Sinus Filter Plus ++®
(Output filter for common-mode high-frequency interference)
Scope of this document

Frequency inverters, which normally have switching frequencies of 2 to 20 kHz, produce considerable common-mode (asymmetrical) noise. The fast switching of the DC voltage causes voltage peaks in motor cables and the longer the length of cable the higher the amplitude of the voltage peaks. The resulting fast rising voltage (dV/dt) comprises many harmonic frequencies and the faster the rise time the wider the resulting harmonic frequency spectrum (above 150 kHz) and the worse the ripple is on the voltage sine wave measured between line and earth. This disturbance is a result of common-mode interference caused by parasitic capacitance between various metal parts of the motor and earth and causes undesirable pulsed currents to flow. The Sinus Plus++ filter provides a means of allowing the common-mode interference to flow back to the DC link instead of through capacitive coupling to earth. Mainly this technique is used to protect motors that are used in critical processes or the replacement of a motor is too expensive but it can also be used when leakage currents in parallel connected circuits cause interference.

Introduction

Most modern motors have a variable-speed drive which uses a frequency inverter employing semiconductor devices (IGBTs). The switching techniques used generate high rates of change of voltage which can cause undesirable effects on the motor, depending on particular application requirements.

Long cable runs between the frequency inverter and the motor and fast switching times can contribute to the premature failure of a motor through bearing damage or insulation failure or other unacceptable phenomena such as power losses, high acoustic noise levels and parasitic earth currents.

The conventional solution is to fit a low-pass filter at the output terminals of the frequency - inverter which reduces the differential - mode interference (Symmetrical) to a smooth sinusoidal waveform with a ripple content of less than 5%.
However, there are some instances where this solution is inadequate, particularly in applications where there are common mode (asymmetric), high-frequency disturbances and the reliability of the motor is of utmost importance or the replacement of a motor would be expensive. Common-mode interference can cause capacitance coupling through the stator, rotor, bearings, frame and connected equipment which will cause pulsed currents to circulate.

There is a solution to this problem which involves the combined use of a conventional differential mode and a common-mode output filter made by REO Inductive Components. This eliminates the bearing damage caused by heat and pitting as a result of circulating, pulsing currents. There are other benefits as well:

- Unlimited cable lengths between the frequency inverter and motor can be used
- Higher switching frequencies > 8kHz can be used
- Audible noise is reduced
- Reduced cable and eddy current losses so a smaller drive may be employed (cost saving)
- Additional filtering on the mains supply side is not required if the inverter has an integrated filter
- Radiated interference from cables is reduced to a minimum
- Unshielded motor cable can be used (cost saving)
- Hazardous voltages and leakage currents are prevented

This is called the Sinus Filter Plus ++® – Type CNW 961

![Diagram showing the earth paths for high-frequency current passing through the motor bearings to the drive-shaft](image)

![Diagram of the Sinus Filter Plus ++®](image)
It can be seen from the diagram that the filter is connected back to the dc link and so provides a low impedance path to source for parasitic currents.

**Comparison of an ordinary Sinusoidal Filter and Sinus Filter Plus ++®**

![Diagram showing comparison between ordinary sinusoidal filter and Sinus Filter Plus ++®](image)

*Figure 4: Voltage traces taken between U - PE and V - PE*

As can be seen the conventional sinusoidal filter does not remove the common mode disturbance but the Sinus Filter Plus ++® does. It also reduces the RFI on the input side....

[www.reo.co.uk](http://www.reo.co.uk)
One typical application for the Sinus Filter Plus++® Filter is for protecting the bearings of an underground pump motor which is used in a combined geothermal/solar panel heating system.

The cable run from the frequency inverter to the pump is very long and the water column provides a low impedance path back to ground which encourages current pulsing through the motor bearings. To replace or repair the pump would be a very costly exercise.

A REO Sinus Filter Plus++® is connected to the output terminals of the frequency inverter to reduce the common-mode disturbances that would otherwise cause premature bearing failure.

The general EMC of the equipment is also greatly improved.

Bearing failure isn’t the only problem that can be solved by applying the Sinus Filter Plus++®. The diagram below shows a water abstraction bore hole. These are often sited in remote locations; in the middle of a forest for example, and the cable run to the pump motor is usually over a long distance.

The high-frequency common-mode disturbances flow back along the path of lowest impedance, to earth through the water pipe as shown in the diagram. One of the conditions of the abstraction license is that an accurate record is maintained of the water pumped out of the bore hole.

However, the high-frequency interference causes the metering equipment to give inaccurate measurements which are unacceptable. This problem can be solved by fitting a REO Sinus Filter Plus++®.

Another application where the Sinus Filter Plus++® can be helpful is when there are several motors connected in parallel to a single frequency drive, as in the case of a multi-storey car park for instance where several ventilation fans are driven for one inverter. Not only is the total cable run very long but there is also a good chance of capacitive coupling between cables.
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