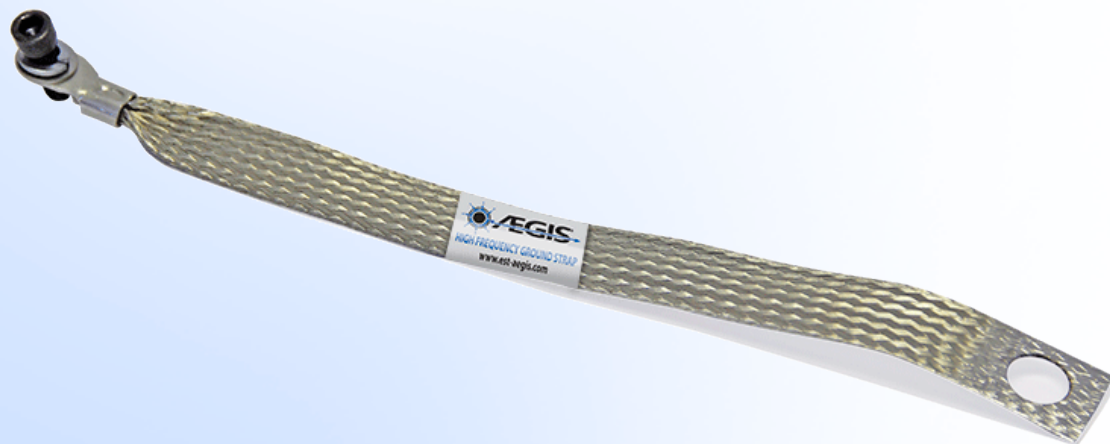
Known as "Skin Effect"



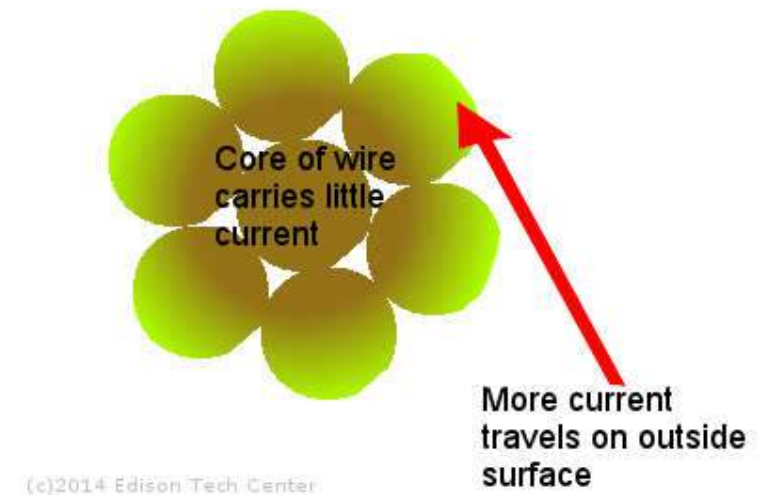
Current Flow – Skin Effect

Technical Note:

- Skin effect refers to a single wire strand.
- Ideal situation would be to insulate every individual strand of wire from each other to maximize skin effect.
 - *Cost prohibitive*
- Flat braided straps provide maximum surface area for greatest skin effect to transfer the high frequency currents.
 - *Best solution for High Frequencies*



Skin effect in stranded wire with no individual insulation



AEGIS® HFGS

- What does HFGS stands for?
“High-Frequency Ground Strap”
- What is it? A flat tin plated copper bonding strap that is pre-terminated on both ends – Ready to install
 - Tin enhances conductivity
 - Inhibits oxidation and corrosion of the copper
 - Low-impedance design with maximum skin effect
 - Designed for NEMA and IEC motor frames



Line Voltage – Balanced Input Voltage

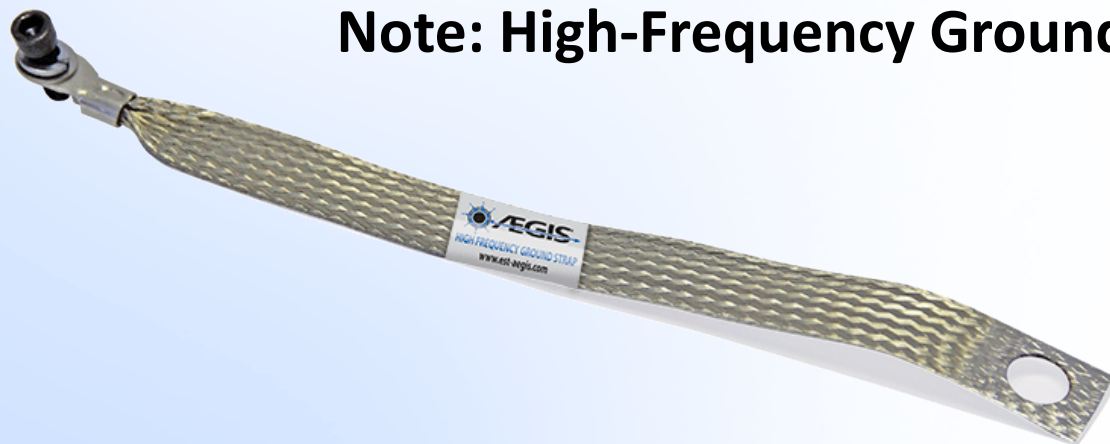
Usually no problem for motors

Balanced voltage condition



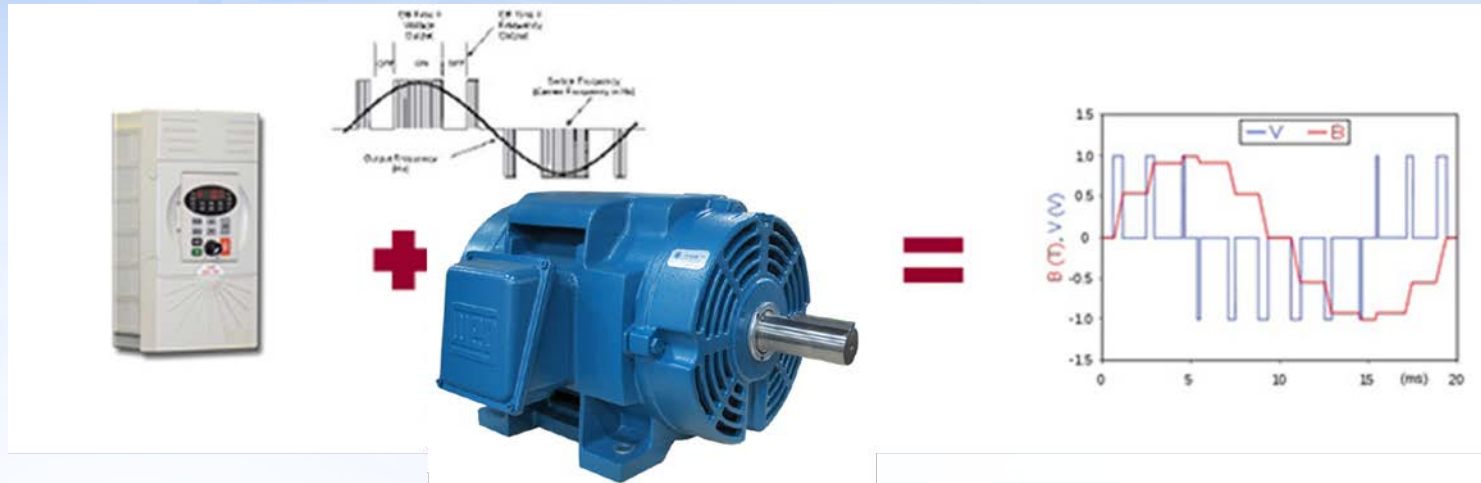
- ☐ Electric induction motors are designed for operation on 3 phase sine wave power - either 50 or 60 Hz.
- ☐ The input power is balanced in frequency, phase (120 degree phase shift) and in amplitude.
- ☐ Common mode voltage - the sum of the 3 phases always equal zero volts when properly balanced.

Note: High-Frequency Ground not needed.



PWM Voltage to Motors - A Problem for Bearings

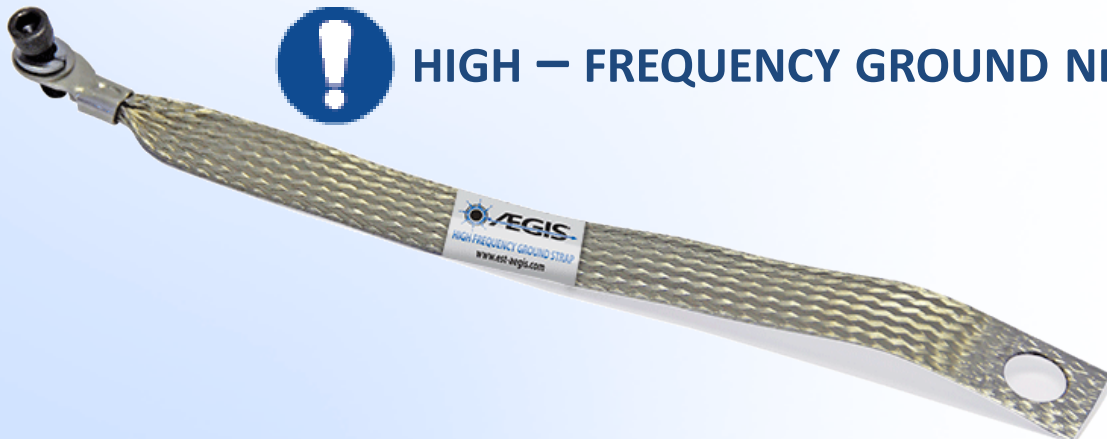
Unbalanced voltage condition



- ❑ When operated by VFD, the power to the motor is a series of positive and negative pulses instead of a smooth sine wave.
- ❑ The input voltage is never balanced because the voltage is either 0 volts, positive, or negative with rapid switching between pulses in all three phases.
- ❑ The common mode voltage is usually a “square wave” or “6 step” voltage wave form.



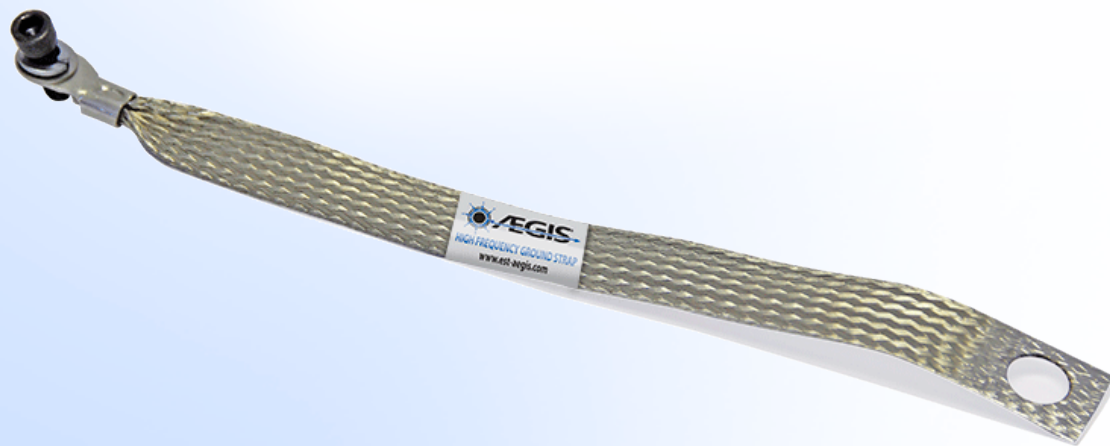
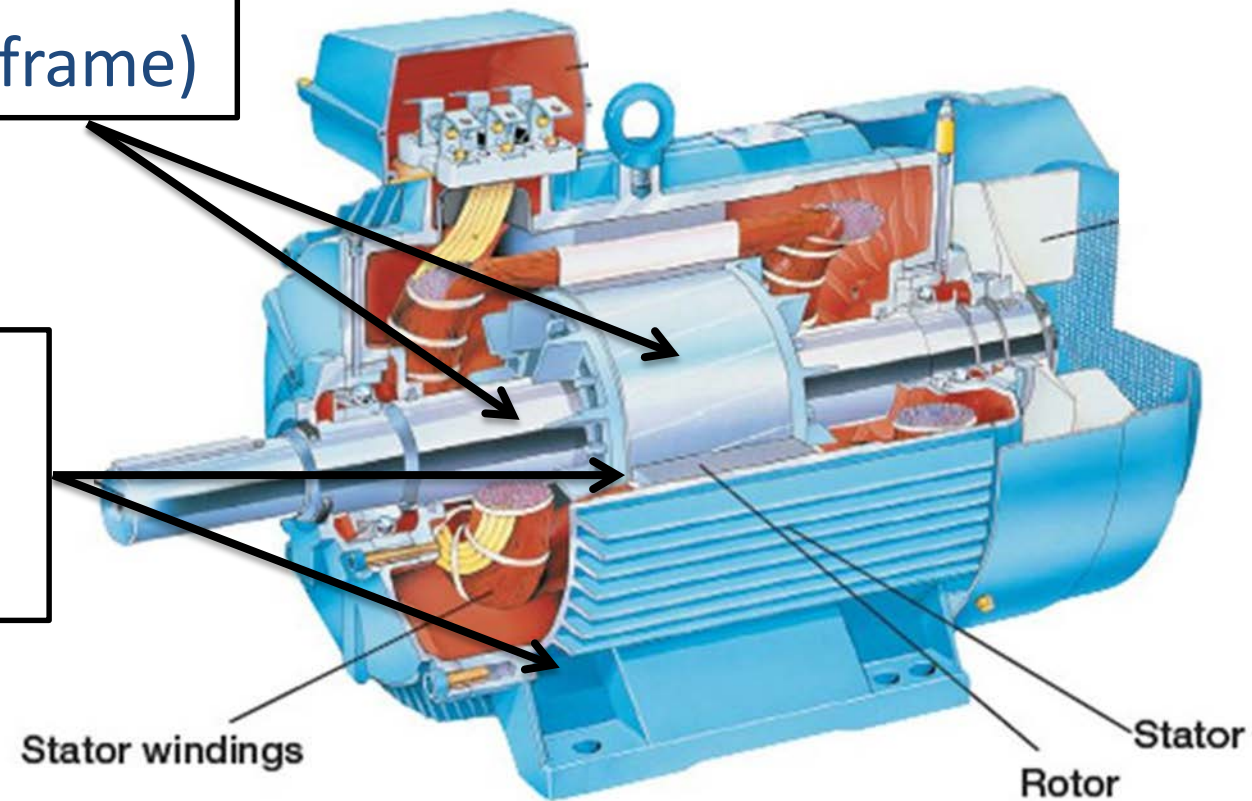
HIGH — FREQUENCY GROUND NEEDED FROM MOTOR TO THE DRIVE.



Motor Design Cause Rotor and Stator Currents

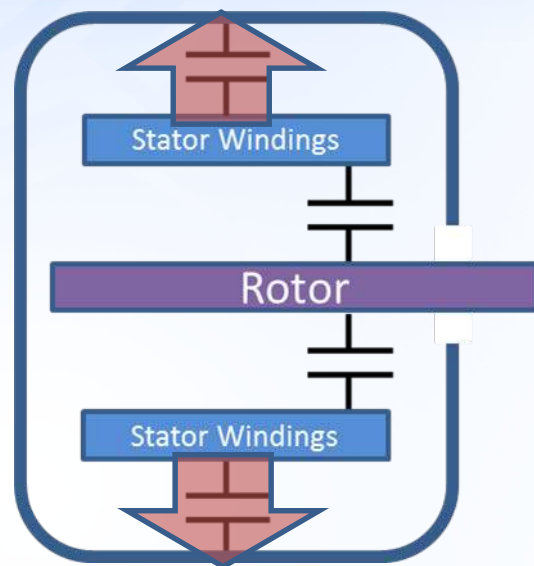
Capacitive Coupling Stator Windings to Stator (frame)

Capacitive Coupling Stator Windings to Rotor

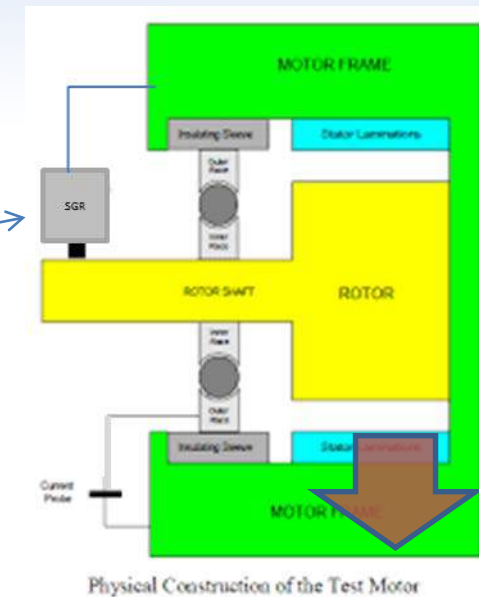


Stator Currents

From Stator Windings to Motor Frame

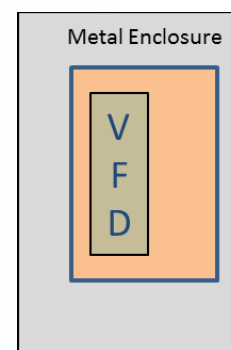


AEGIS® Ring

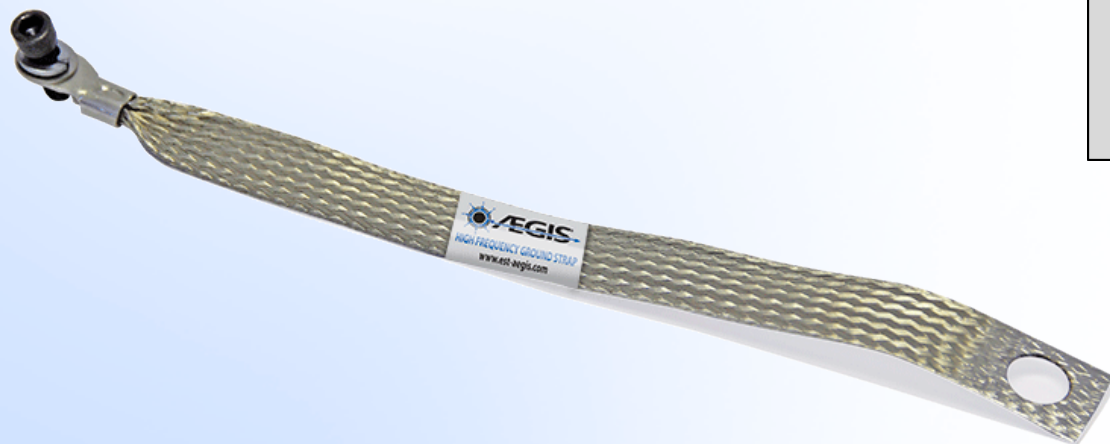


Stator Current
can be 2 x
Rotor Current

Physical Construction of the Test Motor

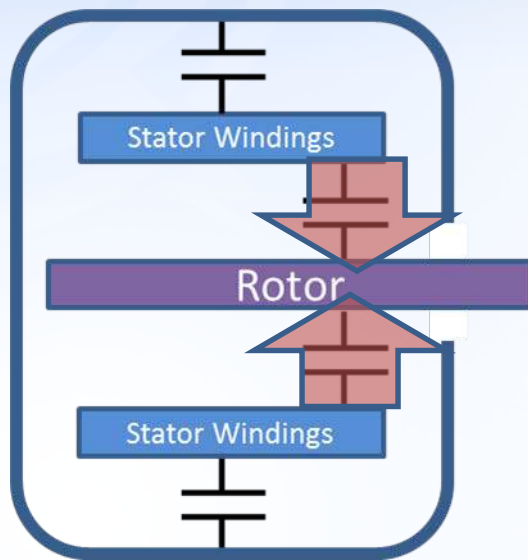


Stator Current
Path to VFD

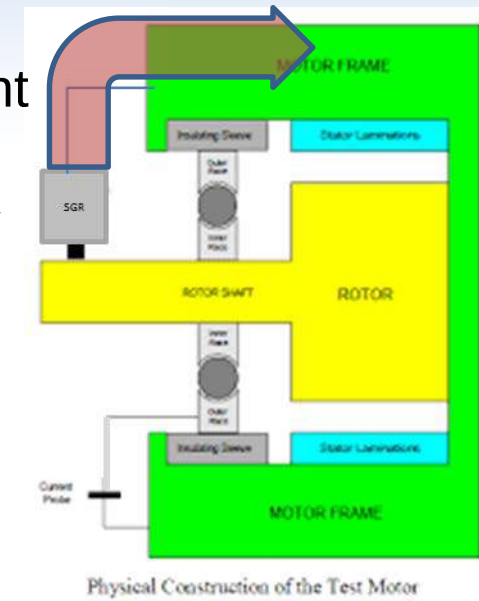


Rotor Currents

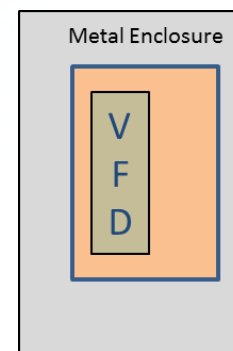
From Stator Windings to Rotor



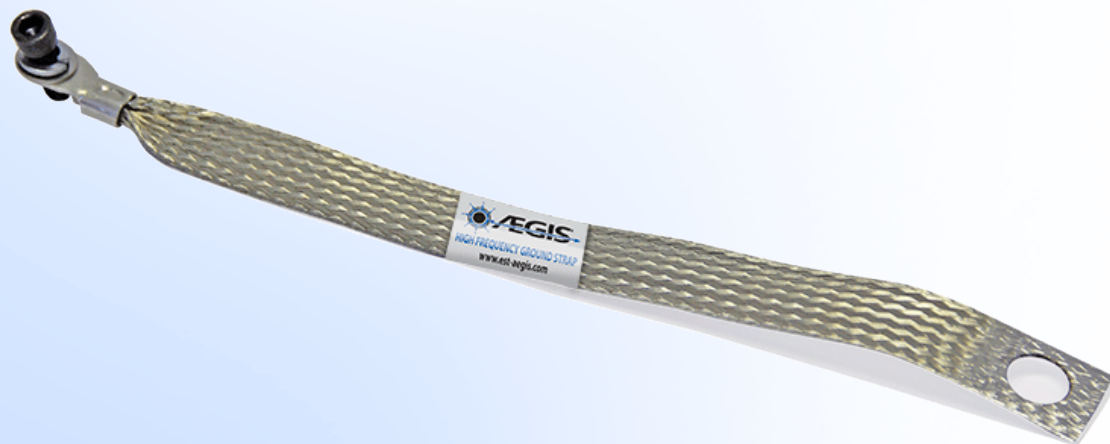
Rotor Current
AEGIS® Ring



Physical Construction of the Test Motor

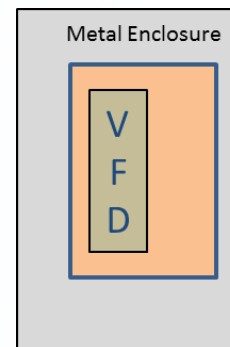
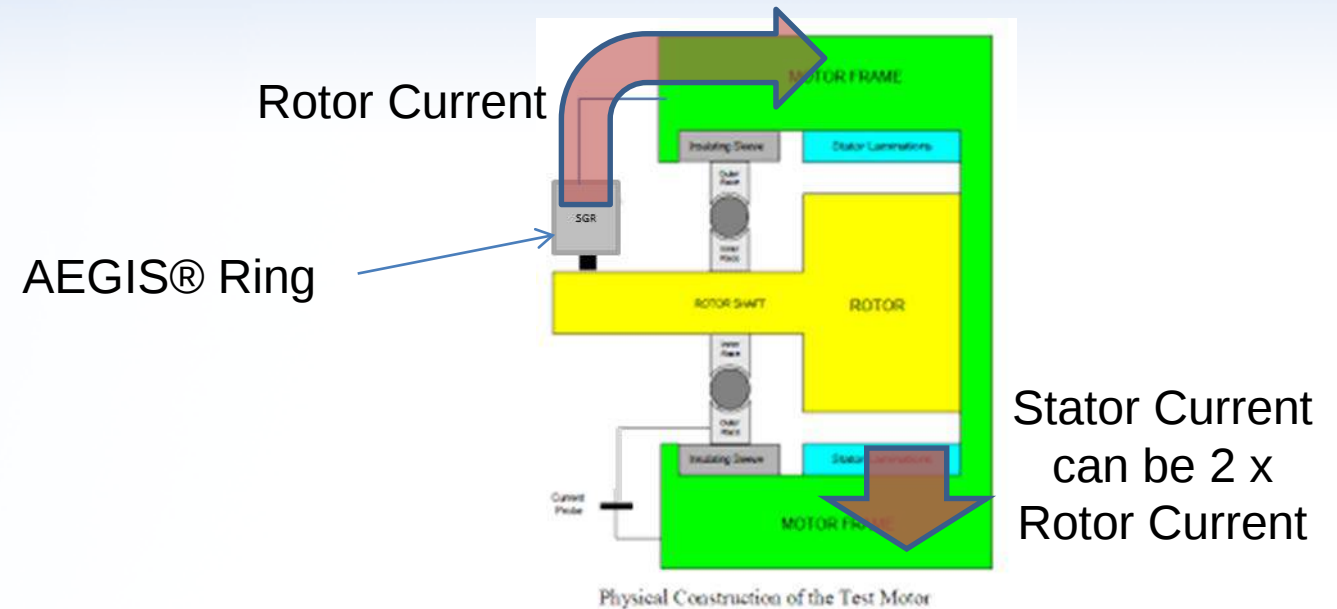
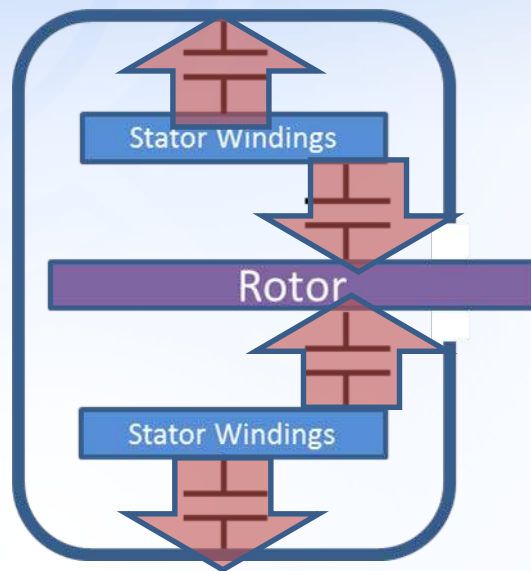


Rotor Current
Path to VFD

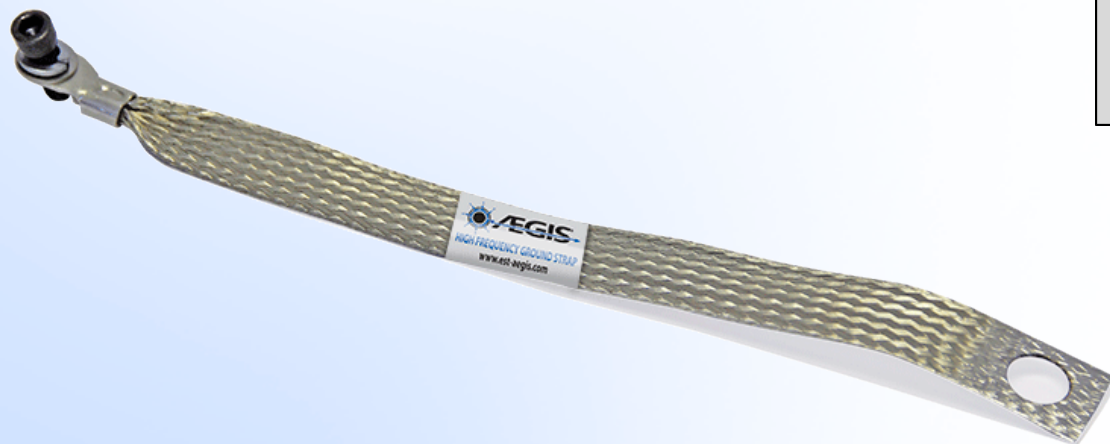


Rotor and Stator Currents

From Stator Windings to Both Motor Frame and Rotor

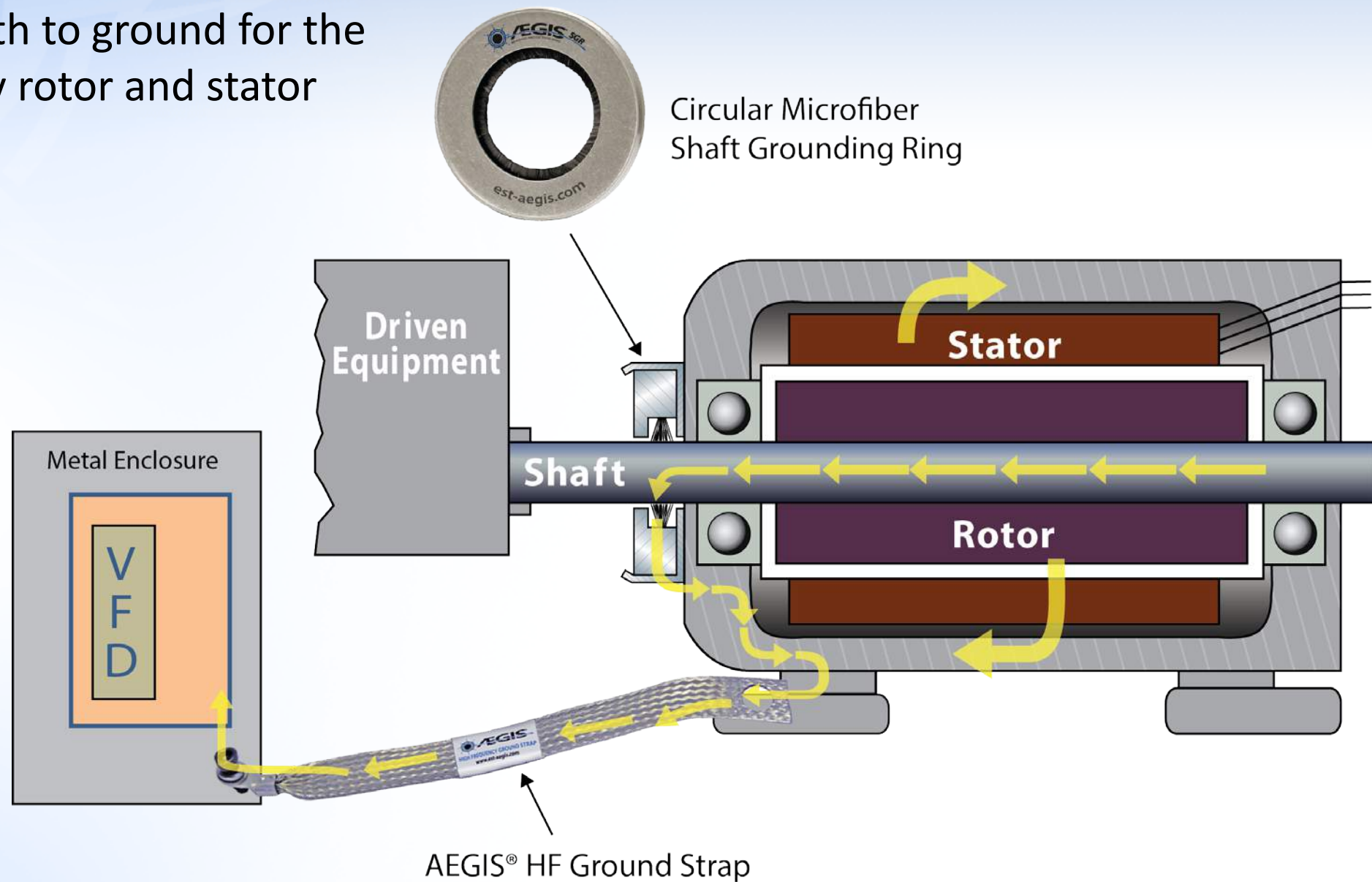


Stator and Rotor
Current Path to VFD



Rotor and Stator Currents

The AEGIS® HFGS provides the low impedance path to ground for the high frequency rotor and stator currents.



Electrical Ground System

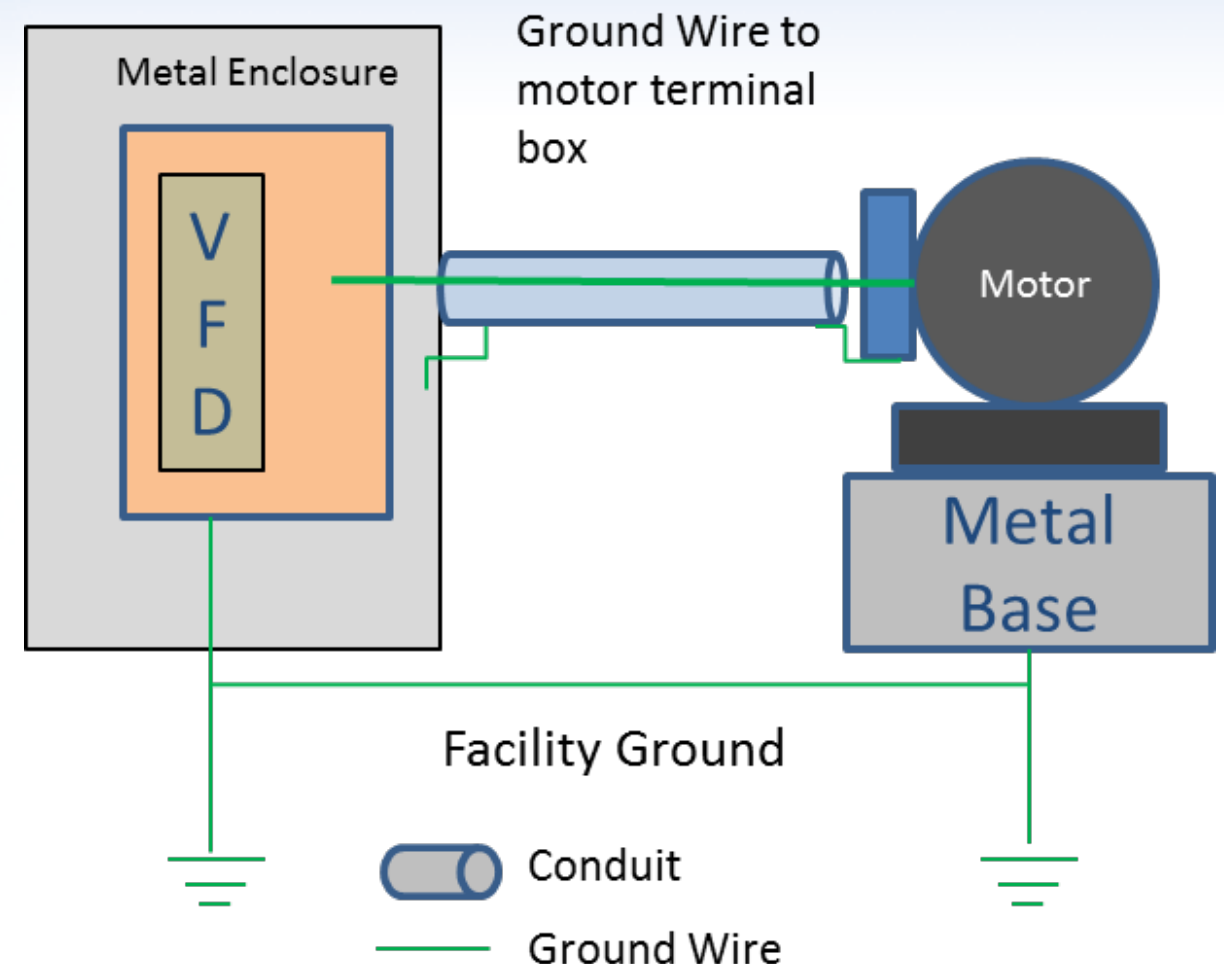
In a typical system the VFD panel, metal conduit, and motor base are all grounded to facility ground, usually via the main electrical ground from the 60 Hz supply.

System ground will be according to electrical code for safety.

Note however that electrical ground does not mean it is a low impedance ground for high-frequency currents.

Also not all ground connections are always tied together.

There can be multiple ground paths from the motor to the drive.



Electrical Ground System

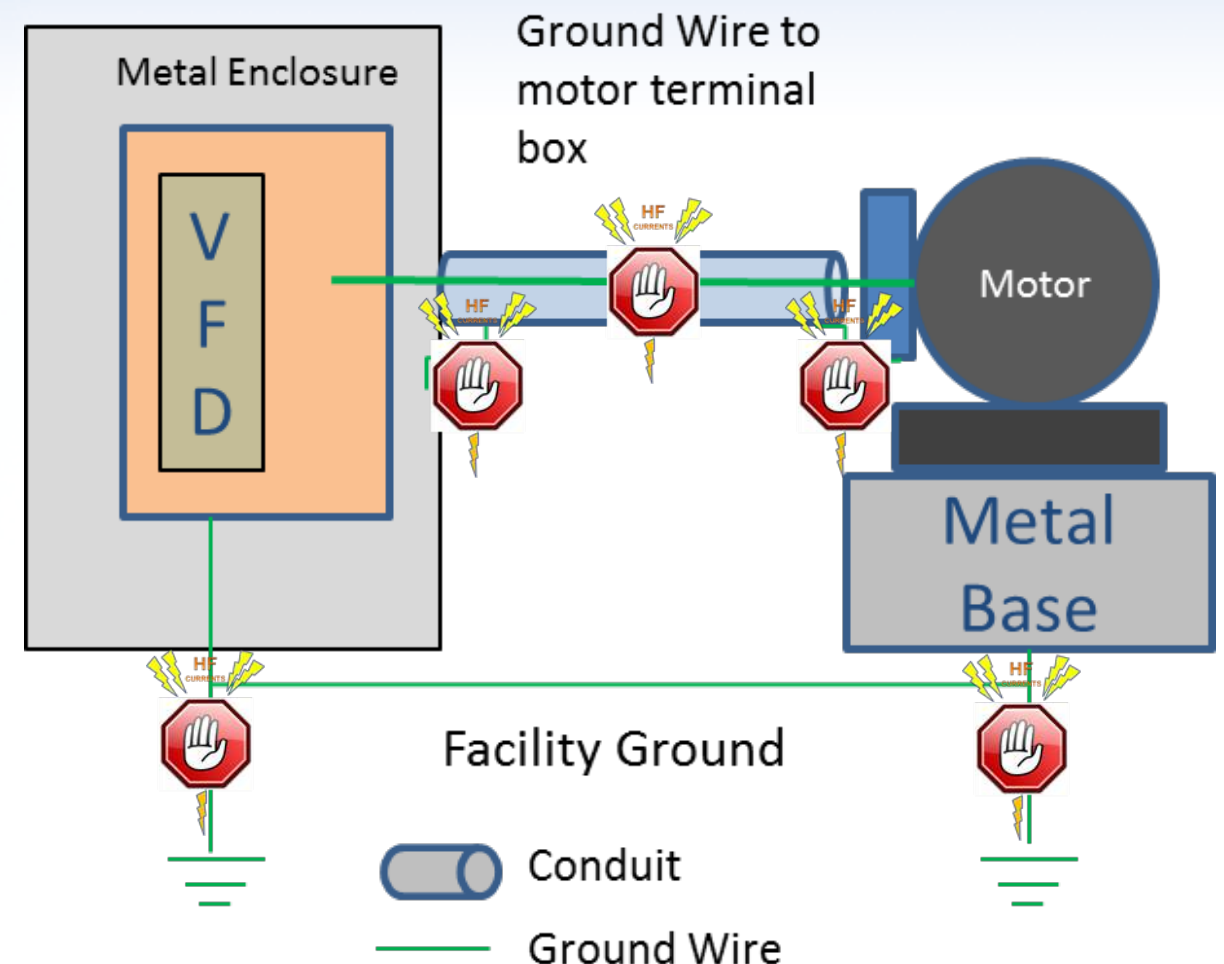
The electrical wiring – while good for safety ground when wired per electrical code – may not be suitable for high frequency ground path from the frame of the motor back to the drive.



Impedances can exist which can impede the efficient flow of high frequency currents.



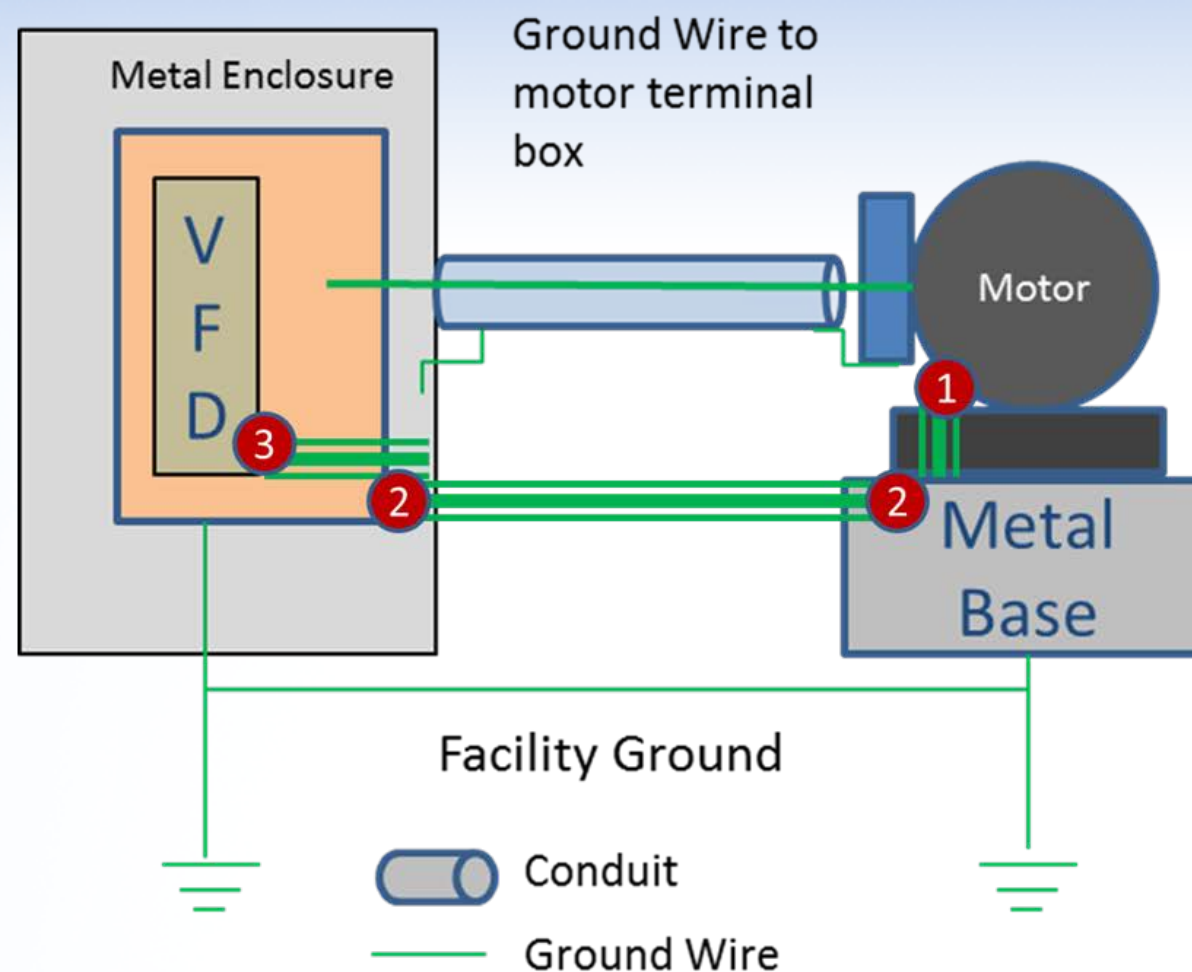
AEGIS® HFGS added to the system will provide this path for the high frequency currents!



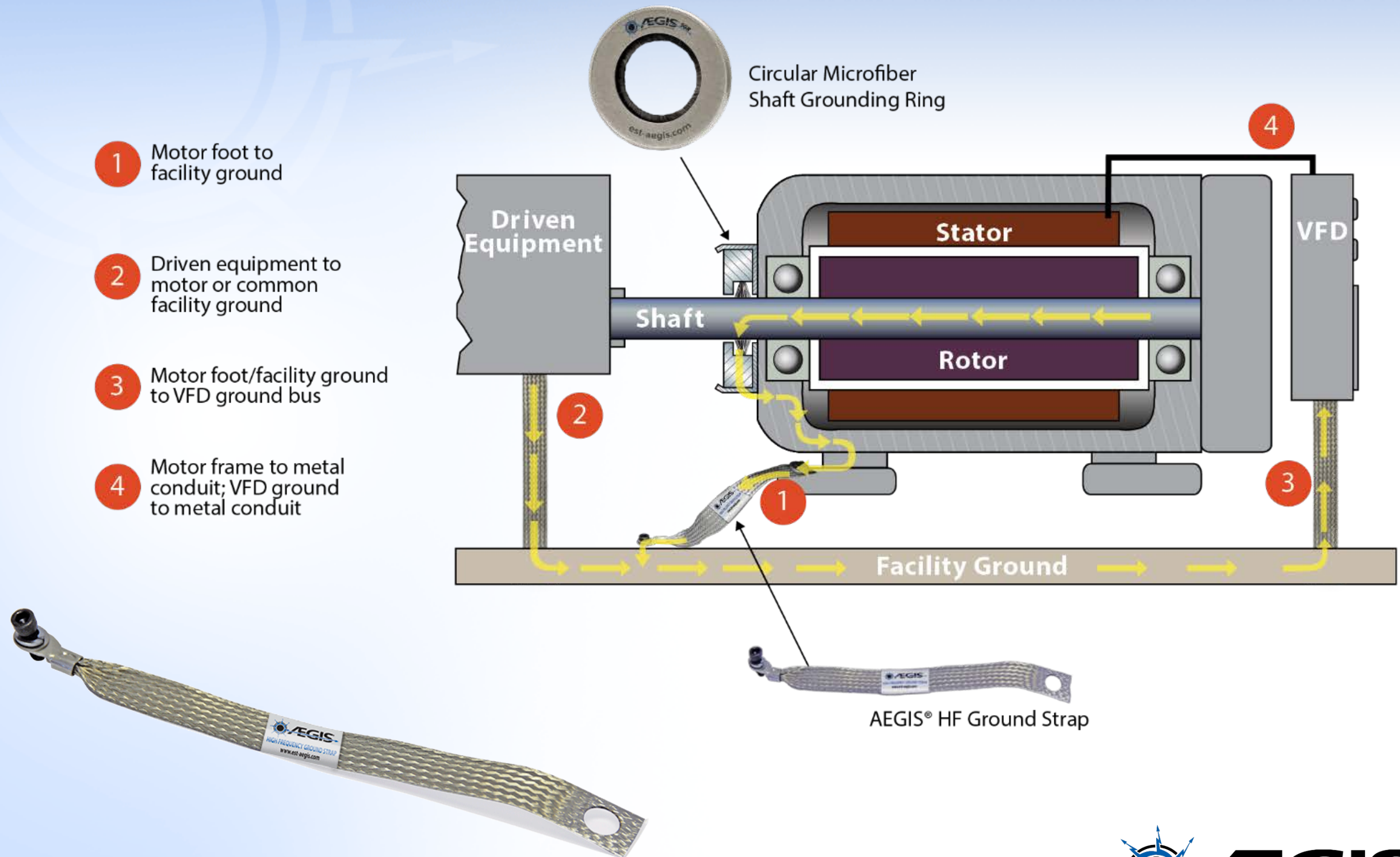
What is Ideal Grounding for High Frequency Currents?

- 1) Motor foot to grounded metal base
- 2) Motor Metal Base to VFD panel ground
- 3) VFD ground connection to panel ground

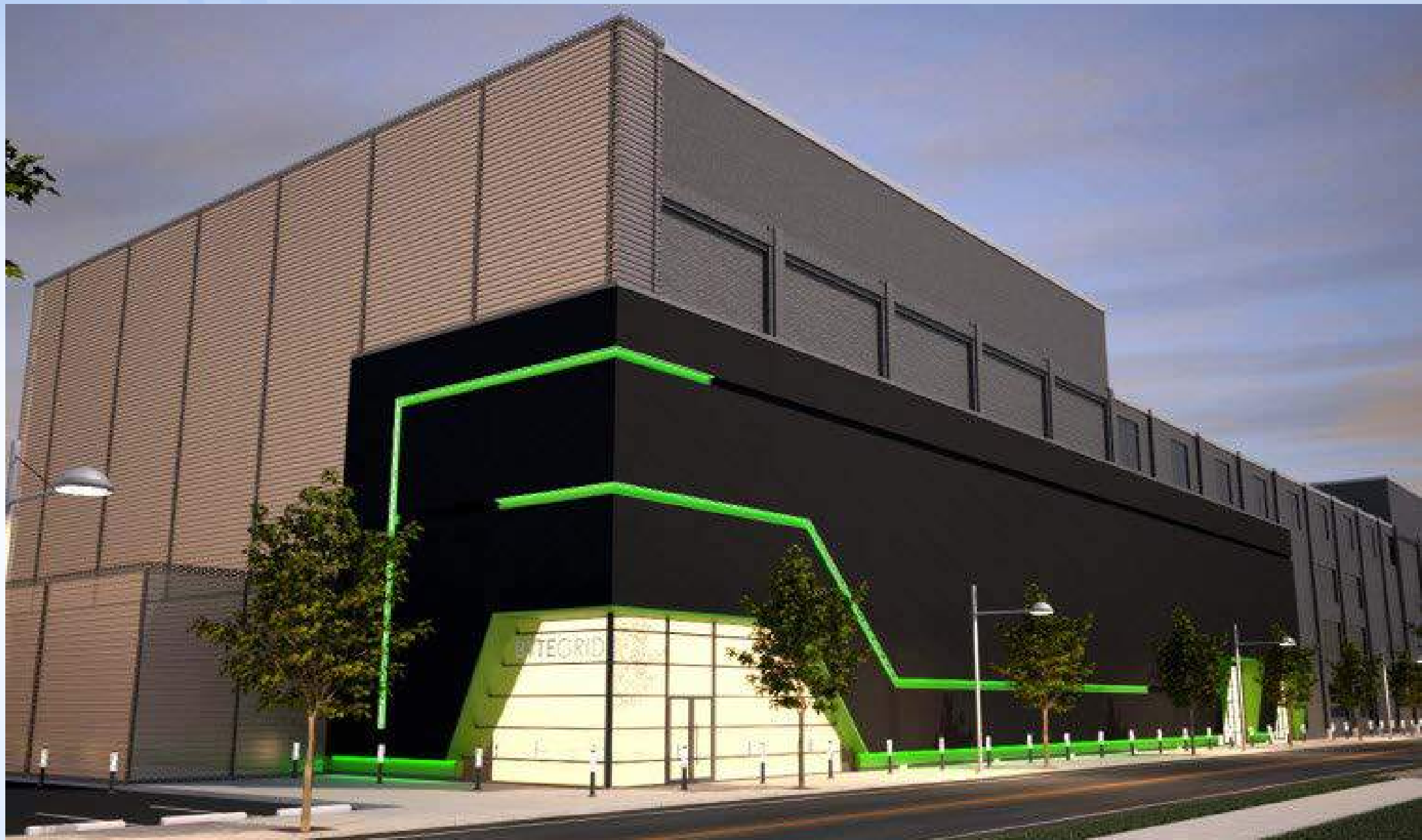
Note: Interconnect AEGIS® HFGS where possible or combine AEGIS® HFGS into a longer strap such as direct from Motor foot to VFD panel



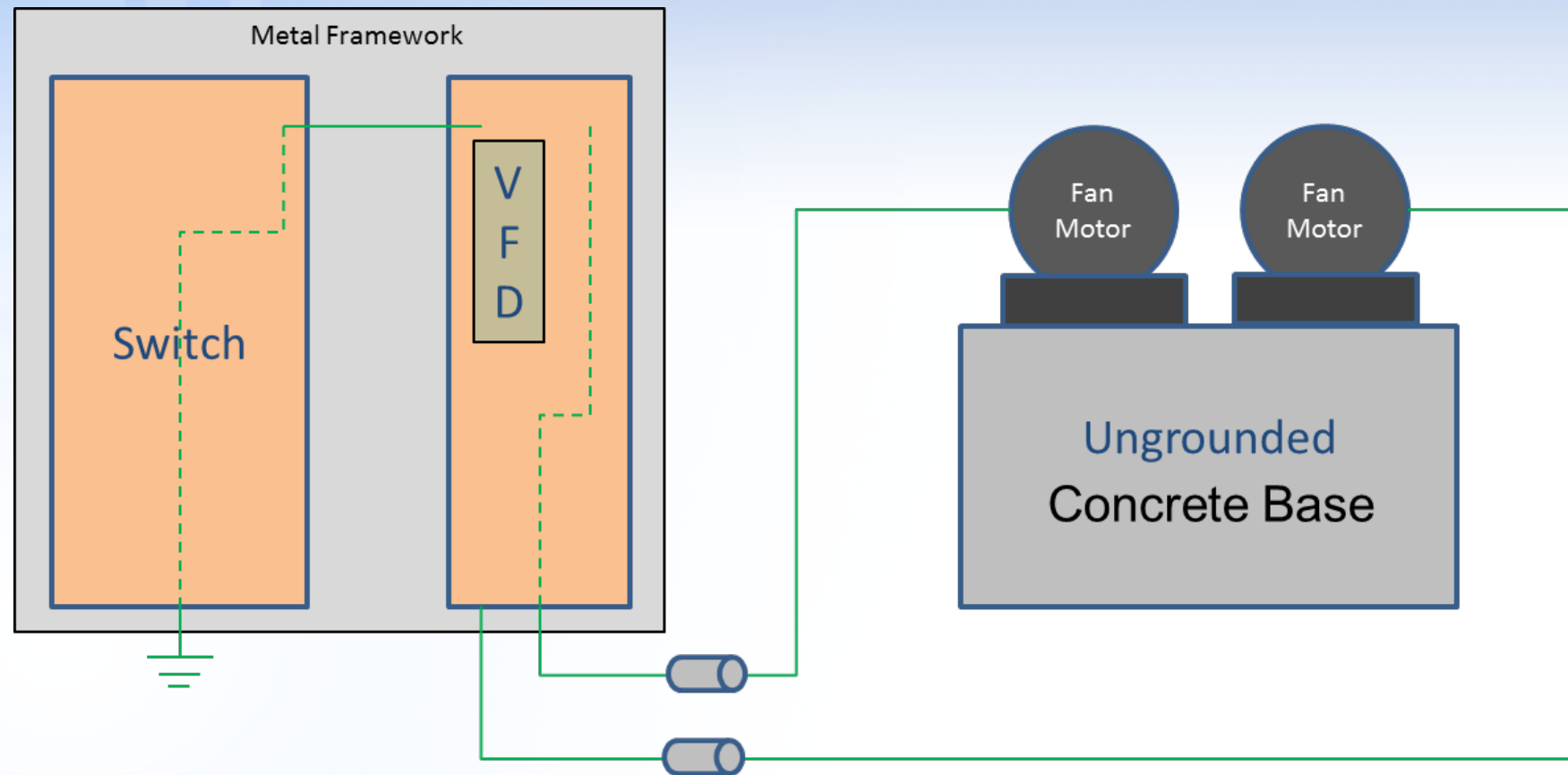
Where are AEGIS® HFGS High-Frequency Ground Straps used?



Case Study – Data Center



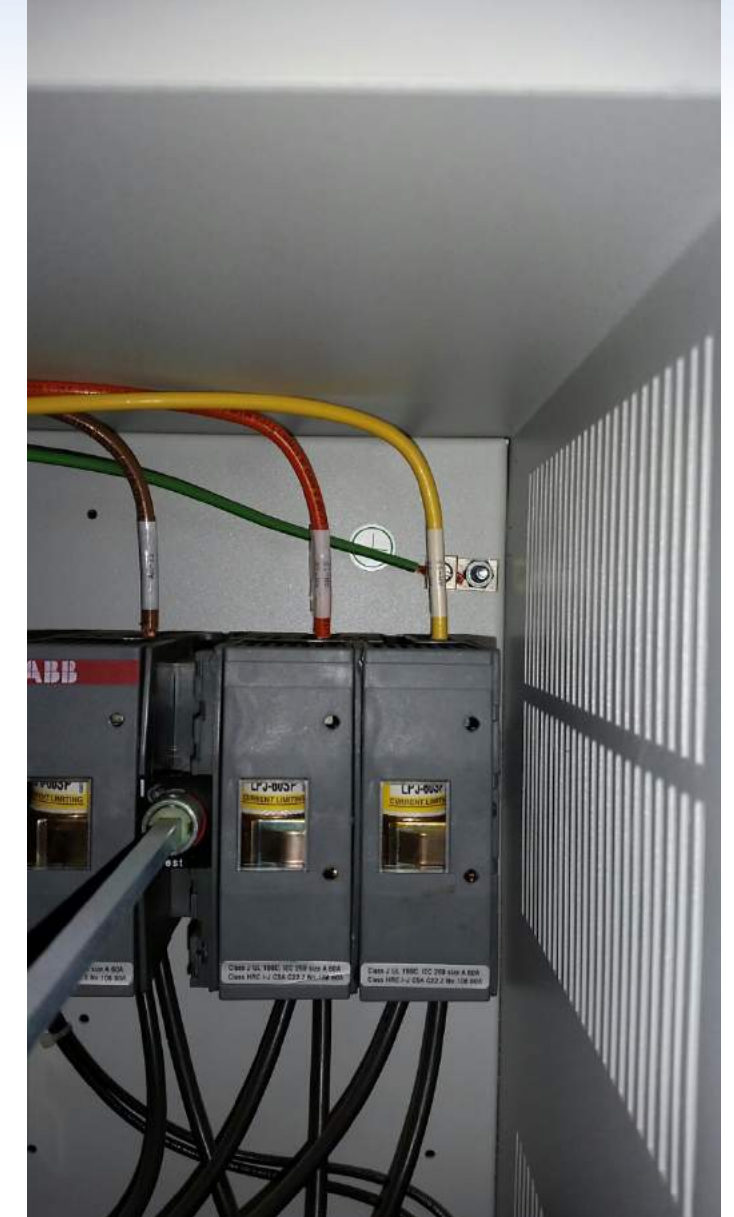
Case Study – Data Center



-  Ungrounded conduit
-  Ground Wire
-  Panel Ground

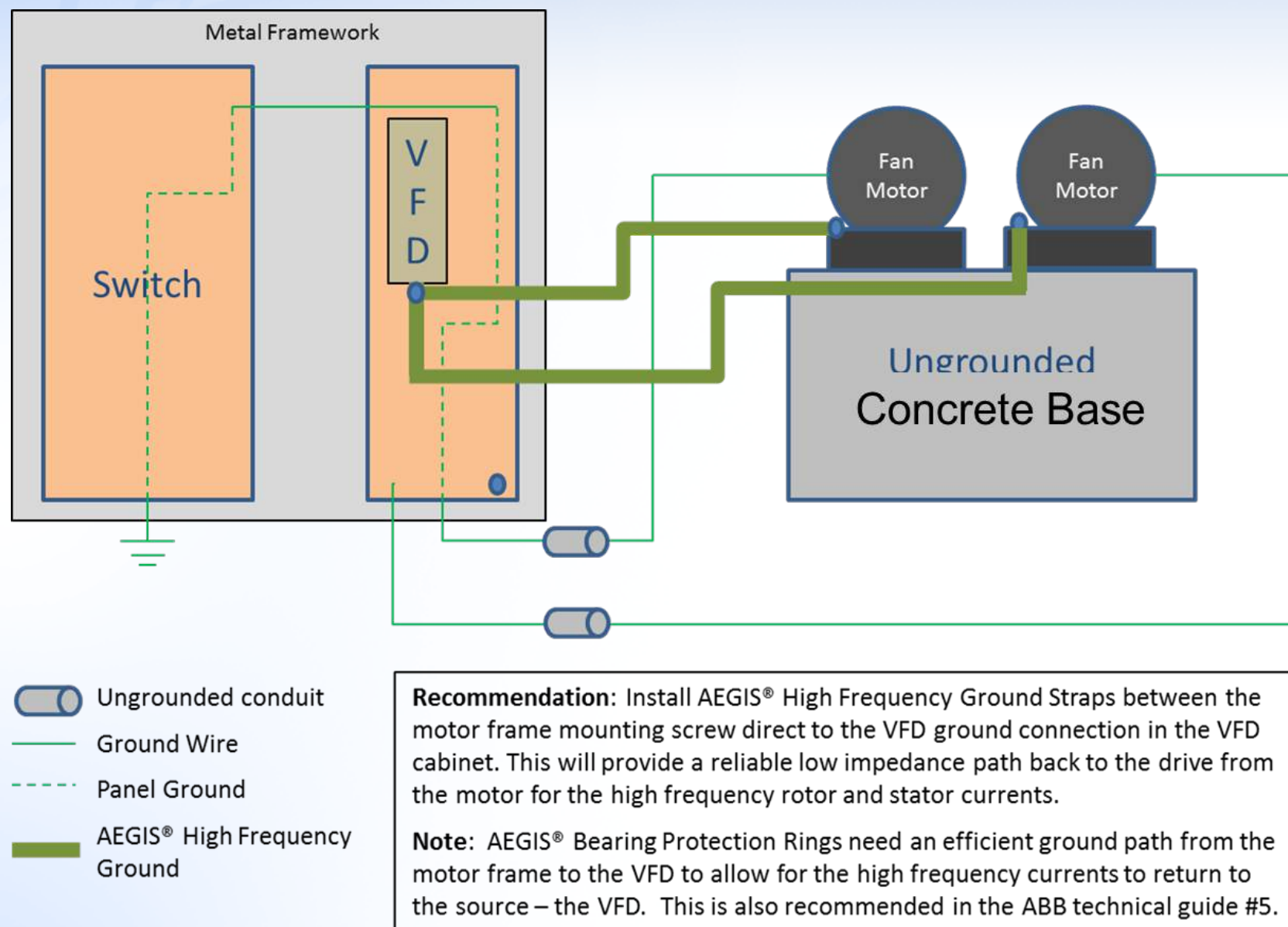
Note: The only ground connecting the motors to the drive cabinet is via a 10 gauge wire running through an ungrounded conduit to the motor's electrical junction box. This wire, while sufficient per electrical code, can have a high impedance to any high frequency currents created by the common mode voltage on the rotor and frame of the motor. There is no separate system ground connection to the motor frame or pedestal.

Case Study – Data Center

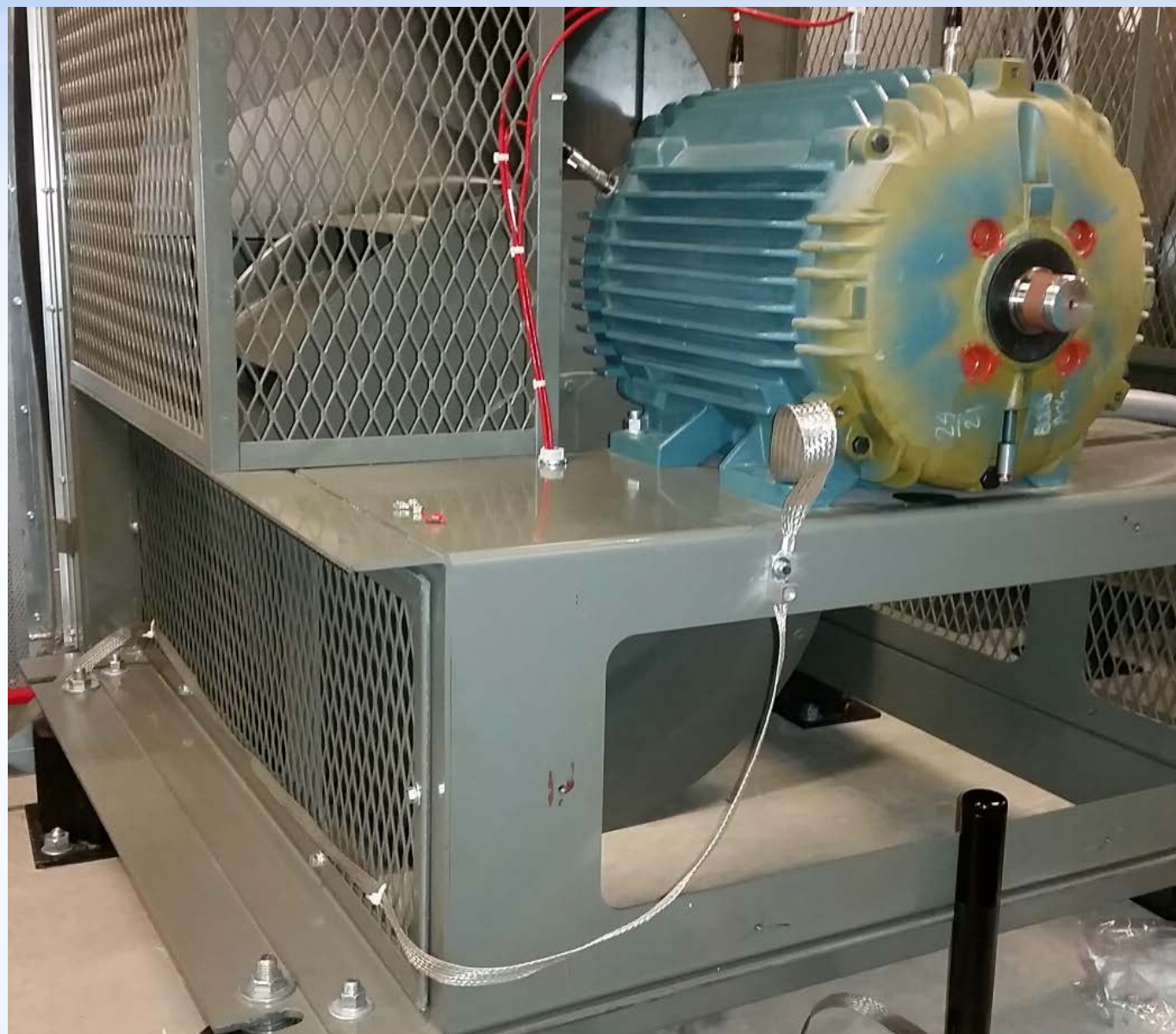


Case Study – Data Center

Solution: Add AEGIS® HFGC from Motor Foot to VFD Panel



Case Study – Data Center



2006-2014 AEGIS® Awards

