The Truth About Cable Lead Lengths From Your Drive to Your Motor

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The Truth About Cable Lead Lengths – From Your Drive to Your Motor

- Abstract
  - Using variable speed drives and motors requires understanding of the application, drive features and motor characteristics. When used together customers can see increased efficiency and productivity. Along with the benefits you need to be aware of some of the potential issues that can occur.

- Objective –
  - The objective of this presentation is to help you better understand the terms and potential issues that can occur when running longer distances with motor cables and devices used to reduce those issues.

The Truth About Cable Lead Lengths – From Your Drive to Your Motor

- Topics
  - Terms and History
  - Variable Speed Drives
  - Motors and Insulation
  - The Effects When Combined
  - Lead Length Tables Found in Manuals
  - Tools to Reduce Problems
  - Summary

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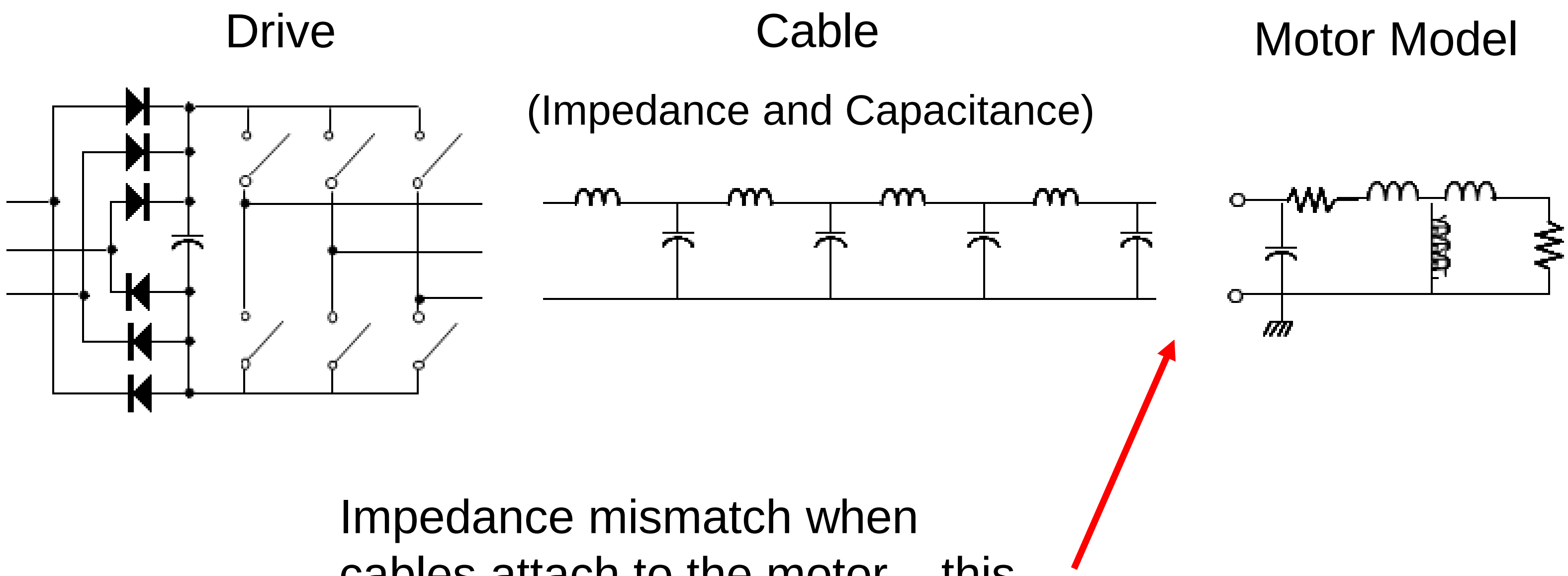
Terms and History

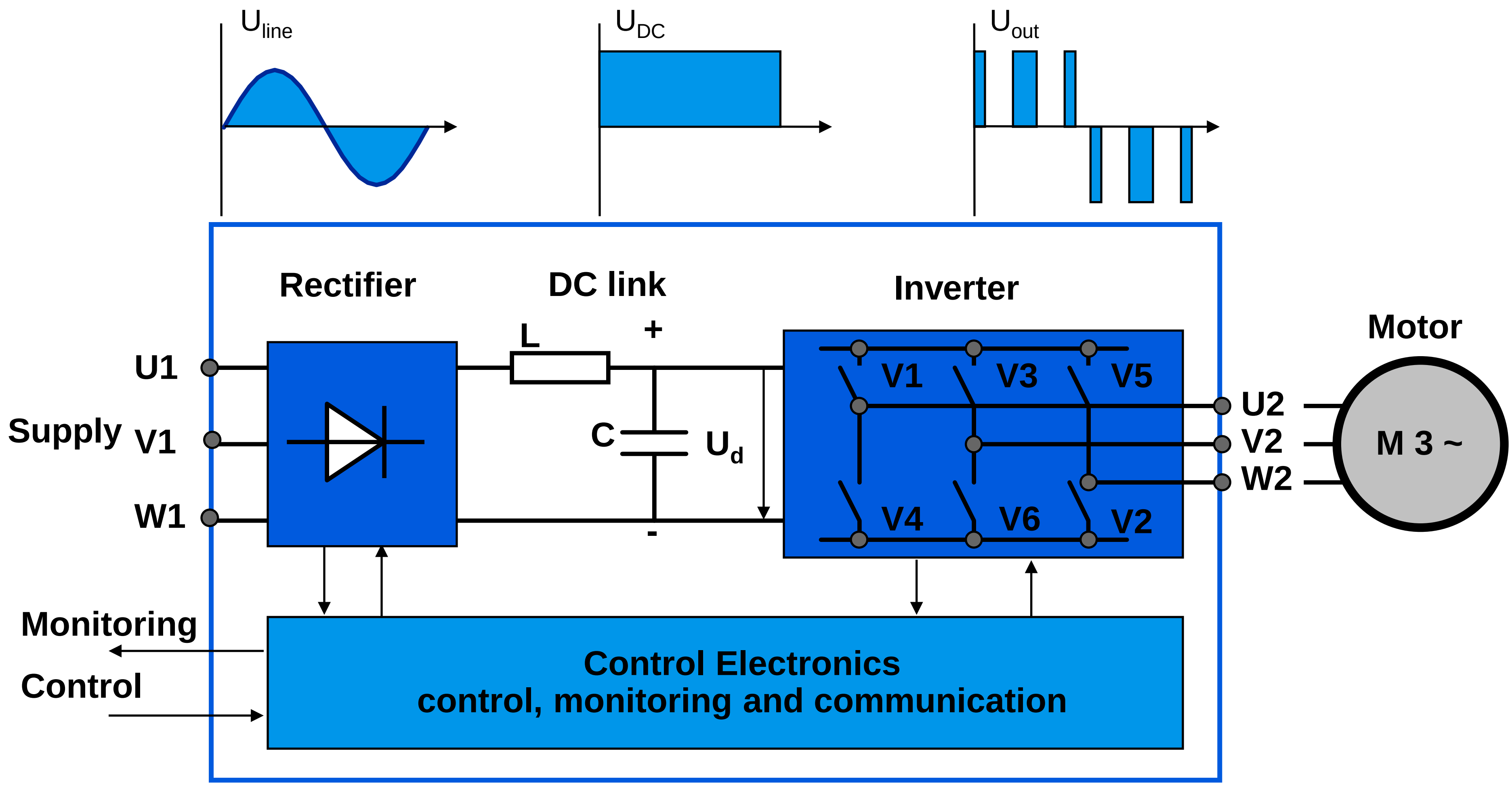
- Reflected Wave – Occurs when there is an impedance mismatch between the cable and the terminating device.
  - First identified in 1880 with telegraph lines (and later power transmission lines)
  - Also known as Standing Wave or Transmission Line Effect
  - Is not limited to higher voltages – common in digital communications
  - Fast rising voltage wave cause a reflection phenomena which raises a device's terminal voltage to a value greater than the source that supplies it
- Capacitive Coupling – Created when cables or other conductors have stray capacitance with each other
- dv/dt – The rate of change of voltage over time
- Dielectric Strength – A measure of an electrical insulating material's capability to insulate
- NEMA MG1 part 31.4.4.2 – Standard for motors to handle a high voltage stress

Terms and History
Creating Reflected Wave



Impedance mismatch when cables attach to the motor – this creates a voltage reflection when the drive starts the motor

Variable Speed Drives
PWM Output

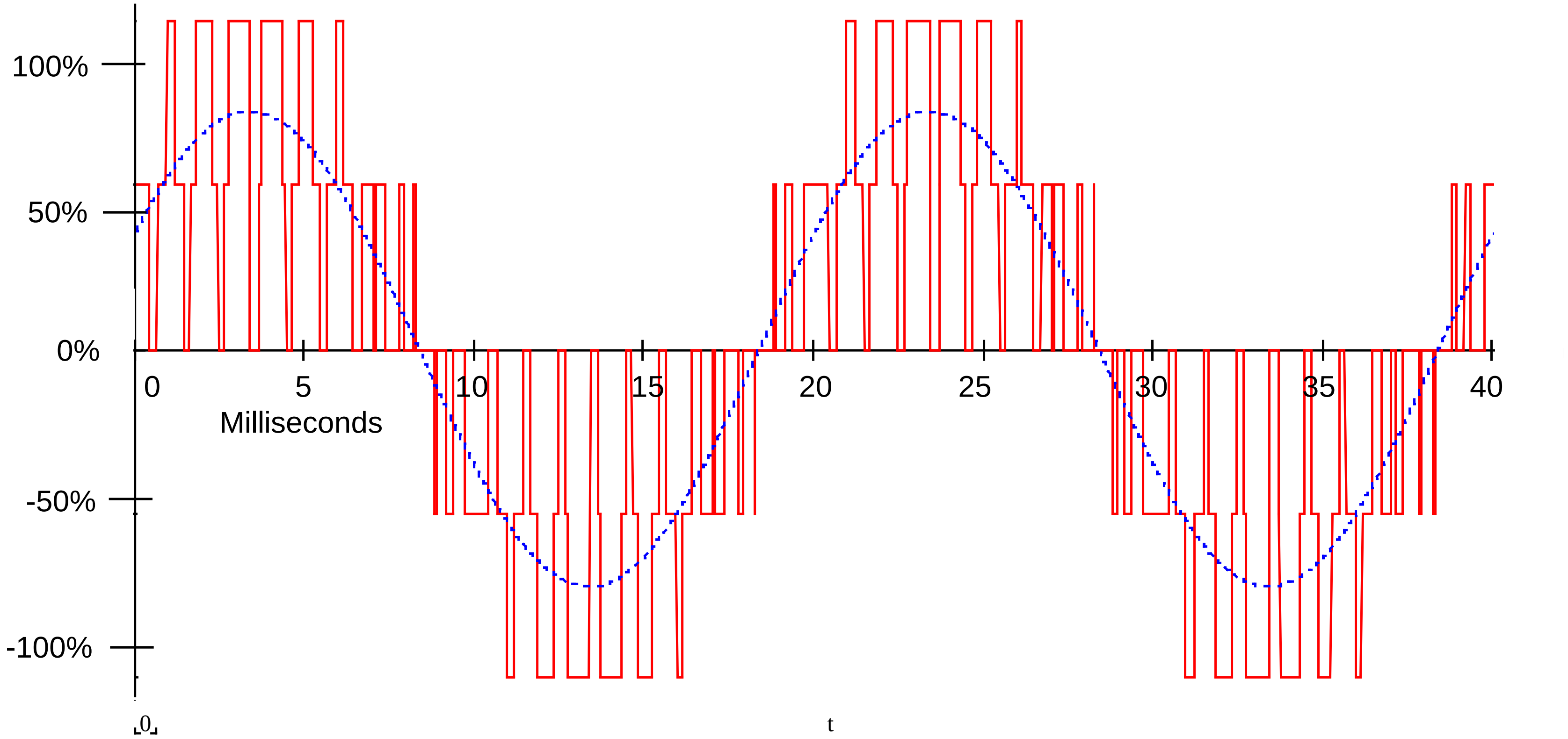


Variable Speed Drives

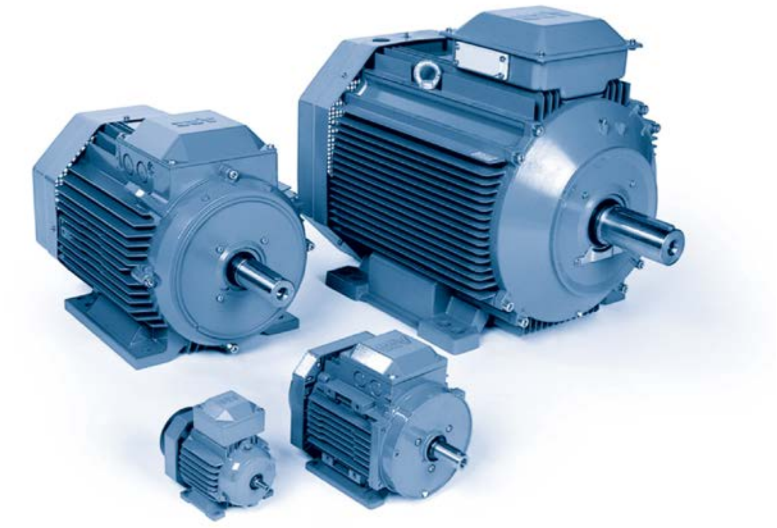
- How do drives benefit us?
- Variable speed drives provide
  - Efficiency and power savings
  - Ability to vary application speed electronically
  - Flexibility
- Drives use IGBT’s Insulated Gate Bipolar Transistors
  - IGBT’s create the output wave form (PWM) Pulse Width Modulation creating a psuedo AC sine waveform
- IGBT advantages
  - Motor runs cooler and quieter
  - Better motor control
  - Smaller packaging and lower cost drives

Variable Speed Drives

- Output waveform of an IGBT drive



Motors and Insulation



- Motors were originally designed to work on a 50 or 60 Hz sine wave signal
- Designed to operate at a peak voltage of 1000 Volts
  - Above 1000 Volts damage can occur
- Rise time greater than 2 microseconds or a dv/dt less than 500 volts per second

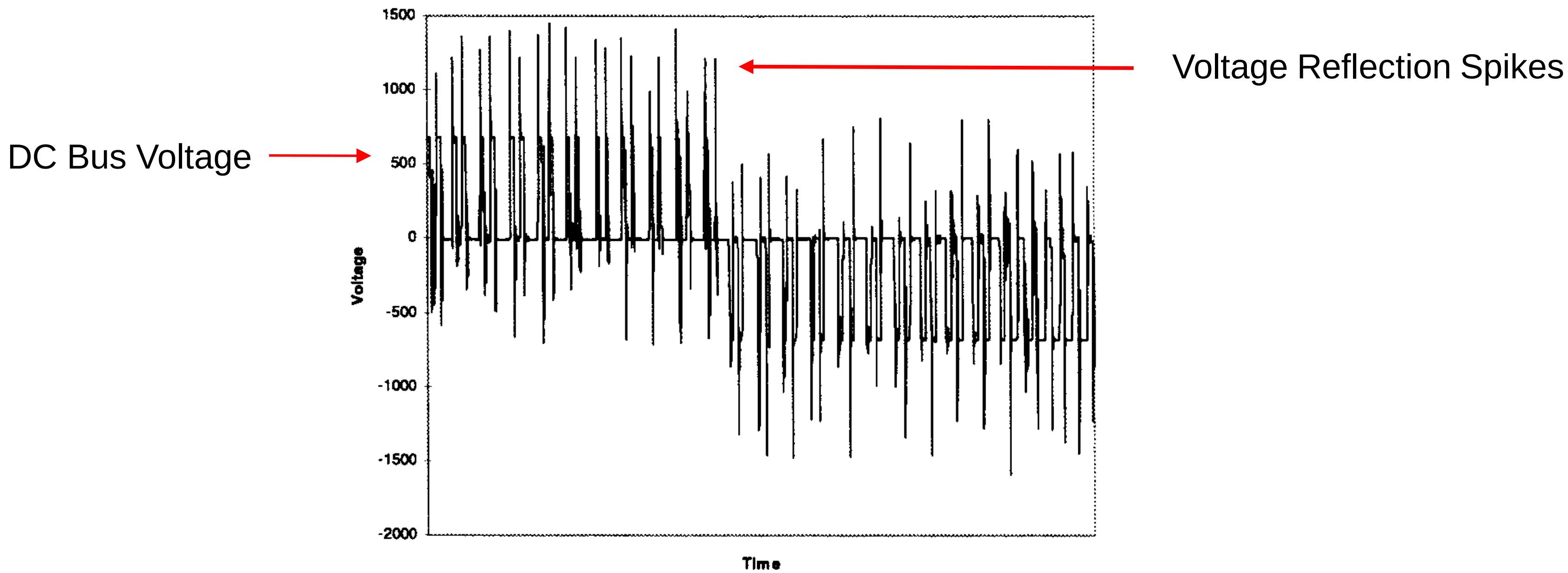
The Effects When Combined

- There are two main concerns:
  - Damage to the motor by a reflected wave
    - Typically a breakdown in the insulation of the first turn of the motor causing an arc to occur
  - Nuisance faults or damage done to the drive
    - Due to long cable lengths and that capacitance that builds up

The Effects When Combined

- Today drives use IGBT's typically have a risetime in the 50-200ns range and up to 400ns when you get above 100 HP
- Critical cable lengths are based the upon semiconductor type used in drives:
  - IGBTs with rise time of 50 – 400ns
    - Can reach 1300V DC at the motor terminals between 35 – 300 feet
  - BJTs with rise time of .6 – 2us
    - Can reach 1300V DC at the motor terminals between 450 – 1500 feet
  - GTOs with rise time of 2 – 4 us
    - Can reach 1300V DC at the motor terminals between 1500 – 3000 feet

The Effects When Combined

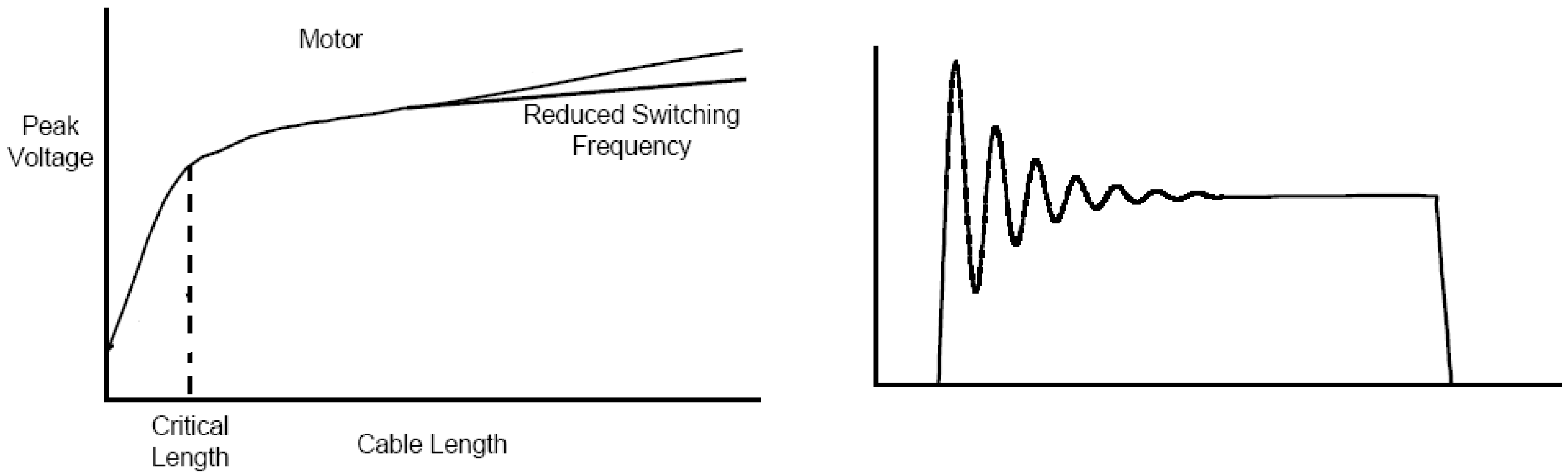


- The Effects on the Motor – Motor Terminal Voltage Without Filter
  - Peak voltage at the drive output is equal to the drives DC bus magnitude
  - Peak voltage at the motor terminals may not be the same voltage seen at the drive terminals
  - Voltage at the motor is dependant on the cable characteristics, distance, IGBT rise time and motor impedance as well as the input voltage to the drive

The Effects When Combined

- The Effects on the motor – when limited or no insulation has been installed between phases
  - 60 - 80 % of the reflected wave is distributed across the first coil group of the motor
  - Damage will occur in the motor when the peak voltage or the voltage risetime exceed the motor insulation rating
  - A breakdown of the insulation can occur leading to a partial discharge
    - Repetitive discharges will form corona
    - The corona will damage the insulation system leading to a short
  - Damage can occur within hours of operation

The Effects When Combined



- Output creates a fast rise time and a voltage level that can be 2 times the DC bus voltage
- The high voltage level or the dv/dt can damage the motor

The Effects When Combined

- The Effects on the Drive
  - The total current of the drive - measured by the current transducers of the drive - is the motor current plus the current from capacitance or common mode
  - The longer the motor cable is, the higher the capacitance of the motor cable is - resulting in higher current
  - This means that as the motor cable becomes longer the motor control accuracy becomes weaker when using DTC
  - At some point the control is lost and/or an over current trip occurs
  - In addition common mode current increases with the cable length
  - This common mode current can cause an earth fault trip
  - Long cables cause a voltage drop that reduce the maximum torque of the motor and increase the motor current (to compensate for lower voltage) and heat rise

Lead Lengths Found In Manuals

- ACS800-U1 hardware manual

Sizing method	Max. motor cable length	
	DTC control	Scalar control
according to I_{2N} and I_{2hd}	R2 to R3: 100 m (328 ft)	R2: 150 m (492 ft)
according to $I_{cont.max}$ in ambient temperatures below 30 °C (86 °F)	R4 to R6: 300 m (984 ft)	R3 to R6: 300 m (984 ft)
according to $I_{cont.max}$ in ambient temperatures above 30 °C (86 °F)	R2: 50 m (164 ft) **Note:** This applies to units with EMC filter also. R3 and R4: 100 m (328 ft) R5 and R6: 150 m (492 ft)	

Additional restriction for units with EMC filtering (type code selections +E202 and +E200): max. motor cable length is 100 m (328 ft). With longer cables the EMC Directive requirements may not be fulfilled.

Summary of the Effects

- Damage to the motor due to reflected wave
- Nuisance tripping on the drive due to capacitance in the cables and motor
  - Capacitance occurs between the output phases and ground, also seen between the motor and motor frame
  - Ground and over current faults on the drive
  - Possible damage to the output IGBT’s

Tools to Reduce Problems

- Keep the motor as close to the drive as possible
- Apply motors designed in accordance with NEMA MG1 part 31.40.4.2.
- NEMA MG1 motors are designed for a peak voltage of 1600 volts at 0.1uS
  - **Note:** Inverter duty motors have different meanings when looking at motor manufacturers – insulation is designed for 60hz operation
  - Inverter duty motors allow for a higher temperature due to the PWM signal produced by the drive and the variable speed range but may not have a high enough insulation rating
- Use 230V for longer motor installations – bus voltage is typically 350V DC

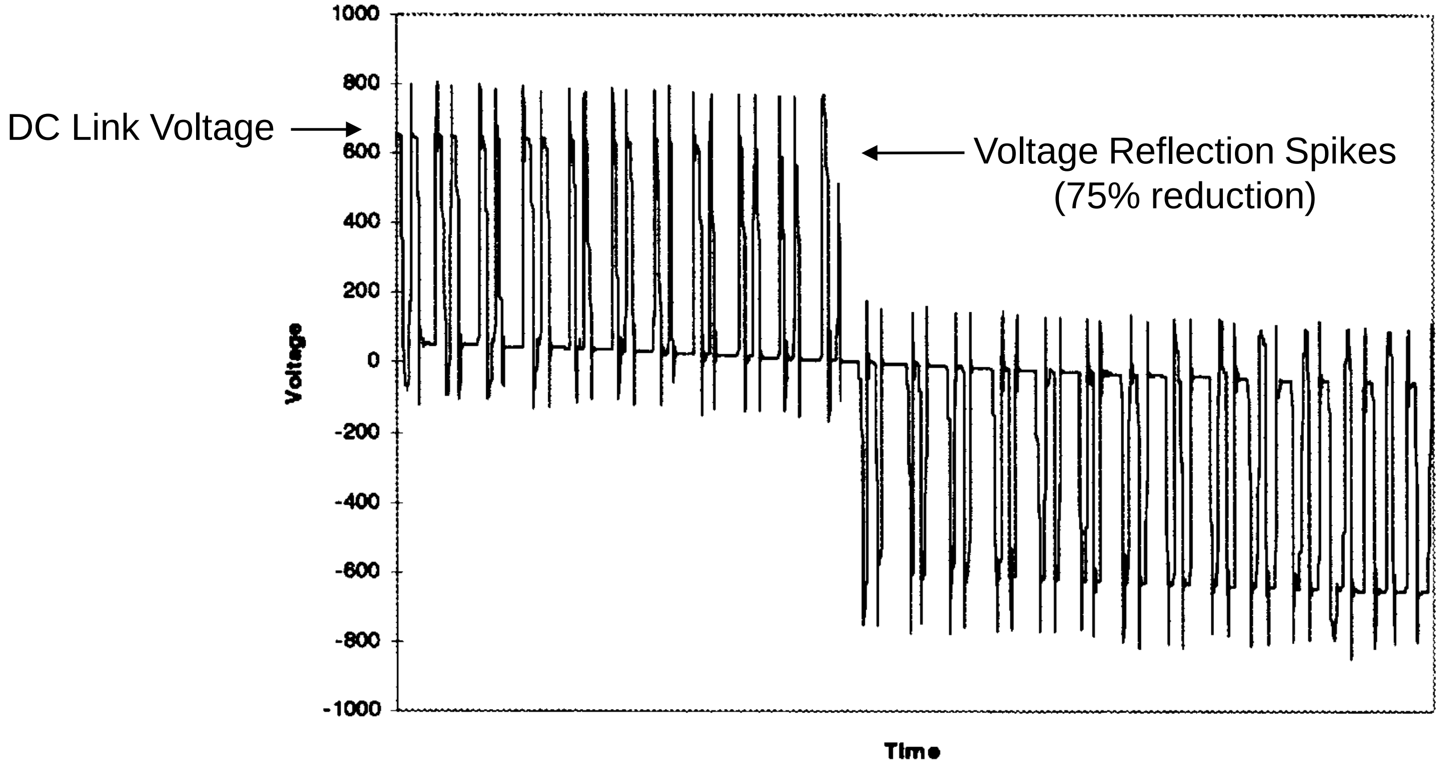
Tools to Reduce Problems

- Use an output filter – recommended TCI
  - Line reactors at the inverter output (typically protects to about 500 ft)
  - dv/dt filters (RLC) at the inverter output (typically protects to about 2000 ft)
  - Sine filter at the inverter output (not distance limited)
  - Snubber circuit at motor (not distance limited)

- These devices reduce the rise (dv/dt) and reduce the voltage level seen at the motor terminals

Tools to Reduce Problems

- The Effects on the Motor – Motor Terminal Voltage With dv/dt Filter



Summary

- When installing motor leads
  - Verify the motor rating can handle the higher voltage stress - Critical in retrofits
  - Check the manual for cable distances the drive can handle without a filter or reactor – EMC guidelines are different
  - Follow proper wiring techniques to reduce stray capacitance
  - Limit long cable applications to less demanding applications such as pumps, fans and conveyers etc
  - Use scalar control
  - Take into account the voltage drop created by the cables and any filter you install
    - Be sure the drive can provide the amount of current needed to run the application

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Questions?

Thank you for coming!

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