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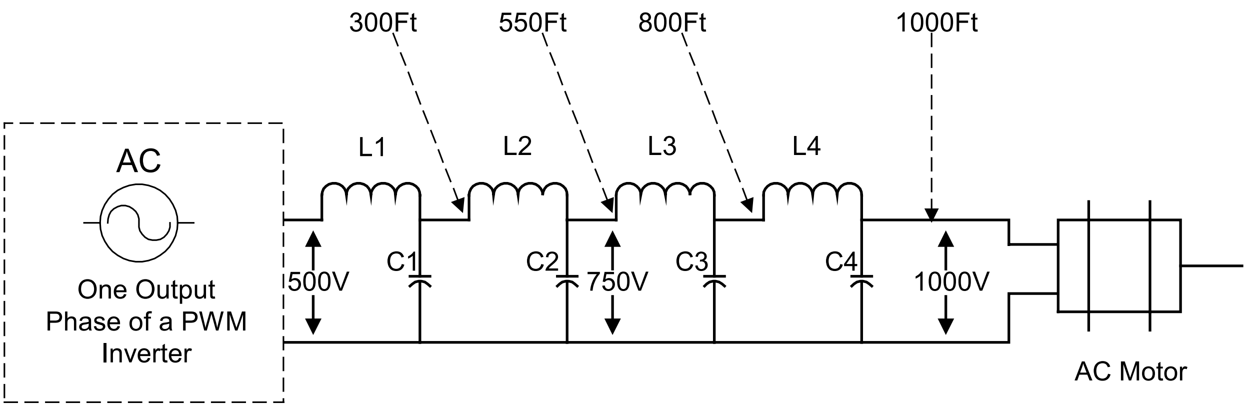
Long Cable runs and the effects on the motor/inverter system

Lab test along with field experience has shown that the increasingly fast rise times (Carrier Frequency) on the output of the PWM inverter, coupled with long motor leads, can result in motor insulation failures, unless proper precautions are taken in the system. The following paper will help to explain the phenomenon that is taking place between the inverter and the motor with long cable length. For the purpose of this paper long cable lengths will be defined as greater than 100M(330Ft).

The following is an electrical model of the circuit between the inverter and the motor including the cabling. All voltages are roughly estimated on the following drawing.



By following the theoretical model, we may take a closer look at what happens when the PWM (Pulse Width Modulation) inverter applies a fast rise time pulse to the inverter-end of the cable. It is from that view, that we can better understand how the length of the cable will add to the voltage applied to the motor terminals.

Initially current starts to flow into the first inductor of the cable and begins to charge the first capacitor to a certain voltage level. This causes current to flow through the next inductor and charge the next capacitor; the process continues from inductor to inductor, capacitor to capacitor. As the energy wave finally reaches the motor-end of the cable, the last capacitor becomes fully charged, but current is still flowing through the last inductor. Because the motor impedance is much higher than the cable impedance, the energy from the last inductor will flow into last capacitor and over-charge it. It is this characteristic that can lead to potential problems resulting from cable length. In theory, this over-voltage can reach a level twice the DC bus level (650Vdc typical). When it reaches this level the current reverses and flows back toward the source, charging each capacitor along the way to a higher voltage. When it finally gets back to the inverter, the current wave is reflected; but this time it travels toward the motor as a negative wave. This is a good thing because when a reflected negative wave reaches the motor (while the first reflection is still building up), it will subtract from the first and lessen the over-voltage at the motor terminals. The problem occurs when the cable is of such length that the preceding reflections are finished building up before the succeeding negative reflection can arrive and help lessen the voltage at the motor terminals**.** The actual ringing frequency at the end of the cable depends on the cable length and the wave propagation velocity; this phenomenon is commonly referred to as standing wave ratio.

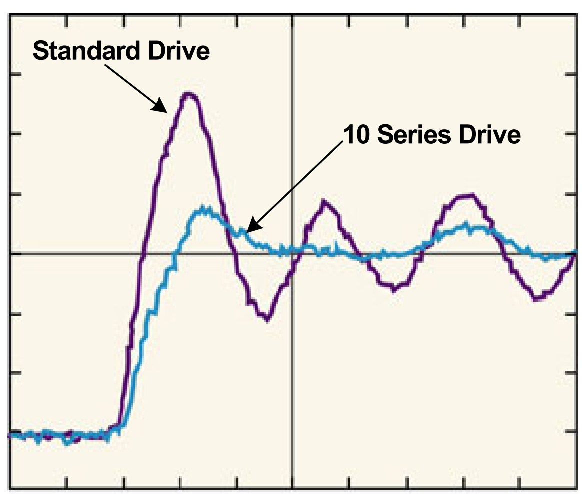
The actual critical cable length will depend on several factors the carrier frequency of the drive (rise time) and the size of the cables, and of course the distance of the cables to the motor terminals.

Possible Corrective Actions

There are several corrective actions to prevent the above phenomenon from occurring in your system. The solution will vary depending on the length of the cable from the inverter to the motor. On multiple motor applications, the cable length will be the additive of all the motor leads connected to the inverter. There are several types of output filters on the market, the first output filter that is commonly used is an output reactor and it is generally used with cable lengths less than 150m. When distances become greater than 150M it is recommended to use a DV/DT type output filter to reduce the voltage at the motor terminals to useable (safe) level. The manufacture of DV/DT filter have a recommended carrier frequencies range which to set the inverter, to properly operate the filter and prevent damage from excess heat on components. Lab tests have shown that the filters would have greater effect if installed at the motor terminals, but due to the adverse environments that motors are generally located in this is not practical. It is accepted practice to install the filters on the output of the inverters. It is always a good practice to decrease the carrier frequency when using long cable length, by reducing the carrier frequency it lessens the effects of above mentioned occurrence on the inverter-motor system. In addition, check with the motor manufacture to insure it is compatibility with a PWM type Inverter and it's electrical characteristics to determine what type filter is necessary.

Corrective Action with 10 Series Product (rev.07/02)

The 10 series products utilize improved forth generation IGBT devices and switching gate controls circuits. This reduces DV/DT by approximately 50%, which in turn reduces the motor peak terminal voltage. The newly developed IGBT have reduced internal losses, while the gate circuitry has been redesigned to provide lower DV/DT without compromising performance. This reduces motor insulation dielectric strength minimum rating requirements allowing 1000V insulation dielectric strength motor (existing motor) to be applied with these drives in many applications.



Peak Voltage across IGBT junction

Drives 7.5 HP and larger			
Motor Insulation Level	1000V	1300V	1600V
460 VAC Input Voltage	66 ft (20 m)	328 ft (100 m)	1312 ft (400 m) *
230 VAC Input Voltage	1312 ft (400 m) *	1312 ft (400 m) *	1312 ft (400 m) *

Recommended cable length between the inverter and the motor for the 10 series product.

The 10 series product enhances motor performance and greatly reduces voltage stress on the insulation of the driven motor, which allows the use of existing motors with lower insulation dielectric strength or newer motors with increased cable distance between inverter and the motor. The new technology in the 10 series product which allows for the increased performance to the motor leads as referred to in soft switching technology technical note. (TN_VFD_GEN_016-G).