MESA

MINE ELECTRICAL
SAFETY ASSOCIATION INC.

MINING ELECTRICAL SAFETY 2017 CONFERENCE

10 – 12 JULY 2017

PULLMAN KING GEORGE SQUARE HOTEL,
BRISBANE

mesaqld.com.au

Earthing Essentials

Electro Magnetic Compatibility and Variable Speed Drives

Introduction

Any electrical circuit interacts with the electrical environment

Electromagnetic field changes produce capacitive and inductive coupling

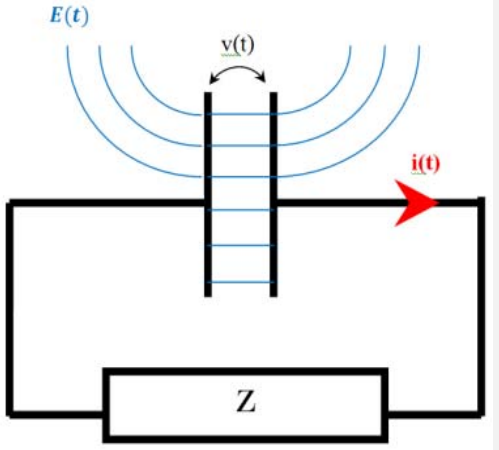
The level of coupling depends on the field strength and speed of change

Magnetic coupling is caused by current (inductive)

Electric coupling is caused by Voltage (capacitive)

Overview

- A capacitor is not only a part labeled “capacitor” in an electrical device or what we see in PF correction systems
- It occurs whenever two conductors are close together, and
- If we apply a voltage V to any capacitor, an electric field E is established between the two capacitor plates (or conductors)
- If we change the voltage between the conductor plates (or conductors) a current *i* will flow through it



Overview

Electric motors are the workhorse of industry

They convert electricity into mechanical energy by driving pumps, fans and conveyors etc.

By applying a VSD to the motor, many benefits can be enjoyed

However, there are negative affects within low voltage systems and equipment earthing

Benefits

VSD’s are primarily used to provide:

- Process Control
- Process Improvement
- Energy Savings

Other benefits

- Electrical protection of motor and load
- Reduce mechanical stresses
- Improve efficiencies and PF

Disadvantages

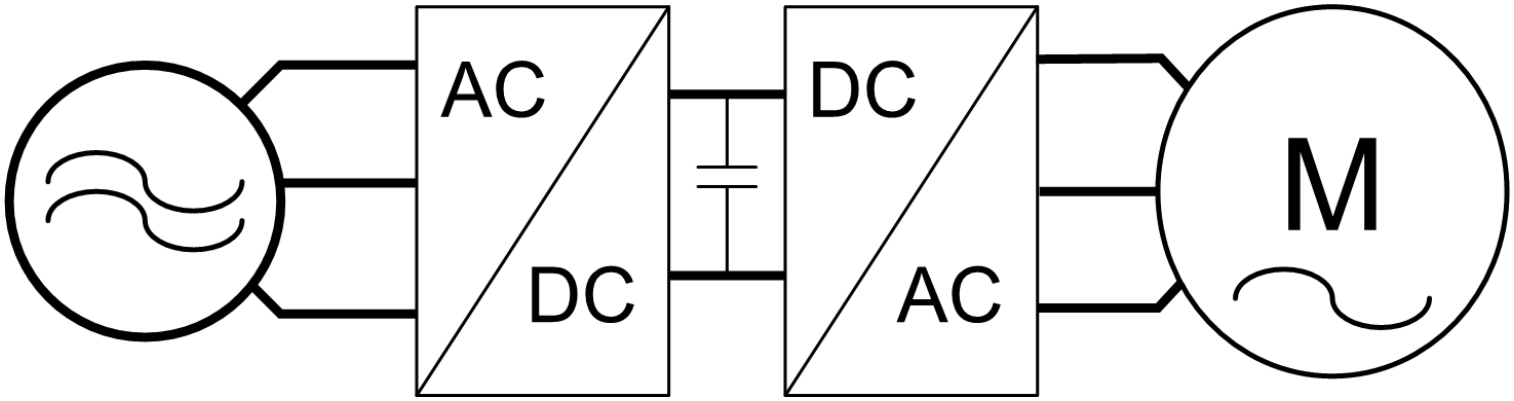
VSD’s can add to losses 1-3%

Will draw non-sinusoidal currents (produce harmonics)

Radiated and conducted emissions

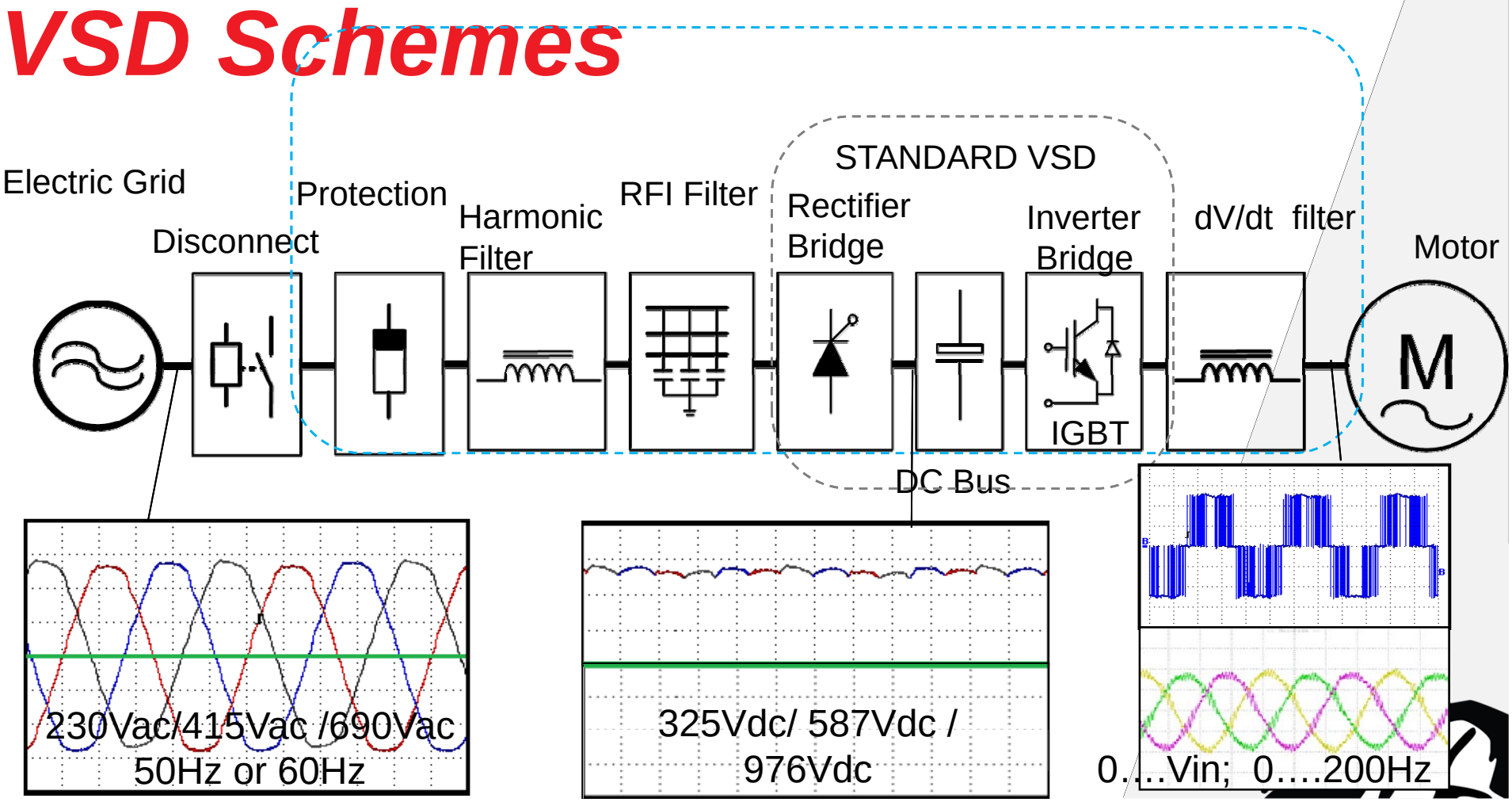
And *Can* add additional installation costs to cabling and motor design

Simplified Inverter Scheme

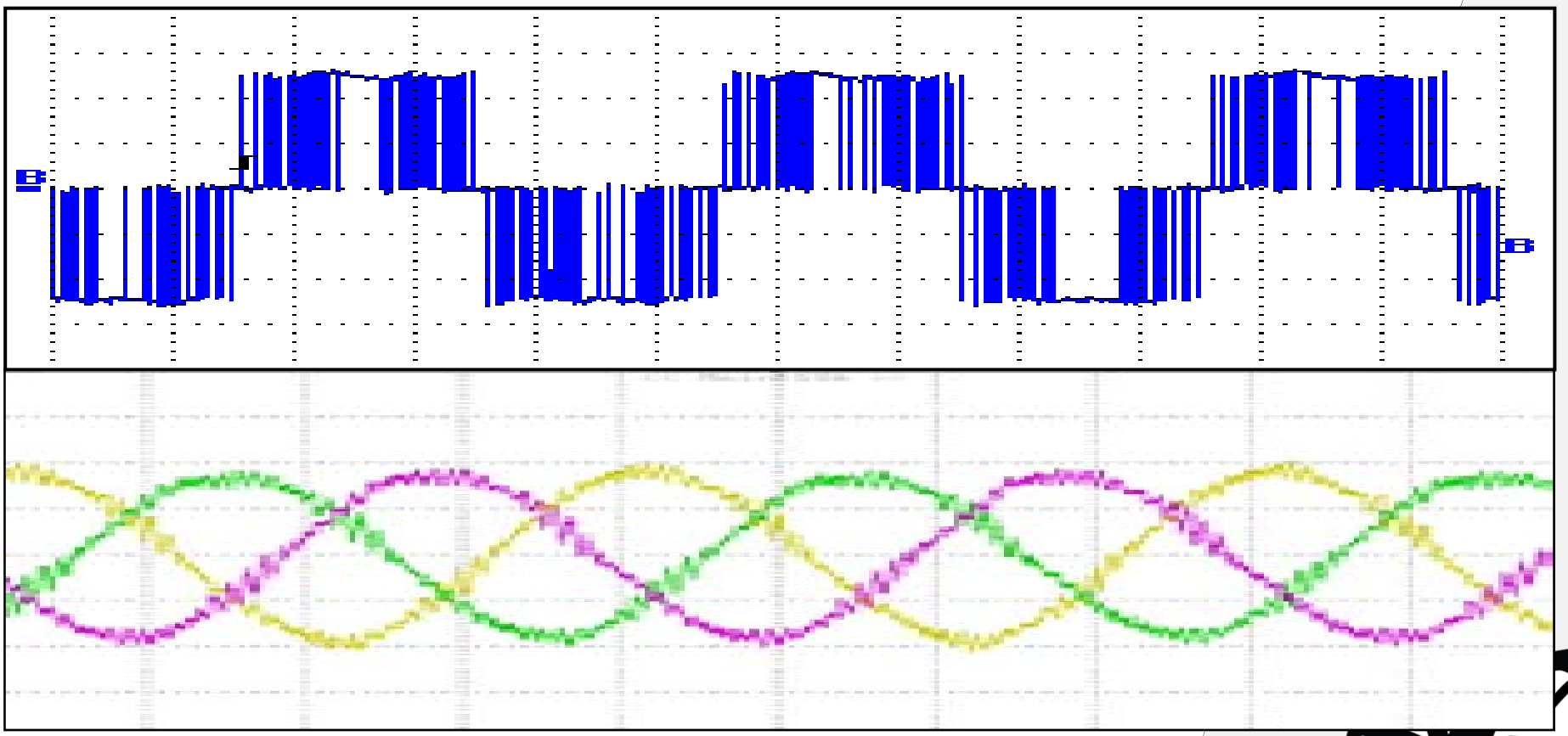


Voltage	230Vac	325Vdc	0….230 Vac
	415Vac	587Vdc	0…415 Vac
	690Vac	976Vdc	0…690 Vac
Frequency	50Hz or 60Hz	DC	0….200 Hz

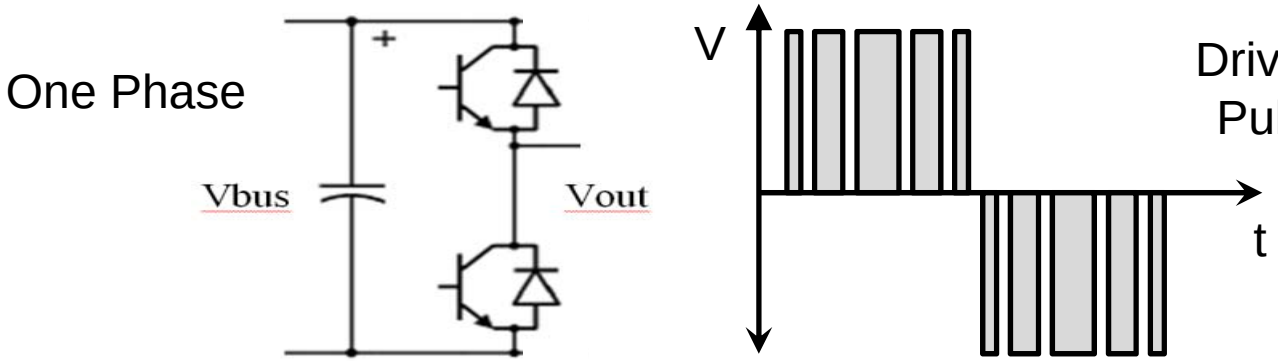
VSD Schemes


Electric Grid
Disconnect
Protection
Harmonic Filter
RFI Filter
STANDARD VSD
Rectifier Bridge
Inverter Bridge
dV/dt filter
Motor
M
IGBT
DC Bus
230Vac/415Vac /690Vac
50Hz or 60Hz
325Vdc/ 587Vdc /
976Vdc
0…Vin; 0….200Hz

Examine the VSD output

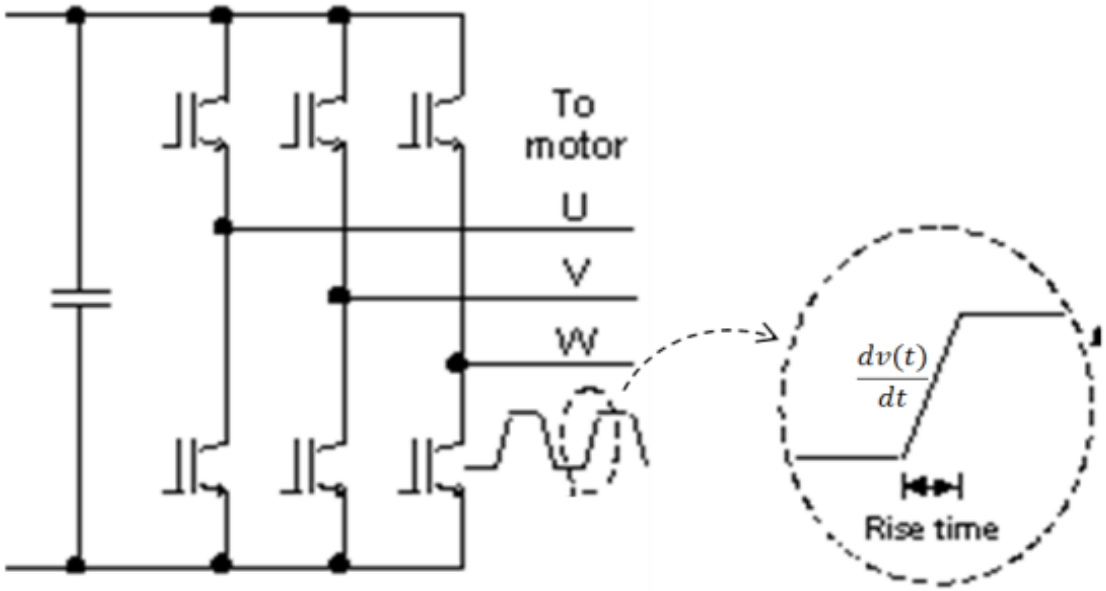


Electromagnetic Effects of Switching



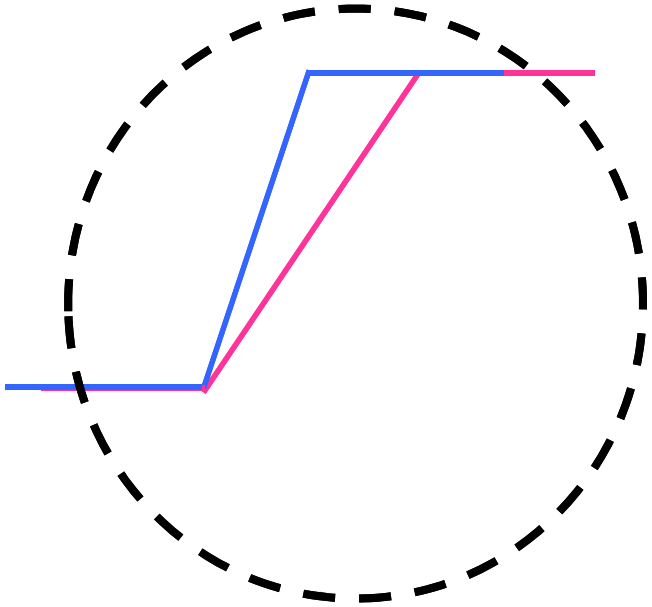
- When the VSD is working the IGBTs are switching ON & OFF alternatively
- 1st, the upper transistor is ON/OFF, followed by both transistors being OFF then the lower transistor is switched ON/OFF and finally both transistors are switched OFF again
- The voltage at the output is changing all the time between V+ and V- so the electric field on the surroundings of this conductor is also changing

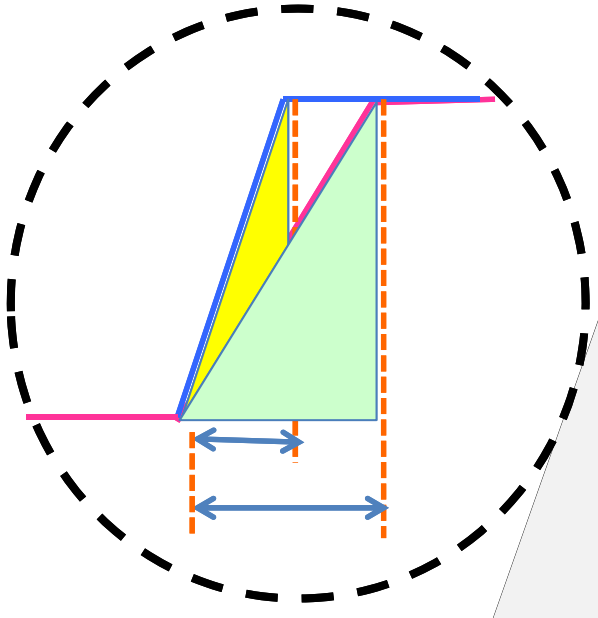
Electromagnetic Effects of Switching



Rectified voltage - Vbus is around 587V in a 415VAC drive and IGBTs are able to switch in less than 0.2µsec, so the change in voltage over time - **dV/dt**, is extremely high and thus the field strength over time

Electromagnetic Effects of Switching

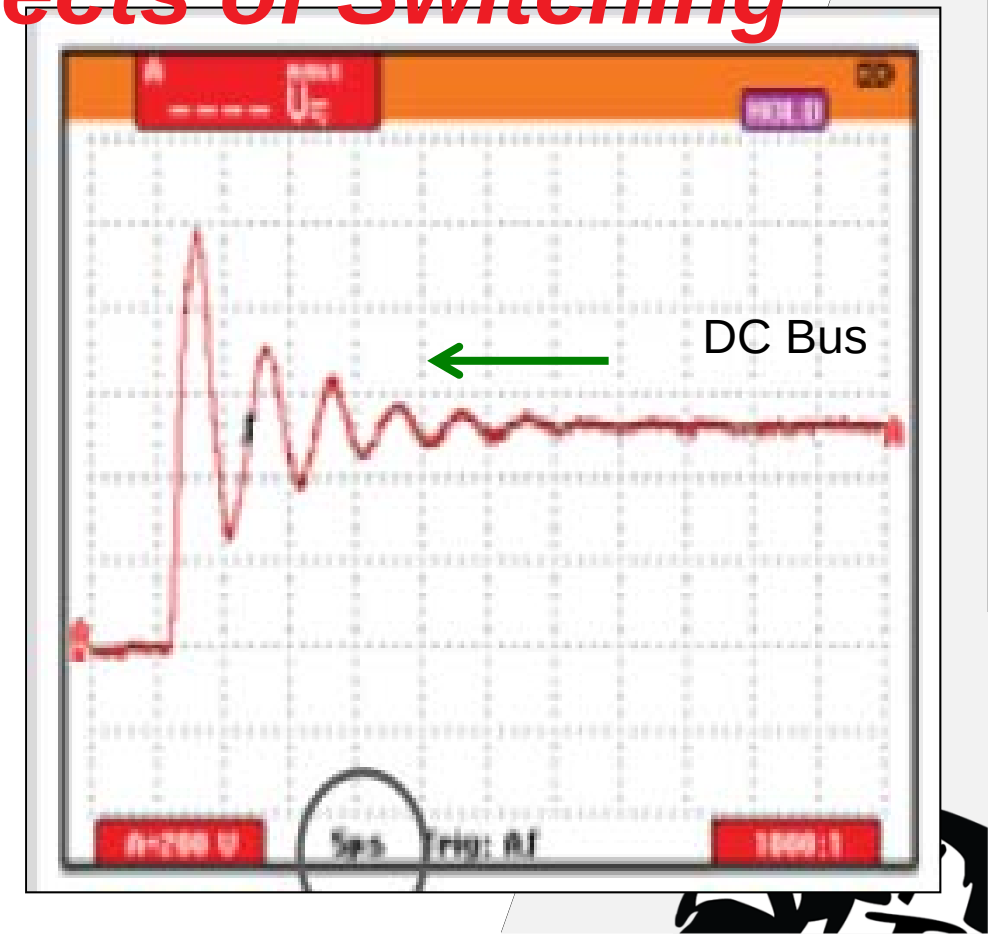




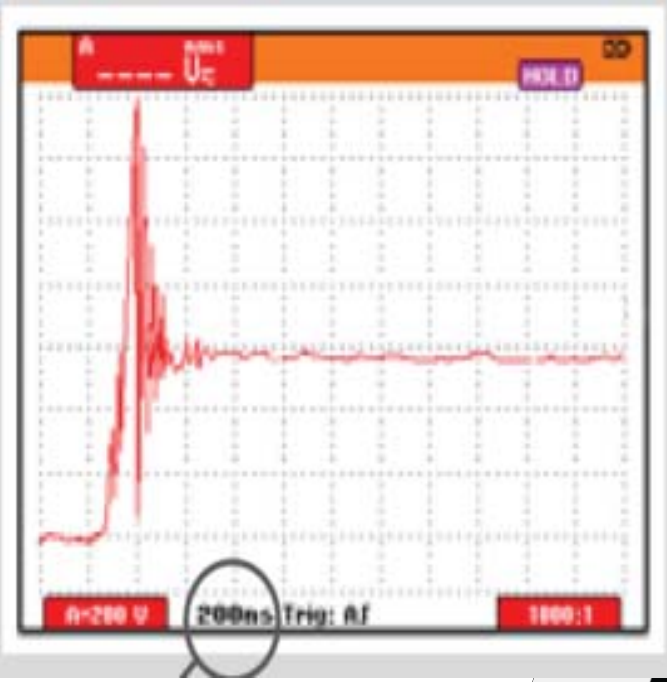
Rectified voltage - Vbus is around 587V in a 415VAC drive and IGBTs are able to switch in less than 0.2µsec, so the change in voltage over time - dV/dt, is extremely high and thus the dE/dt

Electromagnetic Effects of Switching

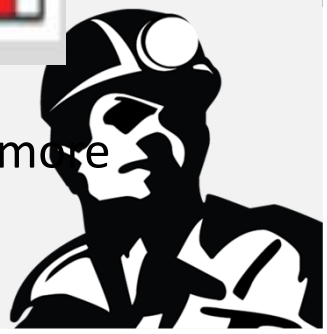
Zoomed in view of igbt turning on. Like a PID, the faster it is turned on, the more overshoot occurs.



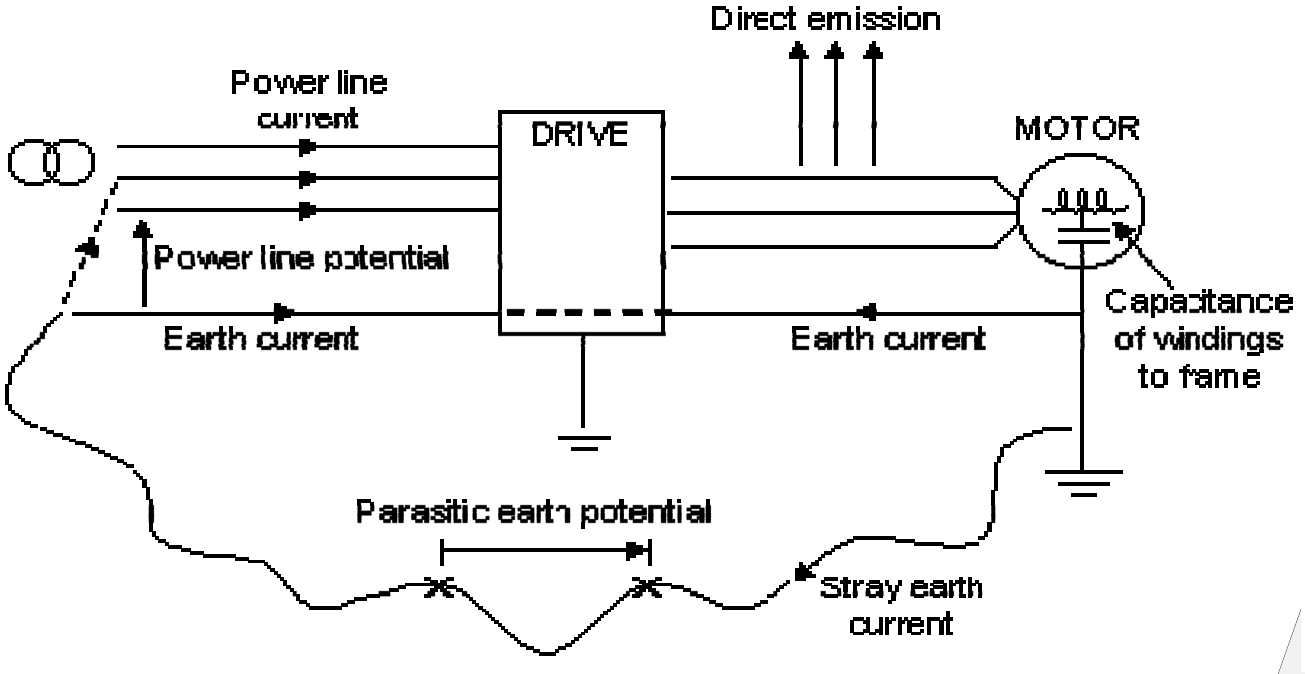
Electromagnetic Effects of Switching



Actual view of igbt turning on. Like a PID, the faster it is turned on, the more overshoot occurs.



Common Mode Current Paths



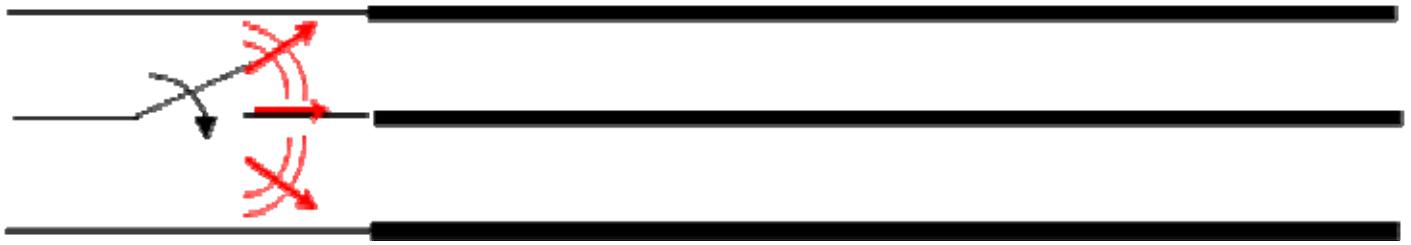
VSDs always have some level of ground coupling so certain levels of CMC will flow outside the VSD. The high frequency CM emissions in VSDs are "electric field" dominant, although CMCs from magnetic couplings also exist.

Consequences

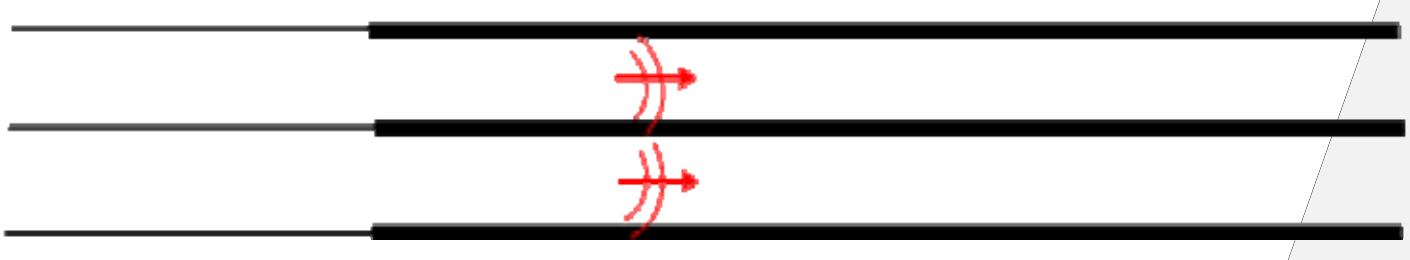
Now we understand the fundamental operations of VSD’s what are the consequences?

When we deal with very short rise times (in the µs range) we have to consider the wiring from the drive to the motor not as simple wires but as transmission lines in a low voltage system

Electromagnetic Energy

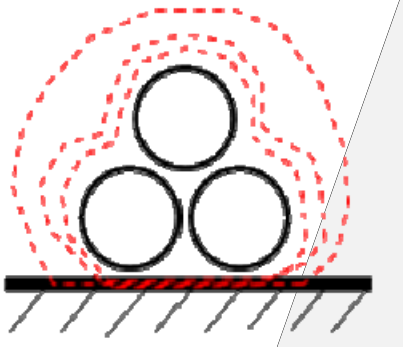


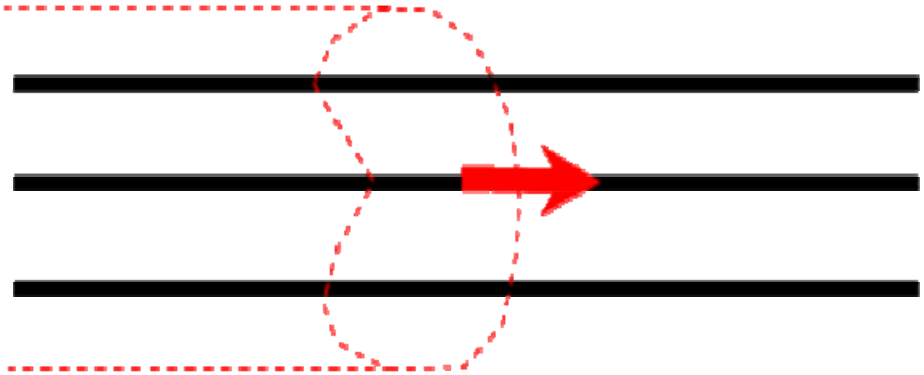
When dV/dt occurs, electromagnetic energy is transferred to the conductors associated the the IGBT's (capacitive effect) and of course the cables being switched.



Electromagnetic Energy

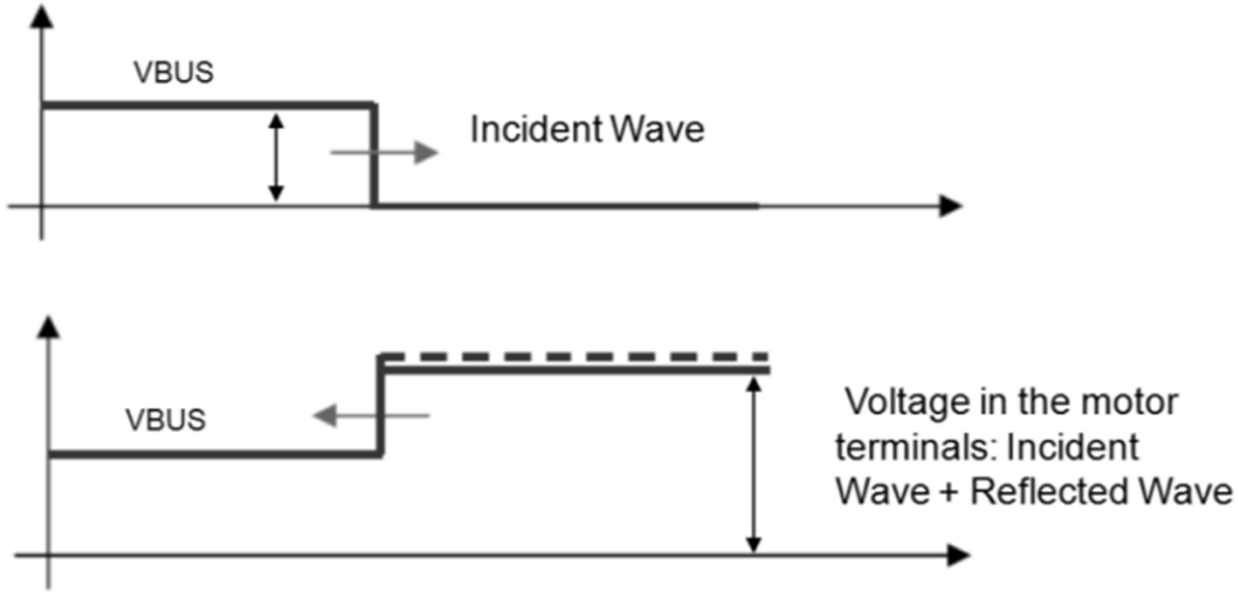
The travelling EM energy is distributed in the space around the conductors and travels along the cables from the VSD to the motor





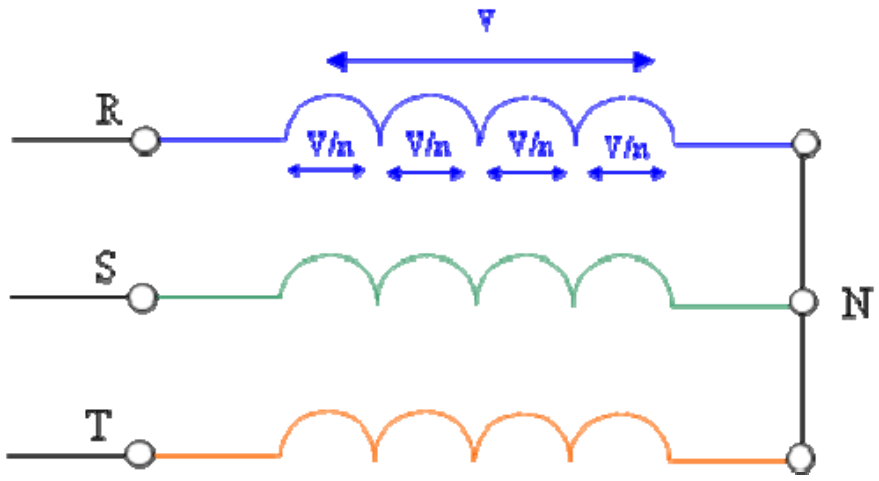
Winding Insulation Damage

Short rise times cause voltage reflections at the motor terminals and when voltage is reflected at the end of a transmission line (or cable) its magnitude (and dV/dt) is increased



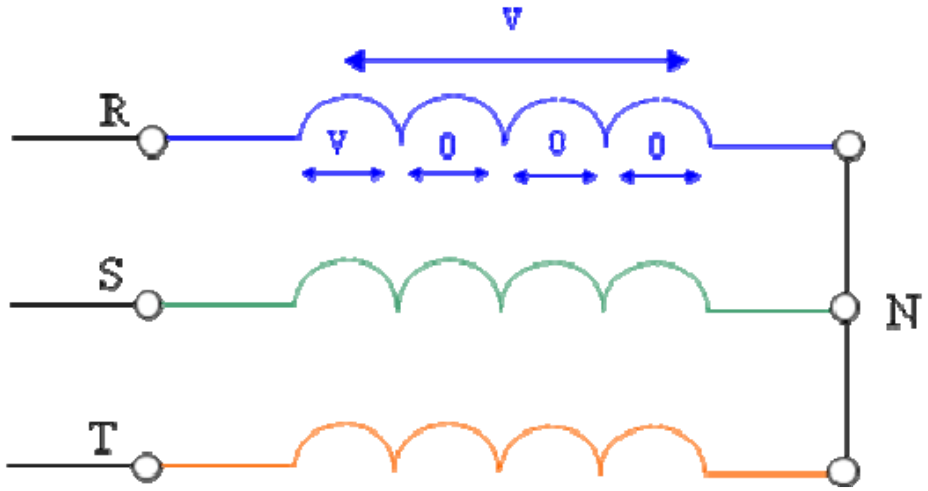
Winding Insulation Damage

When low rise time voltages (50 – 60Hz) are applied to an AC motor, the voltage space distribution across the windings is uniform



Winding Insulation Damage

But when high rise time (pwm voltages) (High dV/dt) are applied to an AC motor from a VSD output, the voltage space distribution across the windings is NOT uniform

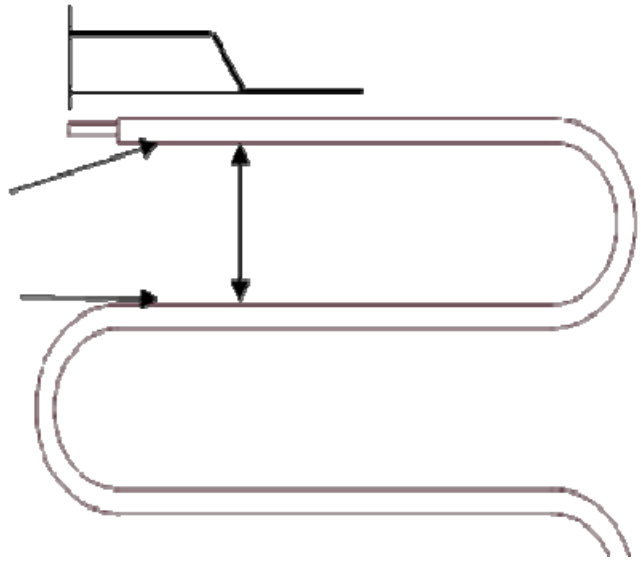


Winding Insulation Damage

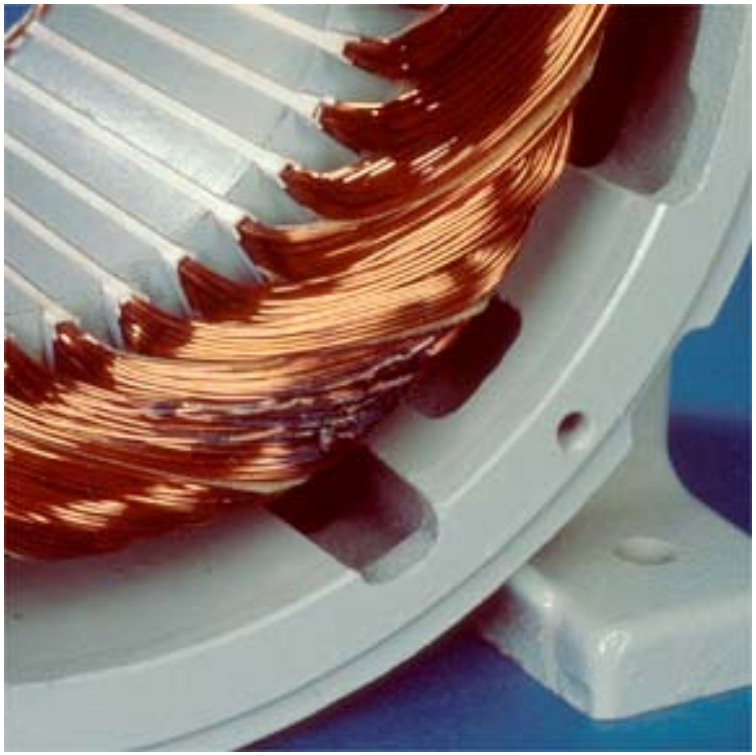
Damage in the motor insulation due to the use of PWM voltages come from dV/dt levels and peak voltages at the motor terminals.

V = 2xVbus plus overshoot

Voltage here is 0

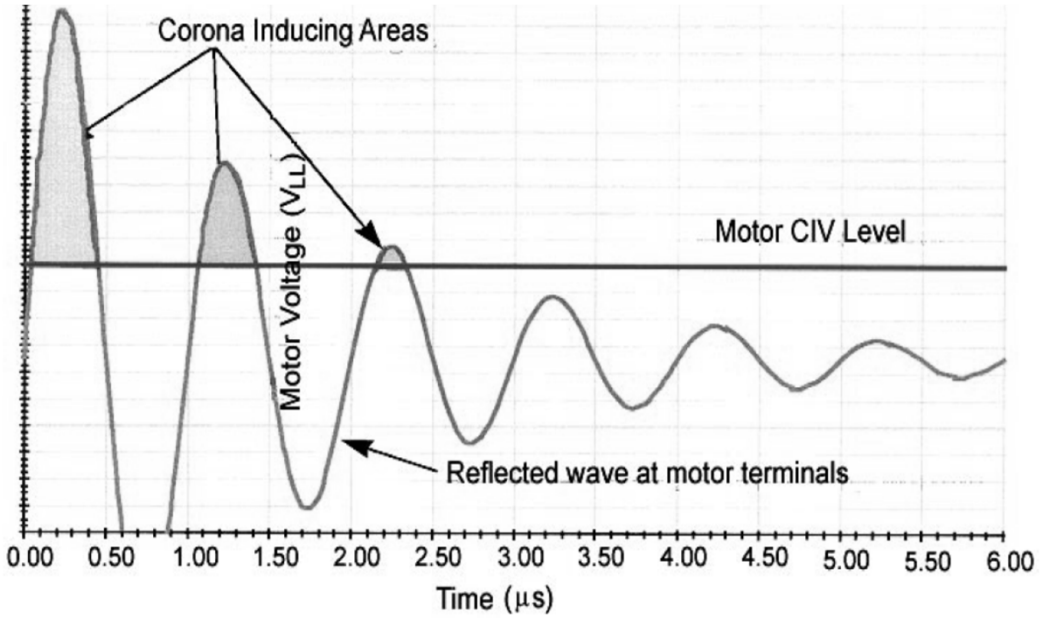


Winding Insulation Damage



Corona Discharge

Corona discharge occurs when the air is ionized by the electric field between the windings.



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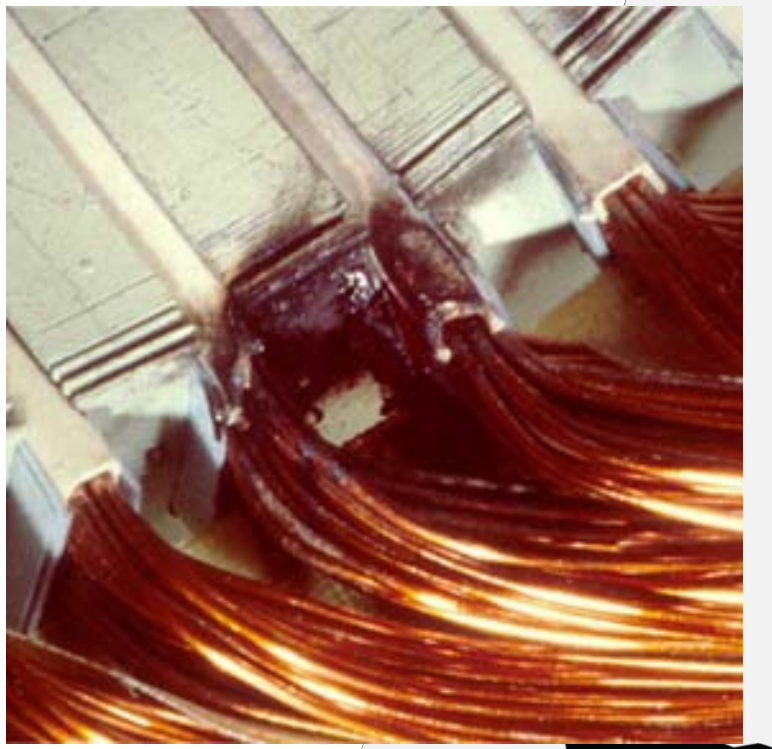
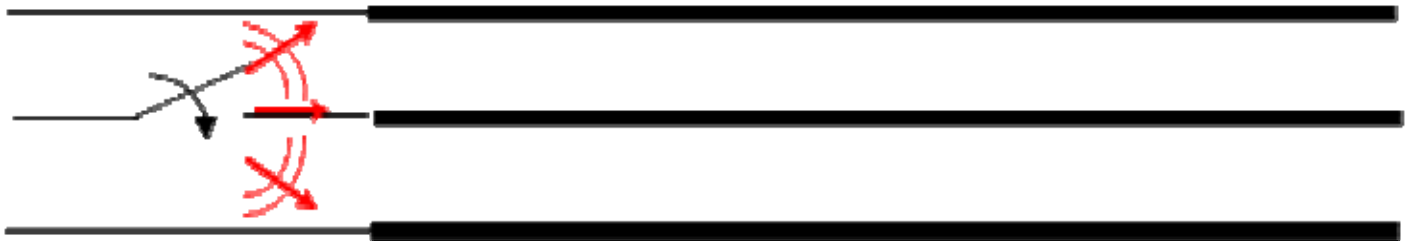


Motor Bearing Damage



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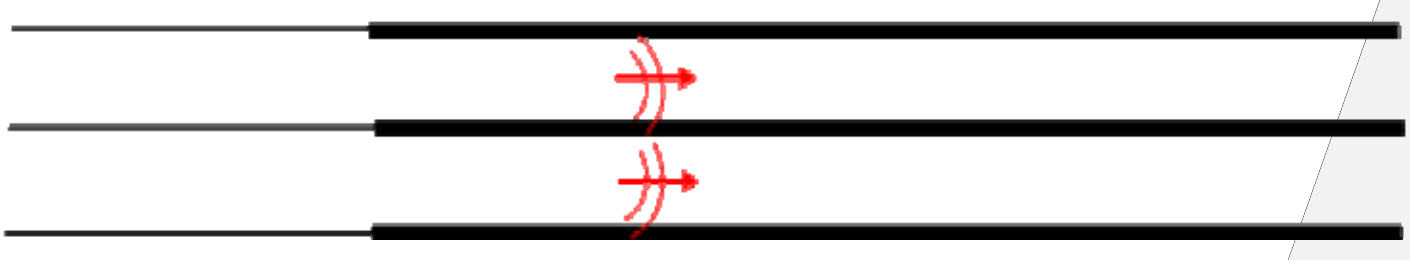

Motor Bearing Damage

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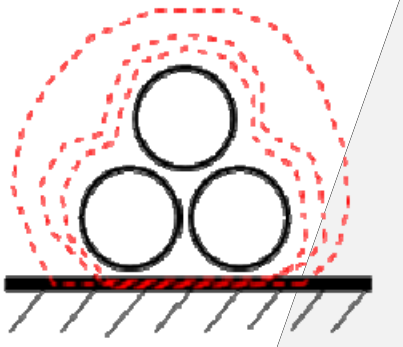
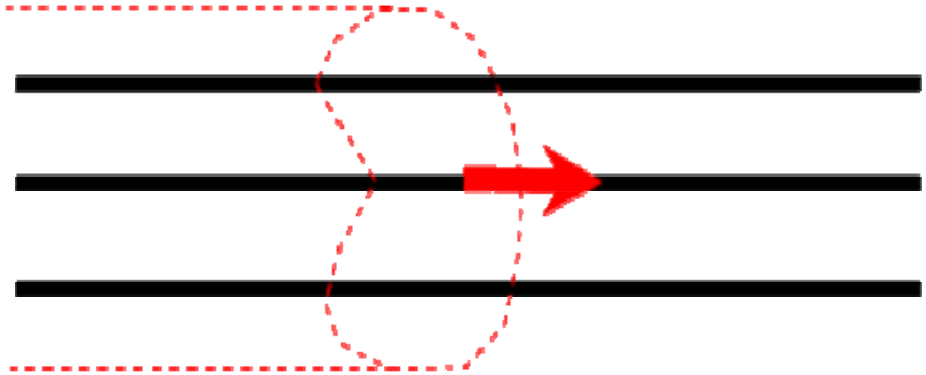
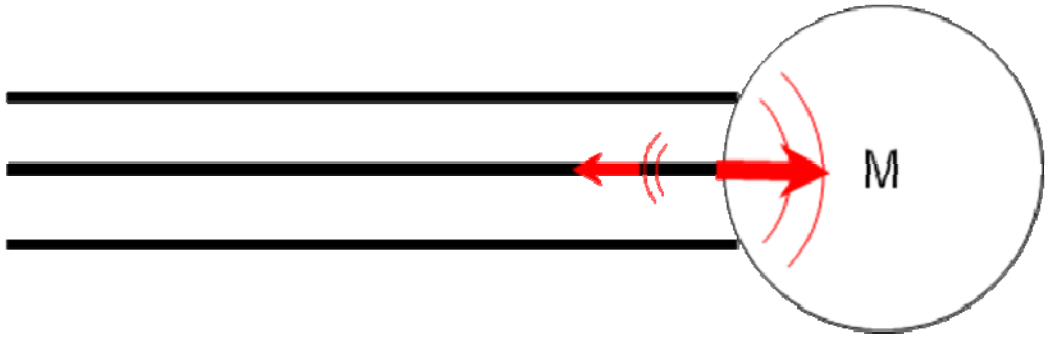




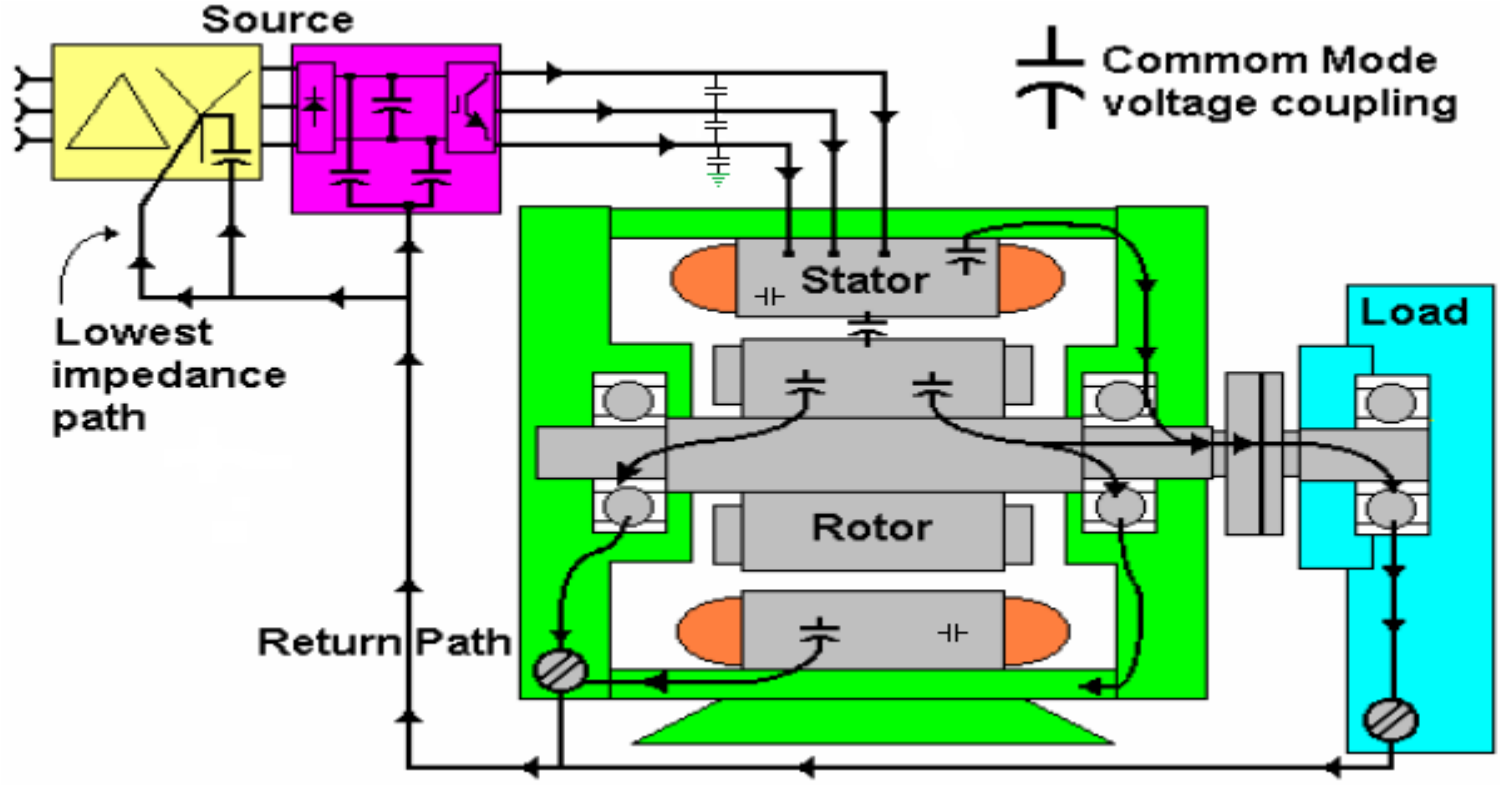
Motor Bearing Damage

When the EN energy arrives at the motor, part of it is absorbed by the motor and part rebounds back to the source



Motor Bearing Damage

If part of the energy finds a low impedance path to leave the motor, it will follow it



Motor Bearing Damage

If part of the energy finds a low impedance path to leave the motor, it will follow it

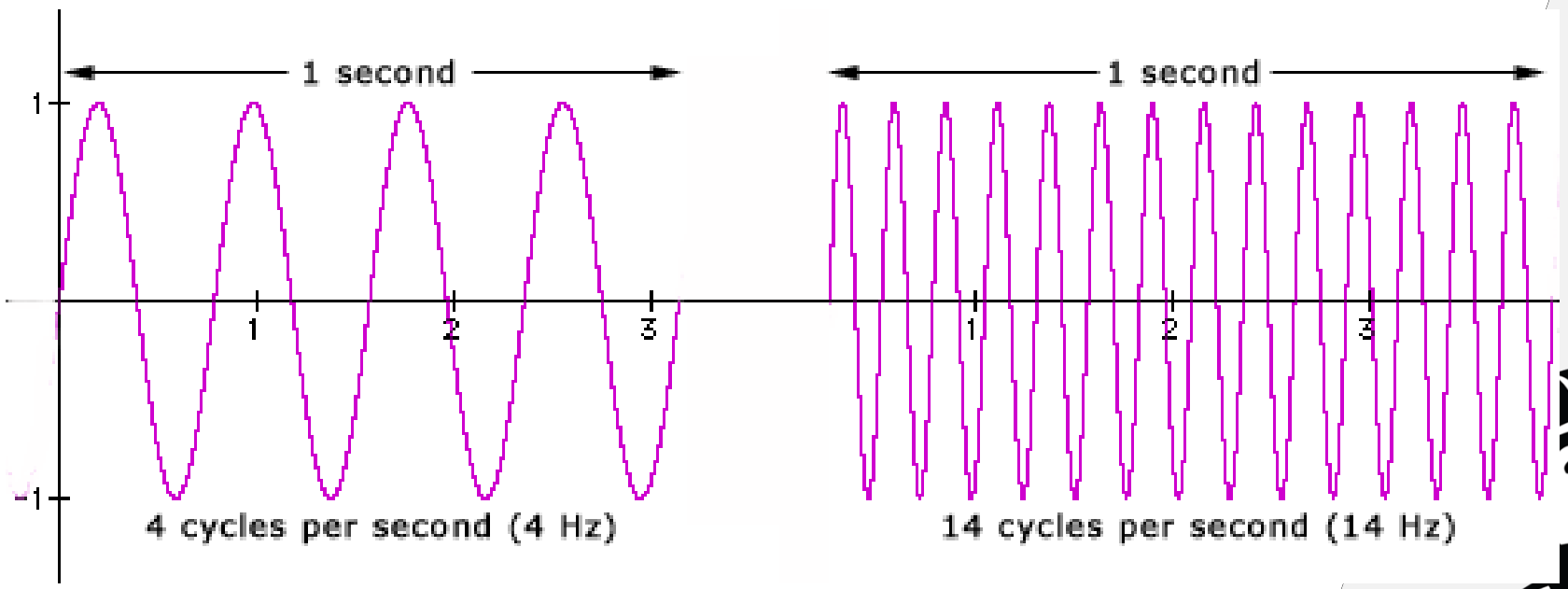
Summary

As with all modern electronic devices, the need for quicker and smaller devices is what fuels the industry. Less cost, smaller space and less internal thermal losses.

But faster is not always better.

Practical Considerations

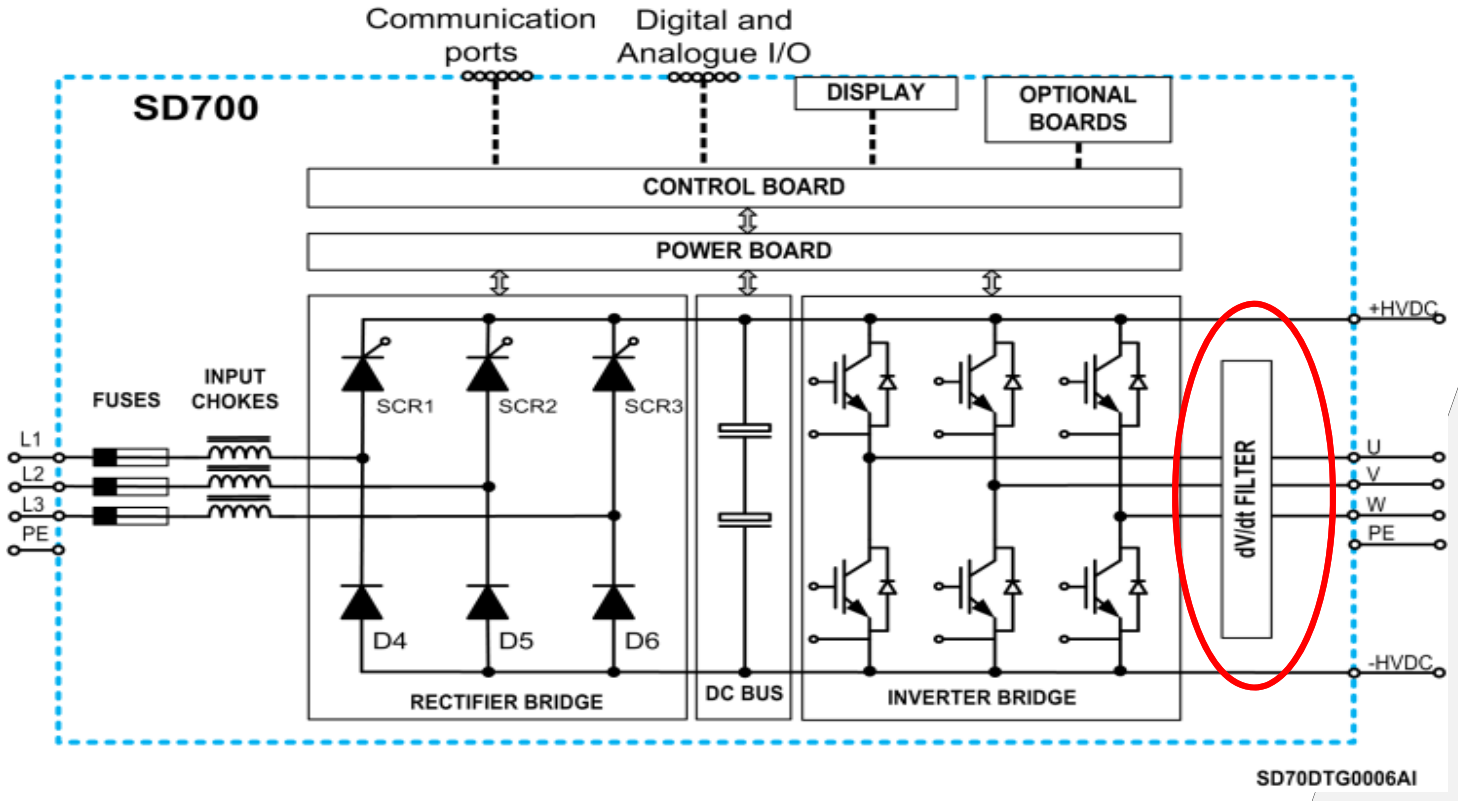
Reduce the carrier switching frequency



Practical Considerations

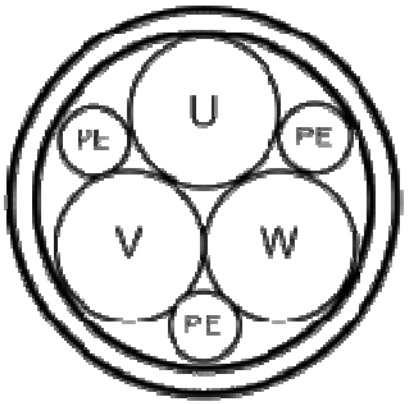
Locate the VSD near the equipment

Practical Considerations



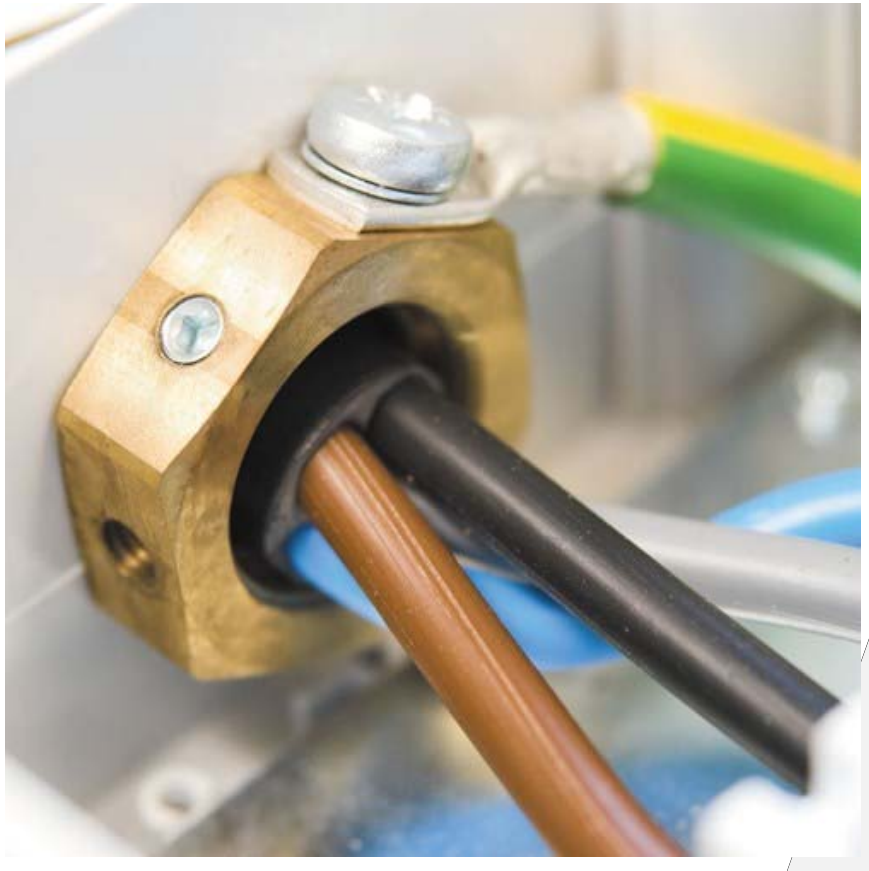
Practical Considerations

SHIELDED



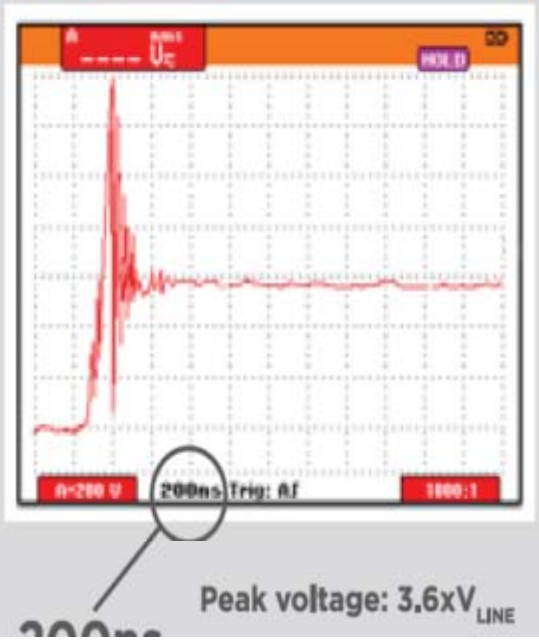
Ideal symmetrical 3-wire cable plus symetrically arranged PE conductor- with concentric shield

Practical Considerations

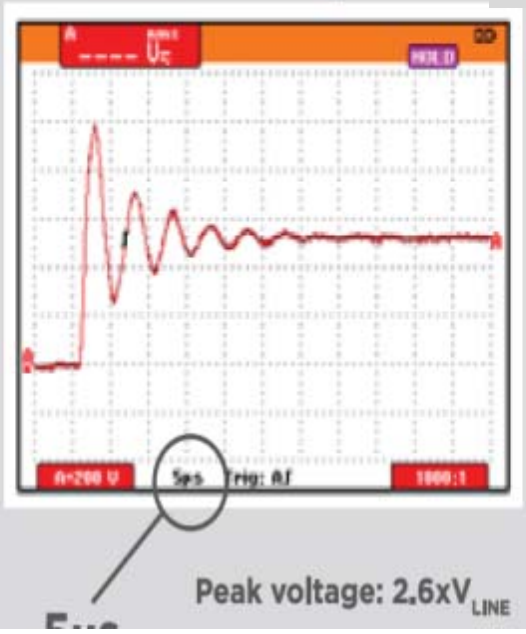


Practical Considerations

No dV/dt Filter



With dV/dt Filter



With dV/dt Filter and control of igbt

Thank You

Nick Hughes
Power Electronics

POWER ELECTRONICS
SAVING ENERGY FOR THINGS THAT MATTER