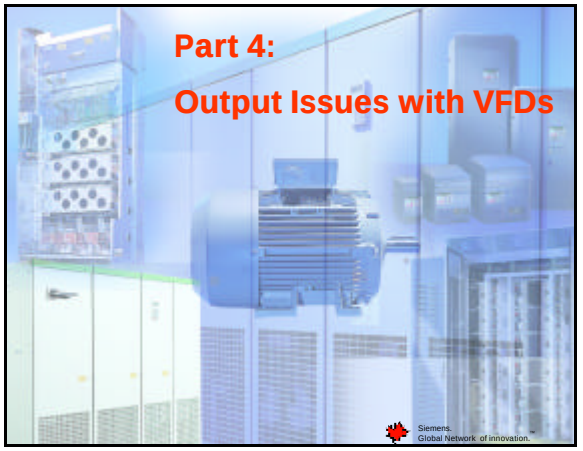
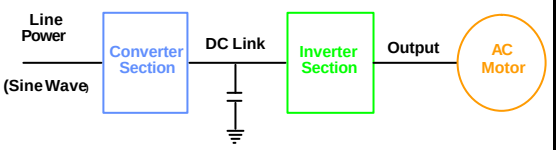


VFD Control (Voltage Source)



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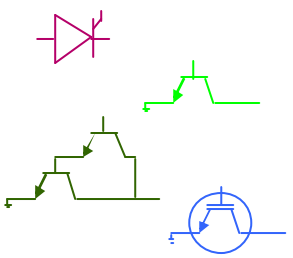
AC Drives - Power Technology

- SCR's
  - GTO's
- Transistors
  - Mosfet
  - Bi-polar
  - Darlingtons
  - IGBT's



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AC Drives - Power Technology

- Why IGBT's
  - Low losses
    Smaller Heatsinks
    Smaller product packages
  - Economical control
    On / off with low level signal (ma)
  - More "robust"
    Faster turn-off after fault sensing
    = Easier protection
  - Relatively inexpensive
    Mainstream device
    Competitive supply

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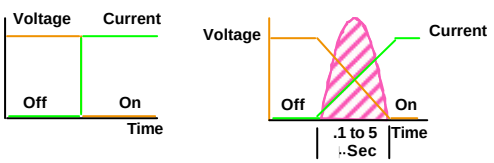
Switching Efficiency

Losses

Losses occur during transition from Off to On and from On to Off. The faster the turn-on time (turn – off time), the lower the losses.



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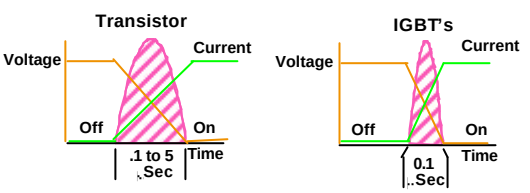
Switching Efficiency

Losses



Faster Switching = Lower Losses

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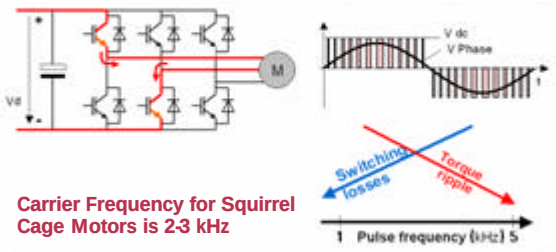
Technical data
Pulse-width modulation

DC link: DC voltage | PWM | Motor: Variable voltage and frequency



Carrier Frequency for Squirrel Cage Motors is 2-3 kHz

Increased utilization for General Performance by: Reduced pulse frequency!

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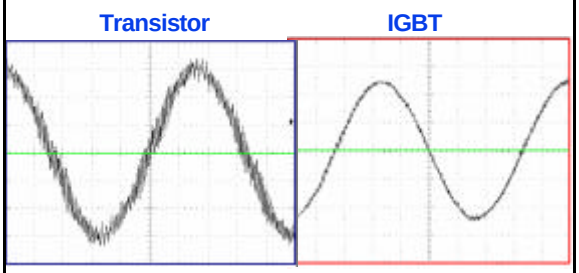
Inverter - Current Wave Shape



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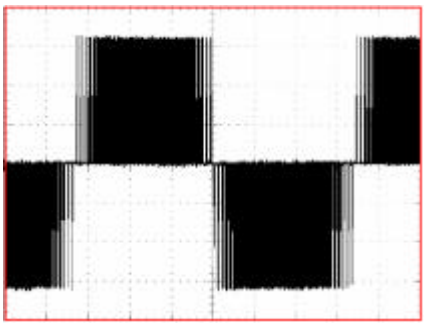
IGBT - Voltage at Inverter



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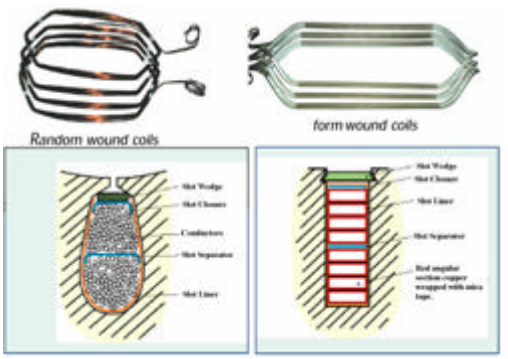
Random and Form Wound



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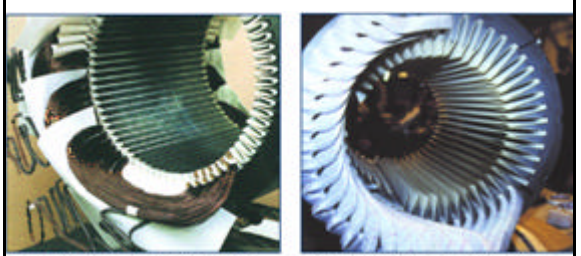
Stator Wiring, Random and Form wound



Partially wound stator core with random winding

Partially wound stator core with form winding

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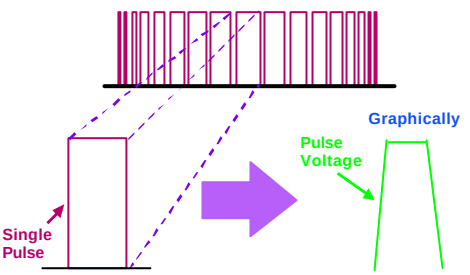
Actual Pulse Voltage



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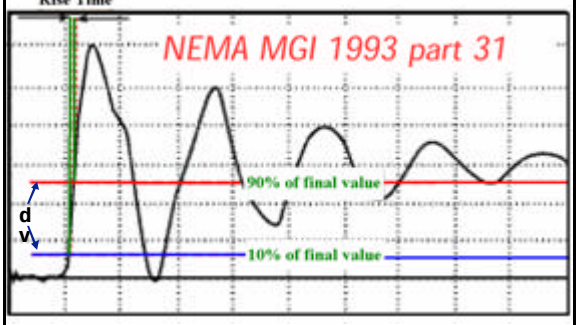
dv/dt = Voltage Rise / Rise Time = ____Volts/microsecond

dt

Rise Time



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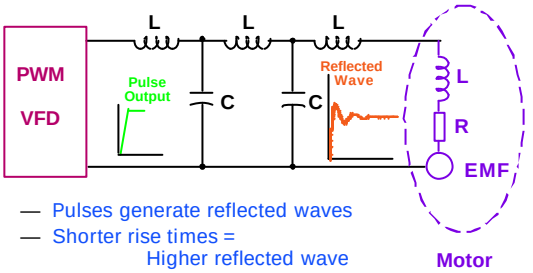
Applying Pulses to Long Cables



— Pulses generate reflected waves
— Shorter rise times = Higher reflected wave

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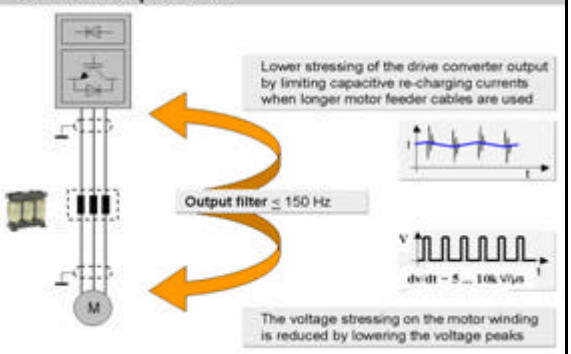
Options
On the output side



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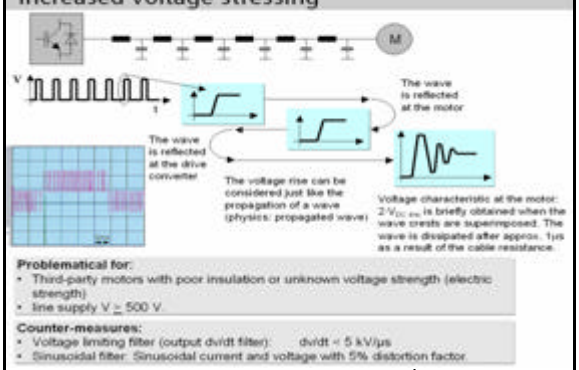
Options
Increased voltage stressing



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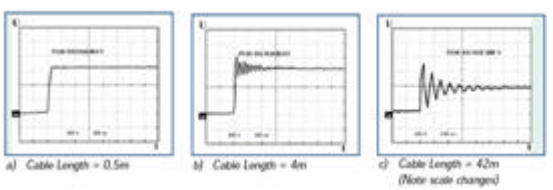
Voltage at Motor Vs. Cable Length



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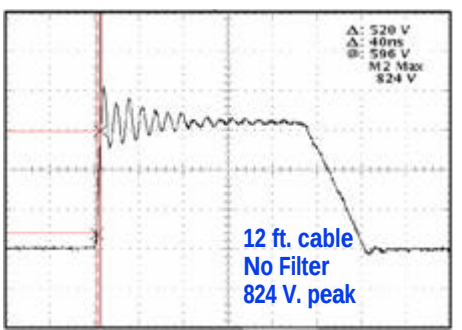
IGBT Inverter - Voltage at Motor



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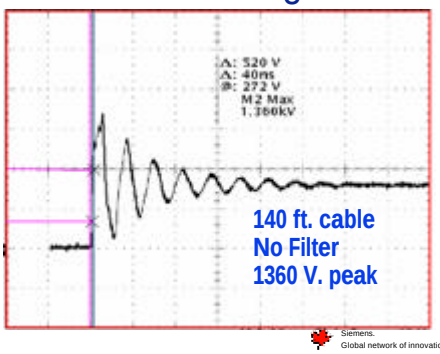
IGBT Inverter - Voltage at Motor



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Reflected Wave Facts

- Higher impedance in motor "reflects" Voltage back
  - — Reflection adds to pulse voltage
  - — Closer to step voltage rise = Greater reflection
  - — Maximum can be 2 to 2.5 times Peak voltage (~ 1350V. On 460 VAC line) (~ 1700V. On 600 VAC line)

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Reflected Wave Facts

- Shorter cables = less reflection (For a given cable length)
  - — Less transmission delay
  - — Lower impedance
- Longer pulse rise-times are better
  - — Longer propagation time (Sine wave is no problem)
  - — Longer cables allowable

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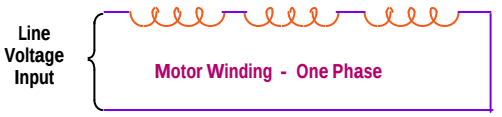
AC Motors



- — Windings in each phase are a series of coils

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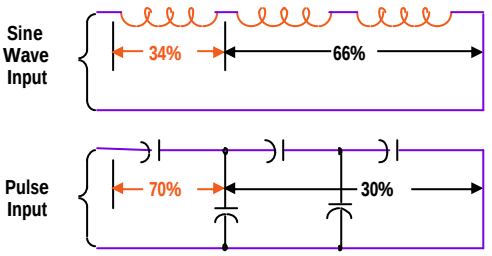
Voltage Distribution in Motor Windings



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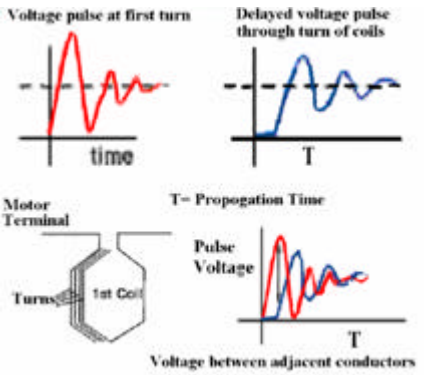

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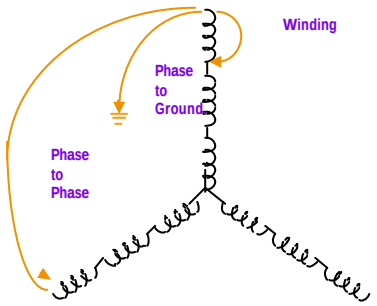
Motor Insulation System Stress



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Protecting Against Winding Stress

- Phase-to-phase
  - — Winding enamel can be enhanced
  - — Phase paper insulation

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Protecting Against Winding Stress

- Phase-to-ground
  - —Winding enamel can be enhanced
  - —Slot liner insulation
- Intra-winding
  - — Winding enamel can be enhanced
  - — Form wound coils

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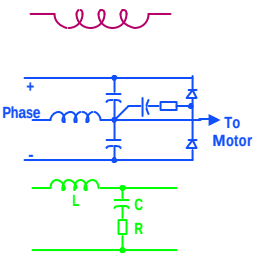
Protecting Against Winding Stress

- Output reactors
  - — Inductor
  - — At output terminals
- Dv/dt filter
  - — At inverter output
  - — And DC bus
- Sine wave filter
  - — Remove harmonics
  - — Sinusoidal power



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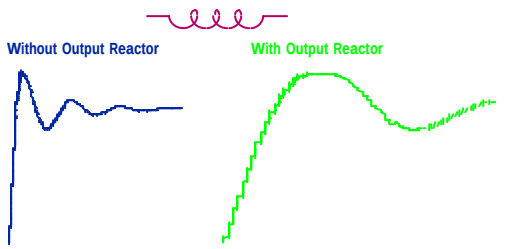
Output Reactor Effects (Rise Time)



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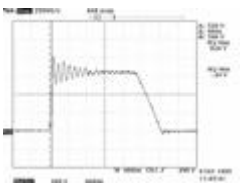
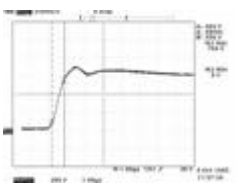
IGBT Inverter - Voltage at Motor

(12 Ft. Of Cable)

Without Output Reactor



With Output Reactor



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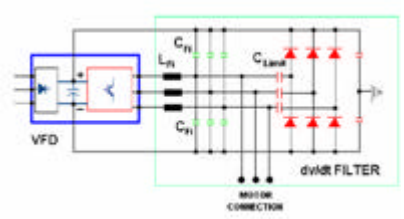
dV/dt Output Filter



- Limits motor.
  dv / dt to < 500 V / micro second.
- Reduces cable Charging currents.
- Reduces motor transient voltages to approx. 1200 V.

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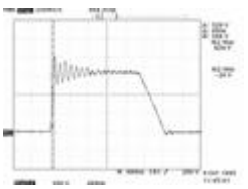
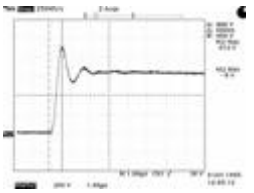
IGBT Inverter - Voltage at Motor

(12 Ft. Cable)

Without dV/dt Filter



With dV/dt Filter



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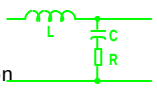
Sine Wave Output Filter



- Absolutely the best protection
- True sine wave at AC motor terminals
- Cost and space must be considered
- Motor parameters cannot be Measured

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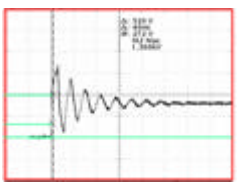
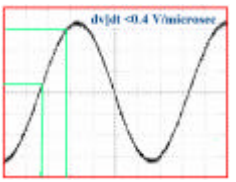
IGBT Inverter - Voltage at Motor

(140 Ft. Cable)

Without Sine wave Filter



With Sine wave Filter



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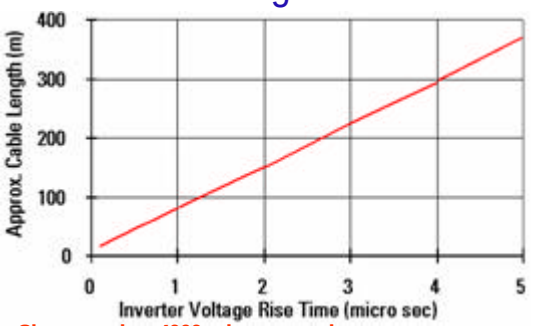
Critical Cable Length Vs. Rise Time



Sine wave is ~ 4000 micro seconds

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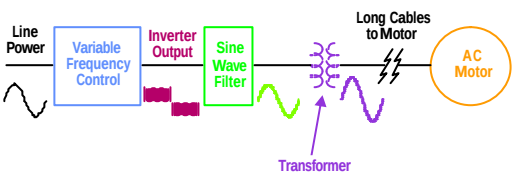
Inverters With Very Long Cables



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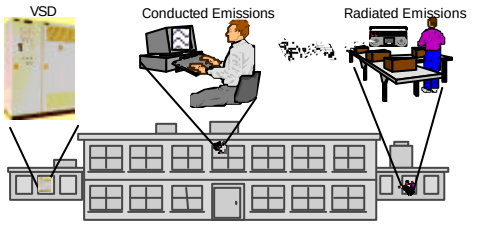
EMC - What is it?



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Noise

Electrical noise is an unwanted and continuous signal on the steady state voltage and/or current waveforms.

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Noise - two modes

Differential mode (transverse) noise refers only to that case where the phase conductors only are polluted with noise.

Common mode (longitudinal) noise refers to the case where the phase conductors and the ground conductors are polluted with noise.

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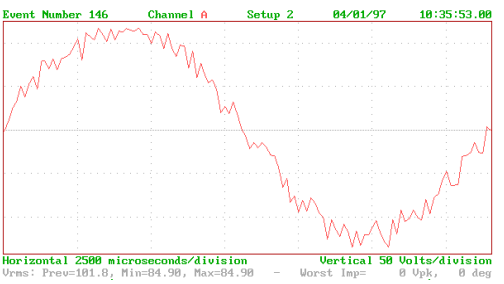
Differential mode noise



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Electromagnetic Compatibility

The essential protection requirements of the EC directive - and common sense - demand that electrical equipment must be constructed in such a way as to:-

Not emit electromagnetic interference which disturbs the intended operation of other apparatus

Have sufficient inherent immunity to externally generated electromagnetic disturbances to enable it to operate as intended

Emissions and Immunity

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Electromagnetic Compatibility

Electromagnetic Compatibility can be ensured by:

Good Design:

- Careful component layout.
- Controlling switching and Oscillations.
- Protection on inputs.
- Good grounding and use of Ground-planes.
- Internal RFI filters.

Good installation:

- Solid Grounding.
- Separation of power and signal cables.
- Suppression of contactors, relays.
- Use of external filters.
- Use of shielded cables.

Good design is the responsibility of Siemens ; Good installation is the responsibility of the installer.

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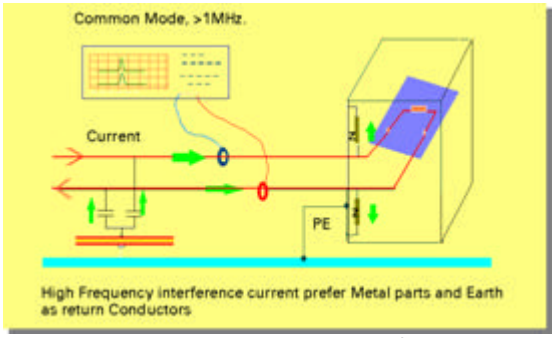
Common Mode Interference



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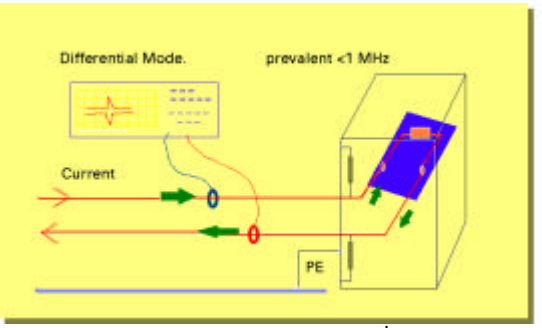
Differential Mode Interference



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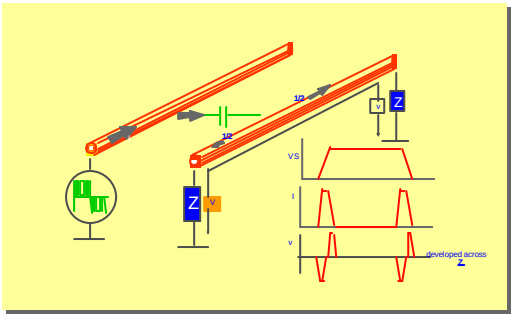
Capacitive Coupling



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EMC: Installation Rules

1. Ground all metalwork together using thick solid straps.
2. Separate signal and power cables.
3. Suppress all coils, contactors, relays, solenoids etc. using RC suppressors.
4. Use shielded cable or twisted pairs where possible.
5. Avoid long cable runs or loops. Keep cables close to grounded metalwork.
6. Ground unused cables at both ends.

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EMC: Principles of Grounding

- All Conductors have a finite impedance which increases with frequency.
- Two physically separate ground points are not at the same potential unless no current flows between them.
- At high frequencies there is no such thing as a single point ground.

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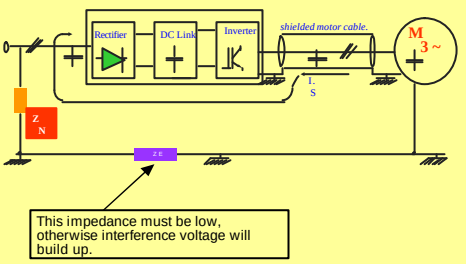
EMC: Good Grounding



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EMC: Good Grounding Practice

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EMC: Principles of Grounding

- Chassis must be effectively grounded!
- This may need paint under the mechanical mounting to be removed, for instance with filters.
- Bonding must present low impedance to high frequency currents.

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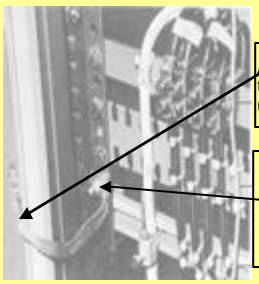
EMC: Good Grounding Practice



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Grounding of Control Cables

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Separation and Zoning

- Separate the power, control, incoming power etc. into different Zones.
- Ensure cables from different zones are routed in separate cable ducts.
- Use shielding between different Zones.
- Ensure cables cross at right angles to minimize coupling.

Poor EMC Installation: all wiring mixed.

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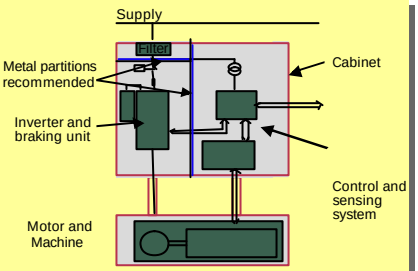
Separation and Zoning



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EMC: To Summarize

- Plan the installation with EMC in Mind
- Segregate the different components screen into different Zones
  Consider using cabinets etc with built in screening.
- Segregate Motor cables from signal cables.
  Screen analogue and digital cables at each end.
  De-couple if necessary.
- Equipotential bonding for high frequency currents.
  Thick flat braided bonding cables.
- Remember - Prevention is better - and cheaper - than cure.

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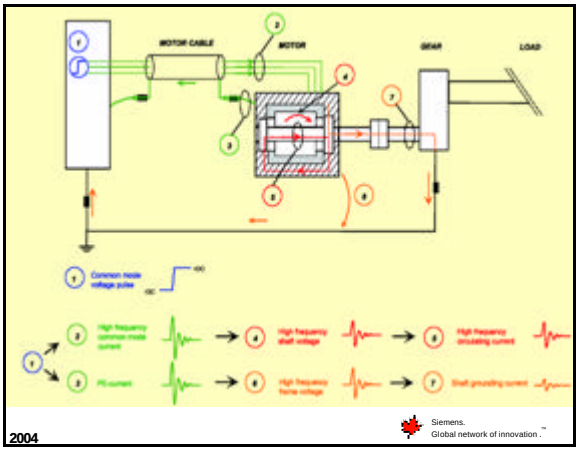

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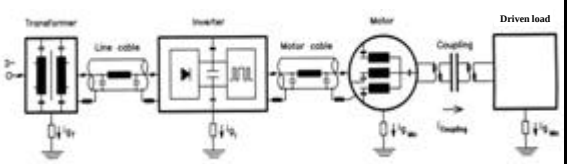
Typical System Configuration



The overall system configuration has an impact on the bearing currents

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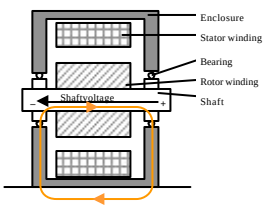
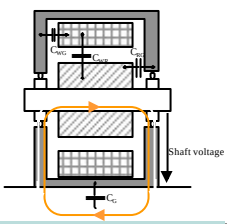
Reducing Bearing Currents



Low-frequency circulating currents
Remedy: Insulate 1 bearing



High-frequency bearing currents
Capacitive bearing current pulses (EDM effect)*
Remedy: Shaft grounding
* Electrical Discharge Machining

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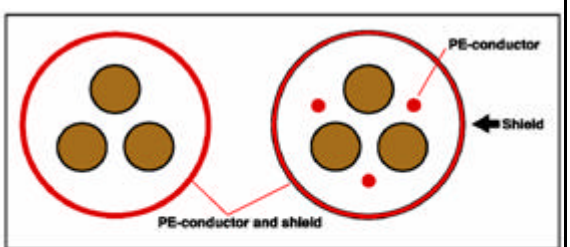
Reducing Bearing Currents



Use only symmetrical motor cables, either with a conductor surrounding all the phase leads or a symmetrical arrangement of three phase leads and three earth conductors

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Drive RX VFD Cable

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