

# VFD Operating Non-VFD Rated Motors

## Whitepaper

Danfoss VFDs are compatible with all standard, non-inverter rated, AC induction motors. However, motors insulation systems may or may not be designed by the motors' manufacturer to be suitable for VFD operation. The requirements for VFD compatible motor insulation systems are specified in NEMA standard MG1 Part 31. The considerations when using non-VFD rated motors on VFD power are discussed in MG1 Part 30.

Danfoss recommends that motors specified for new VFD installations are designated by the motor's manufacturer as meeting NEMA MG1 Part 31 or are otherwise suitable for VFD operation. If the motor is not VFD rated, as in some retrofit cases, then the customer should consider the increased insulation stress potentially caused by the VFD and how it may affect the life of the motor. In most cases the risk is small and is not a problem. However if the customer wishes to manage the risk of a possible motor failure then he has a few possibilities:

- MEGGER the motor to determine a baseline for condition of the existing motor
- Accept the risk that the motor may have a shortened life and plan for a replacement.
- Replace the motor with a new VFD rated motor.
- Add a dV/dt filter\* to reduce the risk significantly.
- Add a sine filter\*\* to reduce the risk to virtually zero.

The risk of a shortened life of a non-VFD rated motor is higher in these cases:

- 600 VAC mains and somewhat with 460 VAC mains.
- Motors in a wet location.
- Motors with class B insulation.
- Motors rated less than 15 – 20 hp.
- Motor cable lengths longer than 75 feet.

Of course these are very broad generalities

\* A dV/dt filter is designed to reduce the insulation stress to non-VFD rated motors by reducing the rate of voltage rise [dV/dt] of the VFD's switched output. The VFD's switched output waveform will still be seen by the motor. Although a dV/dt filter will coincidentally reduce the motor's acoustic noise that is not their primary purpose. The rate of voltage rise is reduced to approximately 1000-1200 V/us.

\*\* A sine filter removes virtually the VFD's entire switching frequency component. The end result is a relatively clean sine wave voltage waveform at the motor terminals. Its purpose is to reduce VFD generated acoustic noise at the motor and to reduce motor insulation stress. The rate of voltage rise is reduced to approximately 3-5 V/us.

### Notes:

1. Output reactors are sometime specified to reduce motor insulation stress. Output reactors will sometimes reduce the dV/dt seen by the motor. However, unlike a sine or dV/dt filter, a reactor is not an engineered system but rather a simple component, meaning "your mileage may vary".

2. The output of an unfiltered VFD will have a rate of rise approximately 1500 – 3500 V/us. The actual rate of rise varies by model and motor cable characteristics.

3. NEMA MG1 Part 30 recommends the dV/dt be limited to approximately 500 V/us. NEMA MG1 part 31 requires a VFD rated motor be designed for approximately 14000 V/us.

4. Sine-wave and dV/dt filters The output filter options include sine-wave and dV/dt filters. Unlike sine-wave filters, the only task of dV/dt filters is to reduce the steepness of the pulse edges. They are simpler in design than sine-wave filters (smaller inductances and capacitances) and are therefore less expensive. Sinewave filters, which are also called motor filters or LC filters, may optionally be fitted to the outputs of Variable Frequency Drives. They smooth the rectangular voltage pulses at the output to convert them into a nearly sinusoidal output voltage.

	<b>dV/dt filter</b>	<b>Sine-wave filter</b>
Motor insulation stress	Reduced – longer motor cables can be used	Reduced – longer motor cables can be used
Motor bearing stress	Slightly reduced	Reduced circulating currents but not synchronous currents
Electromagnetic compatibility	Eliminates harmonics in motor cable. No change in EMC class	Eliminates harmonics in motor cable. No change in EMC class
Maximum motor cable length, EMC compliant	Depends on manufacturer FC 202: max. 500 ft. shielded	Depends on manufacturer FC 202: max. 500 ft. shielded or max. 1000 ft. unshielded
Max. motor cable length, not EMC compliant	Depends on manufacturer FC 202: max. 500 ft. unshielded	Depends on manufacturer FC 202: max. 1500 ft. unshielded
Motor noise at switching frequency	No effect	Reduced
Relative size (compared to Drive)	15–50% (depends on power)	100%
Voltage drop	0.5%	4–10%