REO

Power Quality For Variable Speed Drives

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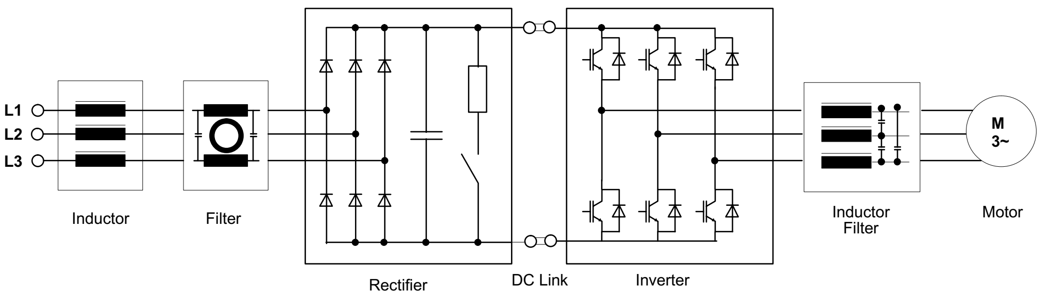
Introduction

This booklet gives an overview of some of the design, installation and operational issues involved in variable speed drives without going into an in-depth technical discussion. It is intended to help users, installers and sales personnel to understand the various problems associated with variable speed drives and the solutions to them. The filters, inductors and resistors can be specified during the design stages of the variable speed drive system without waiting until installation is complete and then having to iron out the problems.

Schematic of Typical Variable Speed Drive



The AC Variable Speed Drive explained

An AC variable speed drive (VSD) is an equipment which can control an Induction Motor at variable speed. Since the development of the Insulated Gate Bipolar Transistor (IGBT), a relatively small number of components are used in this equipment, resulting in an efficient and low cost product. Electronic component and system developments have enabled very accurate control of the three phase induction motor which is as good as, or better than, that previously only obtained with a DC motor drive system.

An induction motor will rotate at a speed corresponding to the frequency of the supply. If we want to vary the speed of the motor then we can vary the frequency of the supply to the motor. The VSD produces this fixed voltage variable frequency output by using an inverter.

If we look at the schematic on Page 1 we can see the various components of the VSD. The input stage is a 3 phase rectifier which rectifies the input supply to produce a DC link voltage. The VSD inverter produces a variable frequency output to supply the motor.

The VSD inverter is switched at a frequency, typically 8kHz, in a controlled pattern of variable width, known as pulse width modulation, (PWM). The VSD inverter is controlled in a pattern to produce a series of output pulses that average to a sine wave. The frequency of the sine wave output can be varied by changing the PWM pattern. There will be many other frequencies in the input and the output of the VSD which are multiples of the mains supply and inverter switching frequencies. The frequency of the sine wave that is the average of the output voltage, is what determines the rotational speed of the motor.

A Look at the Problems Caused by VSDs

The power conversion process of the VSD creates many problems at the input supply system and the output by introducing unwanted frequency components. There are corrective steps which can be taken to reduce these to an acceptable level, or to eliminate them. Excessive levels of these frequencies can lead to electromagnetic interference, (EMI).

EMI and Electromagnetic Compatibility, (EMC), are now subject to mandatory EU directives.

The performance of the motor is also affected in many ways:- overheating of the windings, insulation failure of the windings, and excessive mechanical vibration.

There are also problems introduced on the input supply by the harmonics. Some of the effects to consider are:- overheating of transformers and capacitors in the supply system, excessive currents in the neutral cable of a 3 phase supply system, interference with telecommunication equipment and incorrect operation of metering apparatus. Other considerations also apply such as voltage fluctuations introduced into the supply by the operation of the VSD, which will be troublesome for other users of the supply, including domestic users.

In the UK and EU there are restrictions which limit the harmonic current levels which can be taken from the supply, and with the ever increasing use of electronic equipment both for domestic and commercial applications, the need for these restrictions is becoming more important.

The VSD and its Environment

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We must consider the environmental conditions for the VSD equipment to ensure that it complies with the EU and UK standards.

The two applications to be considered in this booklet are 1) domestic, commercial or light-industrial LV power networks – where the LV mains power is shared with households or other organisations, and 2) Industrial LV power networks – where the LV mains power is derived from a high-voltage distribution transformer dedicated to a site owned by a single organisation.

The limits set by the various EU Standards for the emissions of mains harmonics, voltage fluctuation, and RF interference will depend on the classification of the VSD system.

The object of the EMC Directives is to ensure that the installations do not interfere with each other or the supply system. Also there are requirements to make the installations immune to some types of interference such as power supply voltage changes, short interruptions of supply, surges etc.

The Health and Safety at Work Act also applies and is mandatory.

To simplify the position the European Union is encouraging manufacturers to test their products to EMC standards and apply the CE mark, thus giving the user an indication that the product conforms with Directives and Standards. The CE mark, or a Declaration of Conformity, does not guarantee that a product is compliant with the EMC Directive. It is recommended that a product's technical documentation is checked to see whether there is confidence in compliance with the relevant Directives and their standards.

However, the CE mark will also be applied under the Low Voltage Directive relating to electrical safety.

The reasons for using Filters Inductors and Resistors

This booklet will discuss the use of filters, inductors and resistors to deal with many of the problems and compliance issues associated with VSDs. The VSD unit is supplied as a standard unit, or range of units, which will depend on the power rating of the machinery to be operated. The filters, inductors (sometimes called reactors) and resistors are also supplied as a standard range of units. Each application has its own requirements and characteristics. Therefore, it is more cost effective to use these devices to adapt to the application, rather than to design each VSD individually.

REO produces a range of these devices.

The mark CE translates to “**C**onformité **E**uropéene" which literally means "European Conformity”.

Electromagnetic Compatibility

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As the term implies, Electromagnetic Compatibility relates to the compatibility of the equipment with other equipment connected to the supply system and also its compatibility with the environment. The equipment must operate successfully in an electromagnetic environment, and also must not interfere with any equipment or installation in its neighbourhood. The terminology used for this is Electromagnetic Immunity and Electromagnetic Emissions.

With the ever increasing use of electronic appliances and power semiconductor equipment, the electromagnetic environment must be carefully controlled. To this end the EU has issued Directives which control the amount of emitted interference and set standards for susceptibility to interference.

Immunity

The equipment must be sufficiently immune to the electromagnetic disturbances that can exist in its operating environment. There are many disturbances which can influence the operation of equipment. These include high frequency disturbance such as electrostatic discharge (which can be caused by an operator touching the equipment), fast transient burst (typically high voltage transients on power and control inputs), radiated electromagnetic fields, conducting radio interference and surges. Low frequency disturbances include supply interruptions, supply voltage steps, phase imbalance and supply voltage harmonics.

Suitable levels of immunity are required for when there is poor power quality and also for conducted and radiated fields. REO have produced a series of EMC booklets relating to immunity phenomena and testing [1].

Emissions

VSD Emissions can be conducted and/or radiated, and can exist over the entire frequency range from almost DC to over 10GHz (10,000MHz). Conducted emissions below 2.5kHz can affect the supply system by causing large harmonic and interharmonic currents to flow – distorting the mains voltage waveform and possibly causing overheating and other problems.

Conducted emissions above 2.5kHz and all radiated emissions are generally considered to be electromagnetic disturbances that can have a bad effect on sensitive devices and circuits in equipment. At low frequencies radiated emissions generally appear as ‘stray’ electric or magnetic fields, but at higher frequencies they appear as electromagnetic fields with both electric and magnetic properties simultaneously.

Below 30MHz, civilian test standards for emissions generally only concern themselves with conducted measurements and limits – and above 30MHz they generally only concern radiated measurements and limits. In general, the EMC Directive's listed standards set no limits for frequencies between 2.5kHz and 150kHz, or above 1GHz, but compliance with the Directive's essential requirements (not to cause or suffer interference at any frequency) may mean applying additional test standards.

This booklet does not go into details about the various test standards for emissions. However REO have produced four detailed booklets on the phenomena and testing for conducted and radiated emissions, harmonics and flicker [1].

Below is a list of some of the present Emission Standards relating to electromagnetic compatibility which apply, and a brief description of each subject. This list is by no means exhaustive and advice should always be taken from a specialist. Standards with international acceptance are produced by the International Electrotechnical Commission, with prefix IEC. Standards listed under the EU's EMC Directive are European harmonised versions of IEC standards, and are prefixed with EN. IEC and EN standards are modified every few years to keep up to date with technical progress.

IEC 61800-3 and EN 61800-3 apply specifically to Variable Speed Drives.

Note that there are standards for individual equipments, which will set a limit to reduce interaction between those equipments installed on the same site, as in an industrial installation consisting of many loads, for example. There are also standards for a complete installation, which will limit interaction between that total installation and the electricity supply authority.

	Lower Frequency Harmonics	Higher Frequency Emissions	
	Mains Current	Conducted Emissions	Radiated Emissions
Frequency Range	0-2500Hz	150kHz-30MHz	30MHz-1GHz
Source of Interference	Harmonics in Input Current	High Frequency Switch of Output Inverter and other devices	Fast Rising Voltage Pulses of Output Inverter
Result of Interference	Overheating of supply conductors, transformers etc.	Interference with other Users on mains supply	Radiated Interference from VSD equipment and motor cables
Standards for individual VSD units in industrial environments	EN61800-3,EN 61000-3-2 up to 16A/phase, IEC 61000-3-12 upto 75A/phase	EN 61800-3, EN 61000-6-4	EN 61800-3, EN 61000-6-4
Standards for complete VSD systems	EN50160 (in(EU) G5/4 in UK EN61000-2-4	Refer to EN61800-3	Refer to EN61800-3
Standards for individual VSD units in domestic, commercial and light industrial environments	EN61800-3,EN 61000-3-2 up to 16A/phase, IEC 61000-3-12 upto 75A/phase	EN 61800-3, EN 61000-6-3	EN 61800-3, EN 61000-6-3

Harmonics, and Low Frequency Emissions

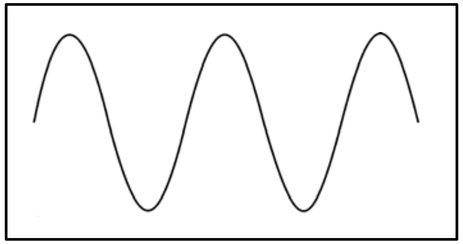
For the VSD we consider the harmonics which it produces in the supply which will interfere with other equipment connected to that supply.

The term Harmonic, or Harmonic Frequency, refers to a frequency which is an integral multiple of the fundamental frequency. In the case of the UK mains supply where the fundamental frequency is 50Hz, then the 3rd and 5th harmonics are 150Hz, and 250Hz respectively. If we look at the following diagrams, then we can see the results of adding up the fundamental and two lower magnitude harmonics.

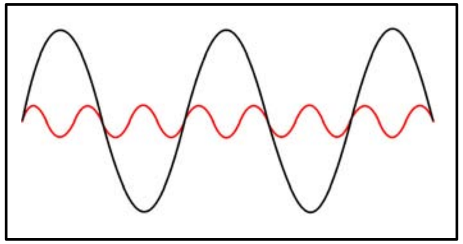
The Causes of Harmonics

Harmonic voltage distortion is proportional to the current consumption of non-linear devices, such as transformers, welding equipment and power electronic devices which include domestic appliances and industrial machinery. Many electrical loads are non-linear: their instantaneous current consumption does not vary directly with voltage. This non-linearity of current will distort the voltage at the supply point, since every supply has its own impedance.

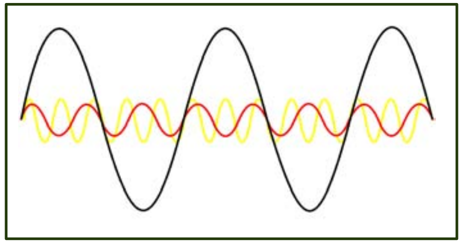
The harmonics produced by non-linear loads are odd multiples. Even harmonics are produced by loads which have a DC component, such as asymmetrical rectifiers. The regulations controlling the production of even harmonics are stricter than those for odd harmonics, as they can disturb power supply transformers.



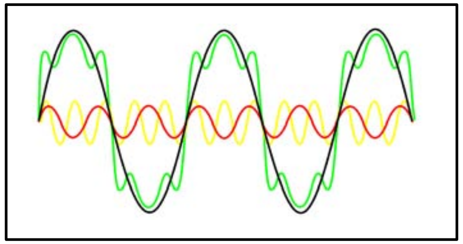
Take a 50Hz sine wave



Add some third harmonic



Add some fifth harmonic



The result is a distorted sinwave (shown in green)

Standards and Regulations on Harmonics

The regulations for complete installations are in place to limit the harmonic voltage distortion caused by loads on the supply system. The internationally agreed limit is 8%. A target level of 5% is therefore set, to allow margins due to short term fluctuations in loading.

The regulations set the maximum levels of harmonics that are permitted to be emitted into the supply, at what is known as the Point of Common Connection (PCC). The PCC is the point at which an installation, and all of the equipment it contains, is connected to the public supply. These rules appear complex at first, but they are logical because the PCC is where the total of the harmonic emissions from all of the equipment in one user’s installation will affect other users

Equipment with a current rating of up to 16A per phase must satisfy the requirements of EN61000-3-2 [1] to be connected without assessment. Single equipments between 16A and 75A are recommended to comply with the requirements of IEC 61000-3-12, which may soon be listed under the EMC Directive as EN 61000-3-12. Neither EN 61000-3-2 or IEC 61000-3-12 apply to industrial power networks (that are supplied from a dedicated HV transformer) but since it is good practice not to pollute industrial networks with harmonics we recommend that they are applied anyway. There are other limits for connection to 11kV systems, depending on their input rectifier configuration. Without going in to further detail, the UK supply regulation G5/4 sets limits on the levels of harmonics at frequencies up to 2500Hz, or the 50th harmonic. After this frequency the harmonics are no longer considered to be a threat. The VSD manufacturer will give information on the levels of harmonics drawn by his equipment. When the limits for a total installation are exceeded, then an assessment must be made.

It is recommended that technical documentation is created to demonstrate that an installation complies with the requirements of the EMC Directive, and in the UK with the requirements of G5/4 for harmonics. The second edition of the EMC Directive (2004/108/EC) will make such documentation mandatory for new ‘fixed’ installations (and maybe for modified ‘fixed’ installations too) from July 2007 – so it is a good idea to get some practice in beforehand.

Standards on Flicker

Rapid acceleration and deceleration of VSDs can cause fluctuations and flicker in the mains supply voltage. Emissions of supply voltage fluctuations and flicker are covered by EN61000-3-3 for up to 16A/phase with unconditional connection, and EN 61000-3-11 for up to 75A/phase with conditional connection. Both of these standards are listed under the EMC Directive [1].

High Frequency Emissions, the IGBT and dv/dt

The main causes of emissions problems from VSDs are the power input and motor connections. Most of the problems they cause are conducted ones at frequencies below 100MHz, usually dealt with by filtering at the input, and filtering and/or shielding the motor cable.

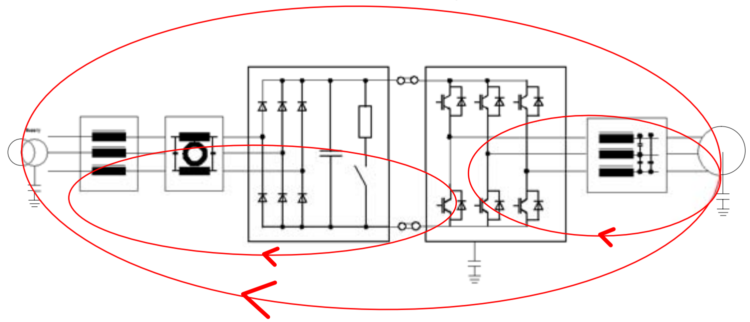
But radiated emissions problems can also occur, caused by the cables and also by the VSD itself. These are usually dealt with by shielding the cabinet the VSD is installed in. When using cabinet shielding, the locations and grounding of VSD filters and the terminations of any motor cable shields are very important, so as not to destroy the cabinet's shielding effect [2].

One of the advantages of the IGBT is that it produces low heat losses by having a fast switching time and low conduction heat losses. The faster the switching time the lower the switching heat losses. The problem with the fast switching time is that it produces a high dv/dt at its output. The typical turn on and turn off time for an IGBT is 0.5 microseconds, or less. Therefore if switching a voltage of 500V the dv/dt will be at least 1000V/microsecond.

The high dv/dt in the output of the VSD will produce a current in the stray capacitance of the motor cables, and more importantly in the stray capacitance of the motor windings. This is called 'common-mode current' and it creates common-mode interference.

In order to minimise the common-mode interference and other types of interference, there are many installation guidelines. The important points of these will be outlined later in this booklet. Correctly-terminated screened cables providing a return path for the common-mode current through the screen will minimise this interference, at the output of the VSD, but it will not prevent it from reaching back to the supply without further measures. If the common-mode current flows in the supply it will cause Radio Frequency Interference, (RFI). Refer to the diagram below.

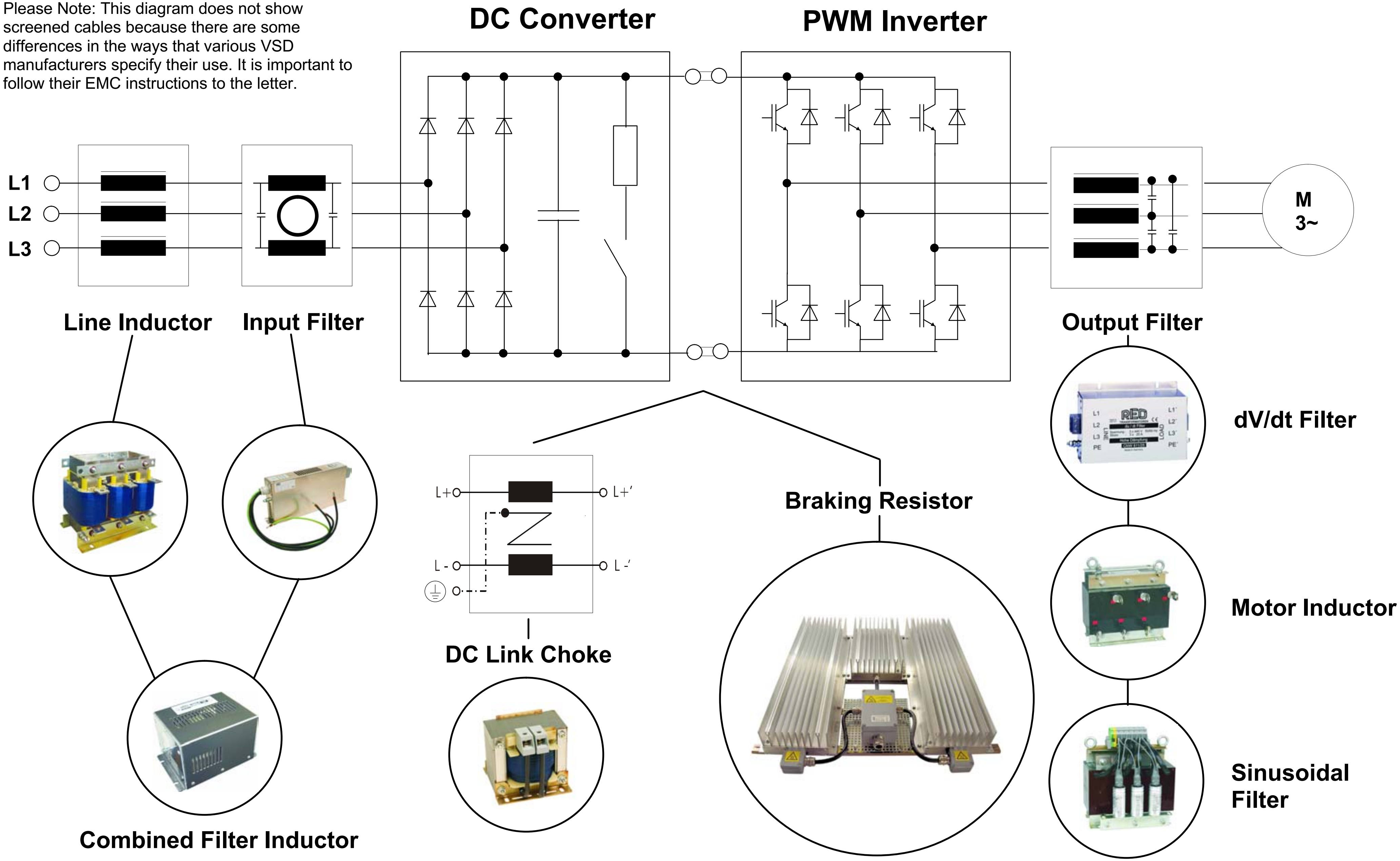
The motor cables have a distributed capacitance and inductance and effectively become a series of LC circuits. The longer the cables, the larger these parameters become. The motor itself has distributed inductance and capacitance in its windings. At high dv/dt these capacitances and inductances cause the voltage at the motor terminals to be significantly higher than that at the VSD's output terminals, increasing the stresses on the insulation. At high levels of dv/dt, not only is the insulation between the windings and earth important, but also between individual conductors. So, high dv/dt can result in a partial discharge in the insulation of the motor cables and motor, which would produce a slow degradation of the insulation.



High frequency common-mode emission routes through stray capacitance to earth

A range of typical components supplied by REO to the Drives Industry

Please Note: This diagram does not show screened cables because there are some differences in the ways that various VSD manufacturers specify their use. It is important to follow their EMC instructions to the letter.



Filters and inductors are used to correct the unwanted effects of the VSD on the mains supply and the electromagnetic environment, and also prevent interference from other equipment connected to the supply. Inductors also store energy, which, in combination with the DC link capacitor, helps to maintain the supply in the event of small fluctuations of the voltage. The choice of whether to use one filter to protect all equipments in an installation, or to have a filter on each equipment will be determined by cost, but less interference between each will be obtained by using individual filters.

Reduction of Input Harmonics

The three phase rectifier bridge shown at the input circuit in the diagram on page 1 of this booklet is known as a 6-pulse system and will draw harmonics currents from the supply. This is because the rectifiers are only conducting at the peaks of the voltage waveform. There are 6 pulses per cycle, and the harmonics typically produced are 5th, 7th, 11th, 13th and so on. Some manufacturers produce VSDs which use 12 or 24 pulse rectifiers and have lower levels of harmonic currents.

An example of the voltage and current waveform at the input of a VSD is shown in the figures on page 13. By connecting an inductor in series with the input to the VSD, a reduction in the peak value and smoothing out of the current waveform is obtained. The resulting smoothed current waveform improves the power factor, gives lower levels of harmonics, and so helps in meeting the requirements of G5/4. This is because the inductor has a higher impedance to the higher harmonics. The disadvantage is that it is also an impedance to the fundamental 50Hz frequency. The inductance values must be kept to a level at which their voltage drop at 50Hz is no more than 2% to 4% of the phase-neutral supply voltage, so as not to have significant effect on the motor at full load. The line input inductor gives a substantial improvement in lower powered VSDs which have only small inductance included in the DC link. An improvement is also obtained in higher powered VSDs.

There are instruments known as Spectrum Analysers which can give measurements of the current (and voltage) harmonics produced on the supply. A specialist will use these instruments and will assess the harmonics to advise on the correct level of inductance to be used.

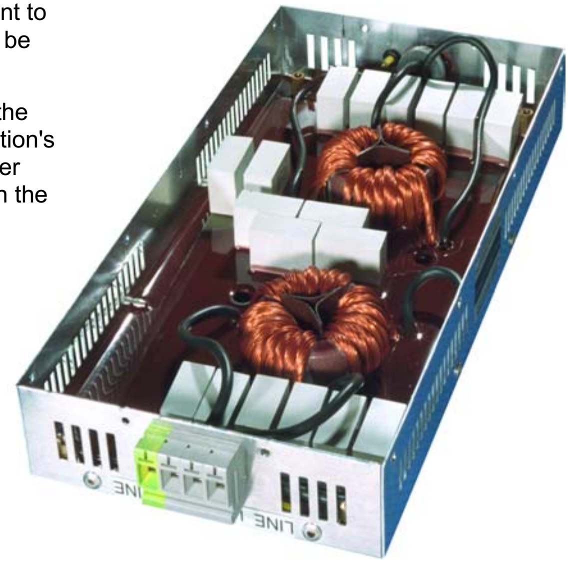
Reduction of EMI and RFI

As described earlier, the switching frequency of the inverter and the high dV/dt rates of its switching devices cause high frequency noises to be emitted into the mains power supply. These could interfere with other equipment connected to the same power distribution network, or radiate from the power cables and interfere with radio receivers or other sensitive equipment. Two types of emissions exist: differential-mode (between the individual power conductors) and common-mode (between the power conductors and the cabinet's earth). Input filters are carefully designed to suppress both types of emissions, using inductors wound to create either differential or common-mode impedances; 'X' capacitors connected between the power conductors themselves, and 'Y' capacitors between each of the power conductors and the earth.

EMC filters are generally chosen to individual system requirements and an important consideration is their insertion loss, which relates to the attenuation of the unwanted frequencies.

When installing an EMC filter the leakage current must be taken into account for safety reasons. The 'Y' capacitors conduct current to earth, the amount of current depending on their value. Some electrical installations have earth leakage detection circuits connected and they will interrupt the supply if this leakage value is exceeded. The permissible level of earth leakage varies according to the type of appliance and its method of connection to the supply; levels vary from 0.25mA for small double-insulated appliances, to very much higher for industrial equipment. Because the filter is conducting current to earth the enclosure for the filter must be securely earthed for safety.

Care should be taken to ensure that the leakage current relates to the application's safety requirements. The manufacturer will state the leakage current value on the filter's rating label.



Typical EMC filter from REO, opened to show capacitors and chokes

Figure 1

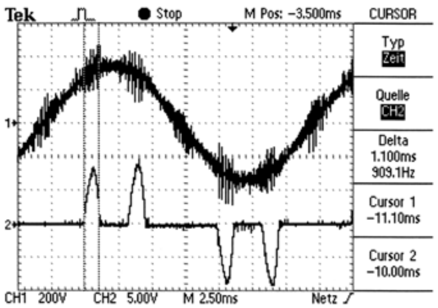


Figure 2

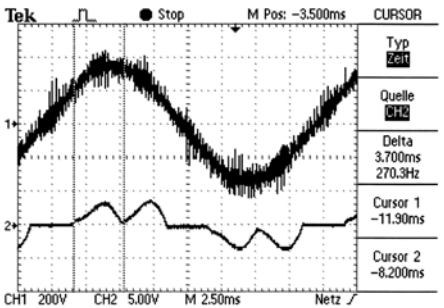
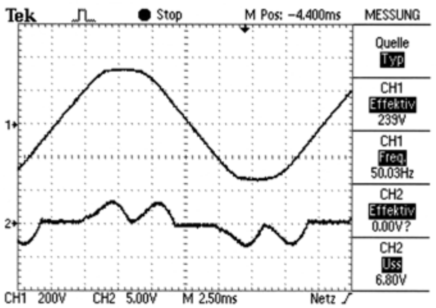


Figure 3



Figures 1 to 3: The oscilloscope traces show the effects on the 50Hz sine wave of introducing a line reactor and a combined filter and reactor.

Figure 1 shows the oscilloscope trace of the original output with a 7.7A RMS and 24.5A peak.

Figure 2 shows the effects of the introduction of a 4% impedance line reactor which reduces RMS to 4.8A and gives a peak of 9.5A.

Figure 3 shows the effects of a combined filter and reactor which produces a clean voltage sine wave, as well as reducing the current distortion.

Below: The CNW307, a typical motor choke and mains filter combination unit from REO.

Surge Protection

An overvoltage protection device is advisable to protect the VSD from line voltage surges which may be caused by other power equipment or by a lightning. The REO 703, as an example, is a fast-acting device which diverts high voltage transients to earth.

Filters on the Output of the VSD

The problem with high dv/dt caused by the rapid switching of the IGBT has been previously described in this booklet.

Output filters can reduce the dv/dt applied to the motor cable and motor, and can help reduce or eliminate emissions and insulation problems. There choice will depend upon a number of factors:-

- The length of the cable run to the motor
- The switching frequency of the inverter
- The insulation standard of the motor
- The use of screened cables
- EMC requirements
- Cost

The 3-phase power supply cables running to the motor are usually screened. This helps to reduce radiated common-mode emissions by allowing the high frequency component of the current to return through the screen back to the VSD. A correctly-terminated motor cable shield [2] provides a preferential return current path for the common-mode current, rather than allowing it to return as leakage through the external ground structure. This helps reduce the radiation from the conductors.

The motor must be securely connected to earth through a high integrity connection. One of the reasons for this, aside from EMC considerations, is electrical safety. If the connection is broken, or not present, then the motor will present an electrical shock hazard due to leakage current through the windings, or in an extreme case, due to a winding insulation failure. This must be taken into consideration when deciding on the earth cabling route to the motor. A secure connection to earth is also required at the VSD for similar safety reasons.

The difficulty with the screened cable is that its capacitance, between conductor and screen, increases with cable length. The choice of filter will be determined by the cable length: the longer the cable, the higher the peak voltage and the dv/dt will be present at the motor terminals and also the higher the cable charging current.

The dv/dt Filter Inductor

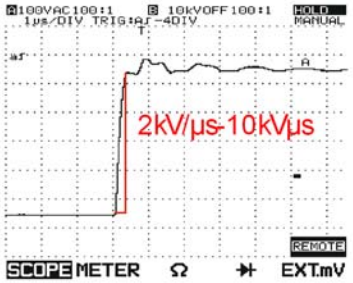
The dv/dt filter inductor is an inductor specially constructed, wound on a toroidal ferrite core. This acts as a conductor to the symmetrical components of the current, since in a 3-phase system these balance out to zero.

The high frequency components however do not balance out. These are known as asymmetric components. The toroidal inductor acts as a high impedance to these components. This slows down the voltage rise rate, or dv/dt. The illustration shows a typical reduction in dv/dt obtained using the REO type CNW 811 series of inductors.

The dv/dt Attenuating Filter

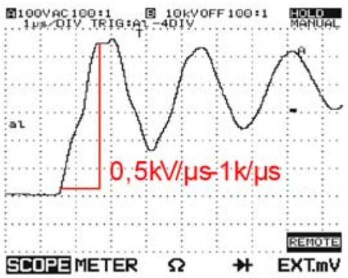
The VSD may be installed as a retrofit to an existing installation using motors with standard insulation, i.e. not insulated for use with VSDs. In this case the dv/dt must be reduced to up to 500V/µs, to comply with the specifications IEC 34-17, or VDE 0530.

Without dV/dt Filter



Voltage rise 2 - 10 kV/µs
Measured with 100m of motor cable

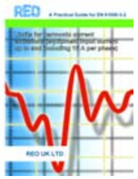
With dV/dt Filter

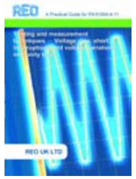


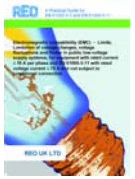
Voltage rise 0.5 - 1 kV/µs
Measured with 100m of motor cable

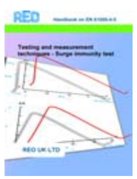
REO have published a series of mini guides relating to EN standards that are called up by Directives or are required for immunity testing. These can be downloaded from the REO website at www.reo.co.uk or hard copies can be sent on request by phone or email.


Magnetic Field


Harmonics


Sags & Dips


Flicker


Surges


Conducted RFI

Cable Length Limitations

The limitation in the ferrite core type inductor is that it produces heat in the process of filtering. The core may overheat, or saturate, if the high frequency currents are large. The currents will increase with cable length: the longer the cable, the more capacitance. Therefore the ferrite core inductor/ filter is limited in its application to cable lengths of up to 100-150 metres.

3-Phase Output Inductor

For longer cable runs of up to 200 metres to the motor a conventionally constructed three phase output inductor can be used. The CNW 854/ series of inductors are designed to provide inductance values required over a wide frequency range. As with the input inductor, they also act as an impedance to the fundamental frequency and should be chosen carefully. Their inductance values must be kept to a level at which the voltage drop at 50Hz is no more than 2% of the VSD output's phase-neutral, so as not to have significant effect on the performance of the motor at full load. The cable length between the drive and motor depends on the switch frequncy - see the table below.

Converter switching frequency	up to 16 kHz	up to 8 kHz	up to 4 kHz
Max. allowable cable length	50 m	150 m	200 m

The Sinus Filter

The Sinus Filter, if applied correctly, can reduce many of the problems caused by the VSD output PWM voltage waveform, particularly when using long cable runs.

The Sinus filter, or Sinusoidal Filter, uses inductance and capacitance to filter out the higher frequencies produced, thus reducing the effects of capacitance and inductance in long cable runs to the motor. In some cases the need for screened cables to the motor is eliminated. The voltage waveform supplying the motor is almost sinusoidal with low distortion. The REO CNW 933/ series of Sinus Filters covers a widerange of current ratings. The Sinus Filter should be chosen carefully as it produces a permanent load on the VSD and also reduces the output voltage to the motor. These filters produce heat and can run at temperatures higher than 85°C. Adequate ventilation is required.

Example of a Sinusoidal Filter from REO

As described at the beginning of this booklet, the VSD control unit is usually supplied as a standardised equipment, or range of equipments. The REO range of filters and inductors are produced to help adapt the VSD control unit to a wide range of applications.

Braking Resistors

The VSD is generally thought of as producing power to the motor to drive a load, i.e. positive torque. However the drive can also produce a negative torque, acting as a brake. This is useful when the drive is being used in a lift, or a crane, for example.

When the motor is used as a braking force it generates power back into the supply. If we look at the diagram on page 1, we can see that the power will be returned to the DC link and can go no further as it is blocked by the rectifier unit. This will result in an increase in voltage on the DC link. A resistor connected to the link absorbs this power and prevents the increase in voltage. The resistor current is controlled by a DC chopper unit which increases or decreases the current level into the resistor according to the link voltage, i.e. the braking power produced by the motor.

The ohmic value of the resistor is chosen to balance the DC link voltage with the maximum braking current produced by the motor. The DC chopper will regulate the voltage for variations in the required motor braking current and in the process the resistor will heat up. Therefore the power rating of the resistor must be estimated. The power rating of the resistor is given by a duty cycle estimate, i.e. time on and time off.

In many VSD units the braking resistor switch is built in, and the terminations are provided for installation of the resistor. However, if the switch control unit is not supplied, then a separate panel must be installed.

The choice of resistor is made by its ohmic value, its power dissipation and its cooling requirements. REO manufacture a wide range of braking resistors with various mounting and cooling arrangements, and special designs can be produced.

Some examples of REO braking resistors

The REOUNITY range of modules fit all the components mentioned in this mini guide into a modular bookcase-style assembly for ease of installation in a VSD panel system. This range of modules is in the process of development and the existing range covers from 6kW to 15kW.

Installation Guidelines

The installation procedures for Variable Speed Drives and power electronic systems in general are now well established and well documented in various manuals and publications. A summary of the important points is given below.

EMC precautions

- Observe procedures for EMC
- Segregate power and control cables
- Segregate earth points for power and control cables
- Filters should be fitted near to the drive unit and earthed to the drive metal plate
- Use screened motor cables to prevent emissions from these cables and route them together to cancel out their magnetic fields
- Clamp the cable screens to the motor frame and drive frame, avoiding use of “pigtails”

Environment and Climatic considerations

Allow adequate space for cooling of devices. This is important if the drive is to be installed in a clean area where the control cubicle is sealed.

Ratings

Take into account the peak voltages and currents for rating components, not only RMS levels. Ensure that the filters will achieve the necessary attenuation at the required frequencies.

Safety

- Safety overrules all other measures
- Ensure good bonding to earth. Do not loop safety earth connections. Use a common connection point.
- Ensure that there is no unauthorised access to live terminals. Cubicles must be locked to prevent unauthorised access.
- Ensure that hot surfaces, e.g., inductors, braking resistors, etc., are guarded.
- Fit safety warning labels to warn of live terminals, hot surfaces, strong magnetic fields etc.

The installation process can be simplified if all of the add-on filters, inductors and resistors can be incorporated into one module. The complete drive package is then fully compliant with EMC requirements, dv/dt filtering, mains harmonic reduction, power factor correction and braking energy dissipation, and requires only input and output cable connections.

References

[1] REO mini guides EN61000-3-11 Power-frequency magnetic field immunity test; EN61000-3-2 Limits for harmonic current emissions; EN61000-4-5 Surge immunity test; EN 61000-3-3 and EN61000-3-11 Flicker; EN 61000-4-11 Voltage dips, short interruptions and voltage variations immunity tests; EN 55022 and EN 55011 Measuring radiated emissions and EN 61000-4-6 (the first seven of a series of seventeen books to be printed by REO).

[2] Chapters 6, 7 and 8 of "EMC Systems and Installations", by Tim Willians and Keith Armstrong, Newnes 2000, ISNB 0-7506-4167-3, RS Components Part No. 377-6463.

Another useful source of information is the series on "EMC for Systems and Installations" by Keith Armstrong published in the EMC & Compliance Journal, http://www.compliance-club.com/keith_armstrong.asp