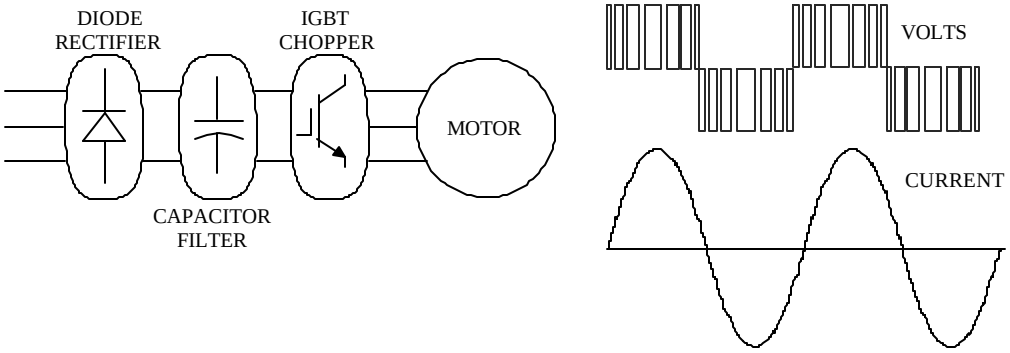
APPLICATION GUIDELINE #36

(Voltage Stress' Caused by PWM VFD's)

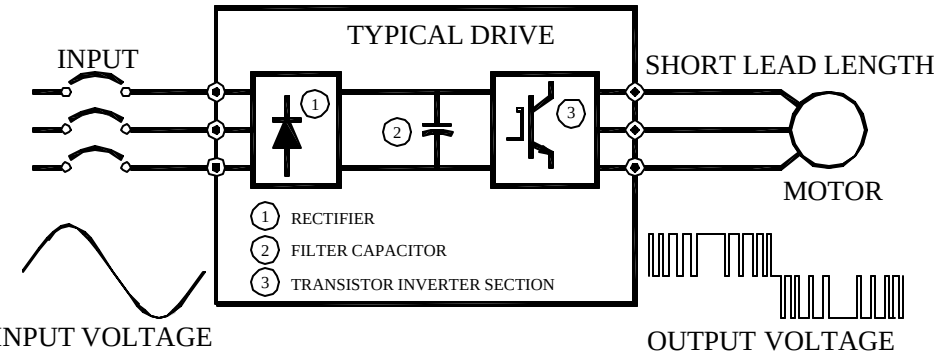
Pulse Width Modulated (PWM) Drives with IGBT Transistors

IGBT transistor technology was released in 1988. This advance in the drive market allowed a PWM output to switch the transistors more efficiently and it was possible to parallel the devices for larger capacities. The faster switching speed device allowed for an improved current control and made the Variable Frequency Drive (VFD) market less application sensitive.



Application Concerns Regarding Carrier Frequency and Voltage Stress

Carrier frequency is the rate at which the IGBTs fire to create PWM output. By increasing carrier frequency, thus creating more pulses per unit time, the resulting waveform better approximates a sinusoidal current waveform. The benefits of a high carrier frequency include less audible noise and less motor heating. Unfortunately, there are disadvantages with high carrier frequency regarding motor insulation stress and currents to ground.



The PWM carrier frequency from most drive companies usually ranges from 2000 to 16,000 pulses per second (2-16 kHz). Standard induction motors were designed for a sine wave voltage. When a Variable Frequency Drive (VFD) puts DC pulses at high amplitude, more stress is placed on the windings. At short distances below fifty feet between the motor and ASD, there is considered to be little application concern. In the figure above, it shows the waveform on the drive output appears at the motor terminal unchanged with a typical peak of 813V (575V x v2).

When motor lead length distances increase above 100 feet, the small values of inductance and capacitance that are insignificant to a sine wave can cause voltage ringing and even reflected waves that can raise peak voltages above 2000V. Higher carrier frequencies can add an additional stress by a doubling of voltage caused by reflected waves. Normal 813V peak levels can be as high as 2000 volts!

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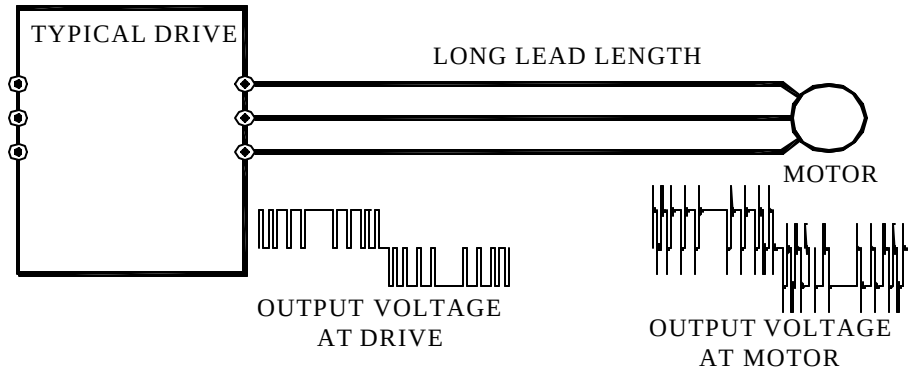

Motor companies have responded to the insulation stress issues by improving motor insulation capabilities. A lot of the focus went into improving the dielectric strength capability of the magnet wire used in the slot insulation system. NEMA MG-1-1998 Section IV Part 31 published a specification for motors used on drives that defines a 'peak voltage' and a 'rise time' that the insulation must be able to withstand, it states [V_{peak}= 1.1 x 2 x $\sqrt{2}$ x V_{rated} = 3.1 x V_{rated}, Rise time ≥ 0.1µs]. There are also several methods of mitigating voltage stress using filters.

Toshiba EQP III motor designs meet the requirements specified in the 1998 guideline ('Application Guideline #37' will discuss the insulation system in full detail). Normal wiring methods may be used, and no special cable is required, however, it should be considered to minimize opportunities for Electric Discharge Machining (EDM) currents discussed in 'Application Guideline #12'. Motor leads should be installed in separate conduit and not mixed with other wiring. The following lead length limitations are safe when used with a Toshiba EQP III motor and any Toshiba VFD.

AC Motor Voltage	PWM Carrier Frequency	NEMA MG-1-1998 Section IV Part 31 Compliant Motors
230 V	All	1000 ft.
460 V	≤ 5 kHz	600 ft.
	> 5 kHz	300 ft.
575 V	≤ 5 kHz	200 ft.
	> 5 kHz	100 ft.

For distances greater than listed above, filters are available that can be mounted near the drive.

Conclusions Regarding Insulation Stress

- Lower carrier frequencies are better for the motor insulation if audible noise is not a concern.
- Not all drives are the same. Check with each manufacturer for their recommendations. Some drives have higher voltage peak outputs and fast (shorter) rise time which both affect motor insulation negatively. Quality manufacturers will provide superior filtering around IGBT's in their VFD's.