Application Note

Sine Wave Filter

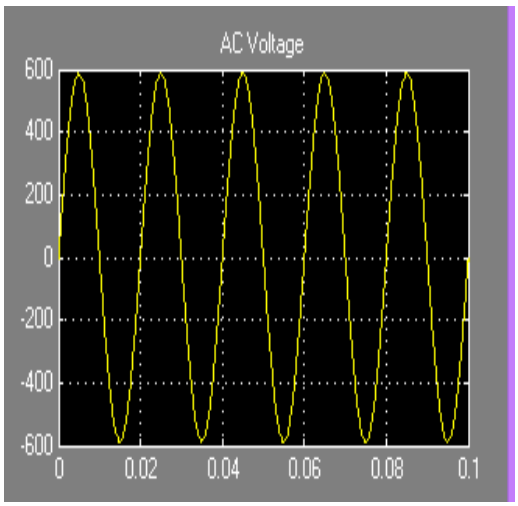
Asynchronous motors, commonly known as induction motors are widely used in industrial applications. They are rugged, require minimum control and are easy for maintenance.

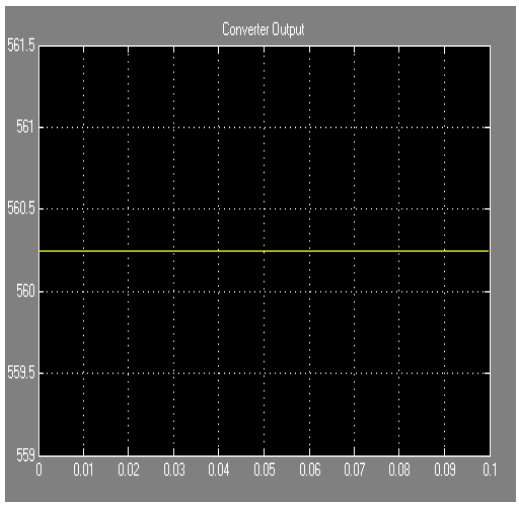
The speed control of these motors is achieved by using Variable Frequency Drives (VFDs), which is the modern method compared to earlier methods of varying rotor resistance, etc.

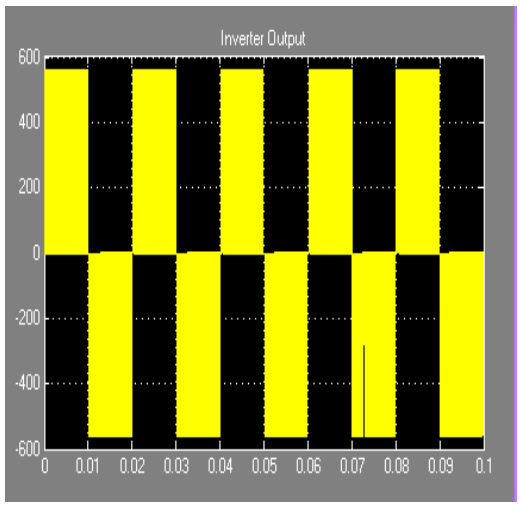
VFDs have 2 stages.

The input line voltage, e.g. 415-V, 3-phase, 50 Hz, is first converted to a DC voltage. This DC voltage is then chopped using Pulse Width Modulation techniques.

The waveforms at various stages look like below.







Line Voltage DC Voltage PWM Voltage

As can be clearly seen, the VFD output is not a sine wave.

The waveform consists of switching pulses symmetrical along the axis. This voltage is applied to the motor terminals.

This voltage is actually a pulse train. The inverter semiconductors are switched high frequency. Higher the switching frequency, lower are the losses within the semiconductors. However, higher switching frequency is associated with higher rate of rise of voltage.

The Rate of Rise of Voltage or dV/dt can go right up to 12 kV / µS.

The permissible limit as per IEC standards for 500-V motors is 1 kV/µS.

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Even if the distance between VFD output and Motor is less than 20 meters, the insulation of motor conductors is not suitable for this high rate of rise of voltage. A cable of less than 20 meters will not offer any effective impedance in the circuit. The entire voltage appears as it is on the insulation.

Enamel insulation with slightest impurity can fail due to this high dV/dt.

If the cable length is more than 20 meters or so, it offers measureable impedance.

The switching frequency signal in this case will act upon this inductance.

In the equivalent circuit diagram of the motor it acts as inductance for 50 Hz voltage. However, for high frequency switching voltage, it appears as capacitance.

With every meter of cable added, the inductance increases. It acts as energy storage device. Every pulse of incoming pulse train gives rise to voltage peaks.

The longer the cable length, higher will be the voltage peak magnitudes.

In this case, the weakening of motor insulation is a certainty.

Apart from insulation failures the motor may suffer from following problems.

- Additional losses in motor associated with harmonics in the voltage
- Parasitic earth currents
- High Frequency Electromagnetic Noise in motor cable
- Bearing Currents and associated bearing failure
- Noise in the motor

In general the savings in running cost of motor accrued out of using VFD may be somewhat offset with the problems associated with motor, since the maintenance costs may increase. Apart from direct costs downtime has to be considered; which may directly affect the production costs.

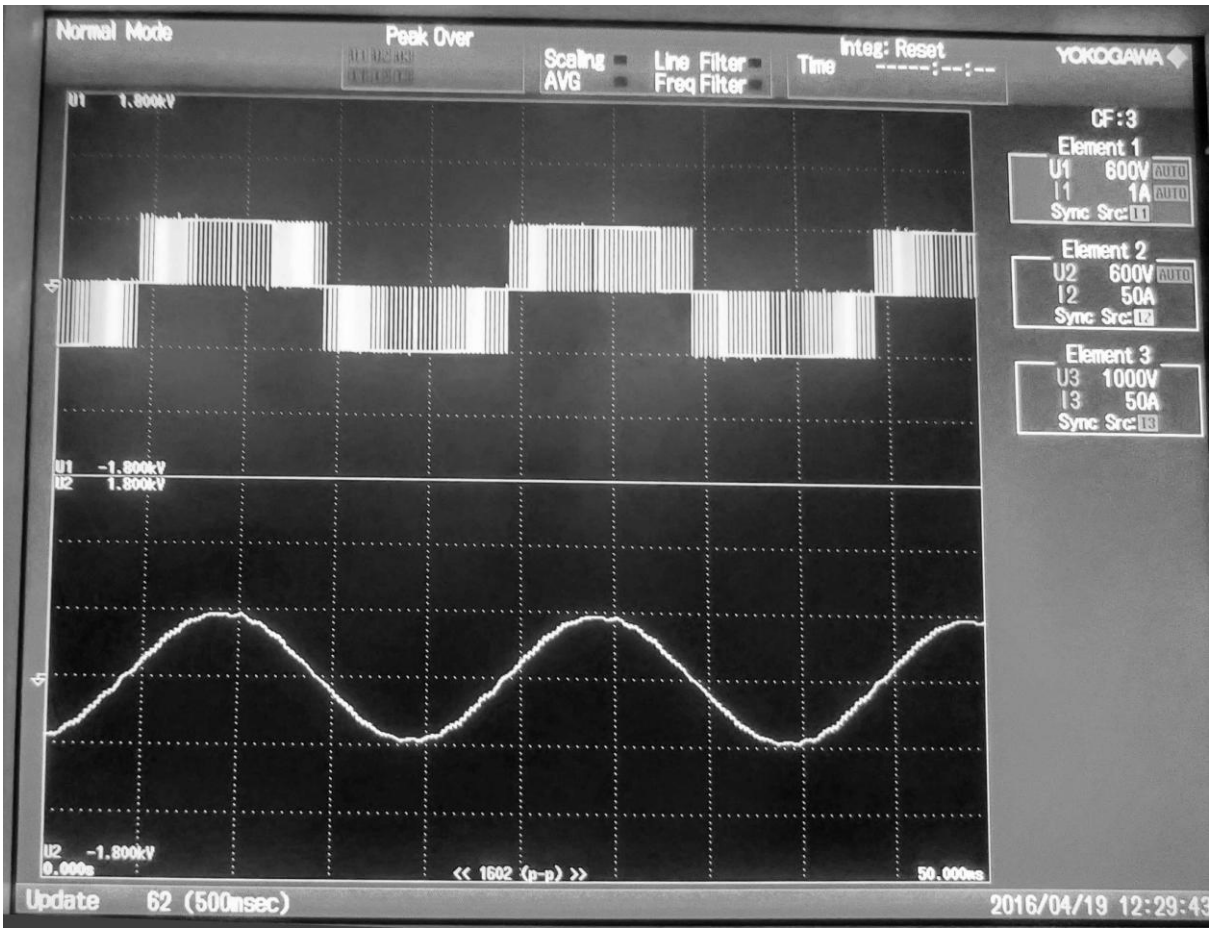
To conclude, if the motor is not rated for VFD application it is likely to suffer more damages. Motors rated for VFD application will be less affected but their performance will not be same as when operated with pure sine wave.

The solution is to introduce a Sine Wave filter between the VFD output and Motor terminals.

We have developed this sine wave filter and the waveforms captured on oscilloscope are shown below.

The upper waveform is the VFD output and the lower waveform is the motor terminal voltage.

Sine wave filters are available for all standard voltage and kW ratings of the motor in both open execution and with IP 20 version.



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