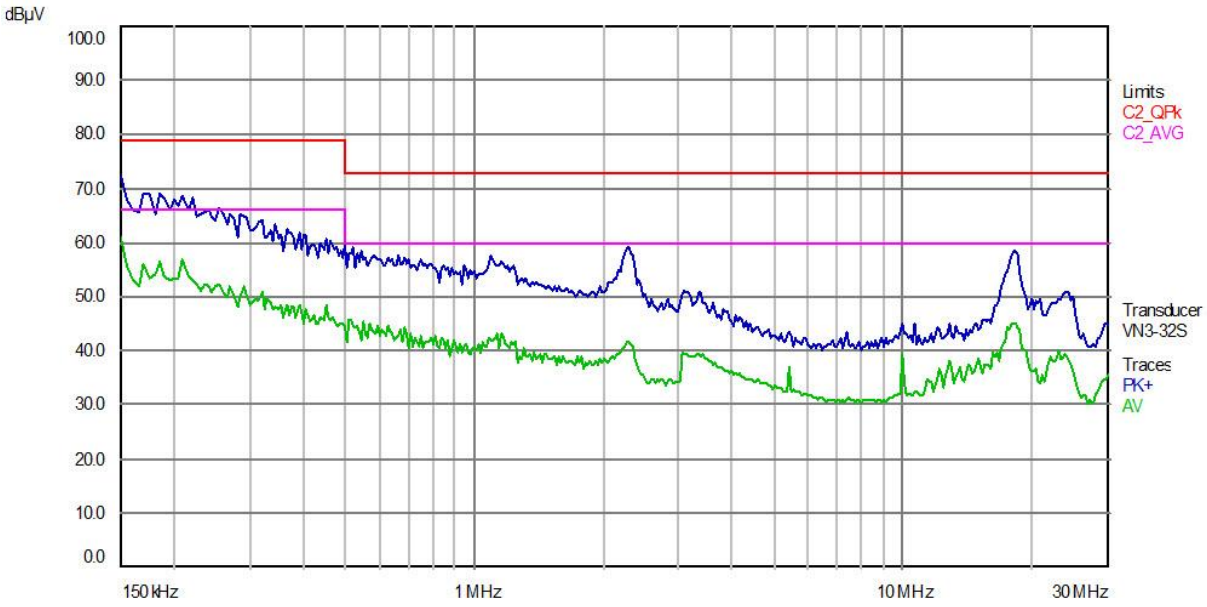
PowerXL™

DA1, DC1, DG1 Variable Frequency Drives and DE1 Variable Speed Starters

Electromagnetic Compatibility (EMC)



Level 1	1 – Fundamental – No previous experience necessary 2 – Basic – Basic knowledge recommended 3 – Advanced – Reasonable knowledge required 4 – Expert – Good experience recommended

Powering Business Worldwide

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Contents

Danger! - Dangerous electrical voltage!

- Disconnect the power supply of the device.
- Ensure that devices cannot be accidentally restarted.
- Verify isolation from the supply.
- Cover or enclose any adjacent live components.
- Follow the engineering instructions (AWA/IL) for the device concerned.
- Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/system.
- Before installation and before touching the device ensure that you are free of electrostatic charge.
- The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization. The system installer is responsible for implementing this connection.
- Connecting cables and signal lines should be installed so that inductive or capacitive interference does not impair the automatic control functions.
- Suitable safety hardware and software measures should be implemented for the I/O interface so that an open circuit on the signal side does not result in undefined states.
- Deviations of the mains voltage from the rated value must not exceed the tolerance limits given in the specification, otherwise this may cause malfunction and/or dangerous operation.
- Emergency stop devices complying with IEC/EN 60204-1 must be effective in all operating modes. Unlatching of the emergency-stop devices must not cause a restart.
- Devices that are designed for mounting in housings or control cabinets must only be operated and controlled after they have been properly installed and with the housing closed.
- Wherever faults may cause injury or material damage, external measures must be implemented to ensure a safe operating state in the event of a fault or malfunction (e.g. by means of separate limit switches, mechanical interlocks etc.).
- Frequency inverters and variable speed starters may have hot surfaces during and immediately after operation.
- Removal of the required covers, improper installation or incorrect operation of motor or frequency inverter / variable speed starter may destroy the device and may lead to serious injury or damage.
- The applicable national safety regulations and accident prevention recommendations must be applied to all work carried on live frequency inverters / variable speed starters.
- The electrical installation must be carried out in accordance with the relevant electrical regulations (e. g. with regard to cable cross sections, fuses, PE).
- Transport, installation, commissioning and maintenance work must be carried out only by qualified personnel (IEC 60364, HD 384 and national occupational safety regulations).
- Installations containing frequency inverters / variable speed starters must be provided with additional monitoring and protective devices in accordance with the applicable safety regulations. Modifications to the frequency inverters / variable speed starters using the operating software are permitted.
- All covers and doors must be kept closed during operation.
- To reduce the hazards for people or equipment, the user must include in the machine design measures that restrict the consequences of a malfunction or failure of the frequency inverter / variable speed starter (increased motor speed or sudden standstill of motor). These measures include: – Other independent devices for monitoring safety related variables (speed, travel, end positions etc.). – Electrical or non-electrical system-wide measures (electrical or mechanical interlocks). – Never touch live parts or cable connections of the frequency inverter after it has been disconnected from the power supply. Due to the charge in the capacitors, these parts may still be alive after disconnection. Consider appropriate warning signs.

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1 General

Drive systems with variable speed offer many advantages in applications, starting from the more flexible production possibilities, higher accuracy of the goods produced up to considerable energy savings e.g. at fans and pumps. The speed variation of induction motors requires a conversion from a supply network with constant voltage and frequency to a new one with variable voltage and variable frequency. This is done by means of variable frequency drives and variable speed starters.

The mains supply voltage is rectified, the energy is stored in the d.c. link of the device and the inverter chops the d.c. voltage in a way, that a signal with variable voltage and variable frequency is available at the output. Due to the principle used, nonsinusoidal signals with a certain content of higher frequencies are generated. Default filtering measures lead to a certain interference suppression, but also generate unwanted parasitic effects like leakage currents…

There is no constellation of measures available, which, on one hand, remove the unwanted effects, but which is also energy efficient (= no / low losses), has a small volume and an acceptable price at the same time.

The default measures inside modern variable speed starters and variable frequency drives are a compromise, enable conformity to standards and cover the most relevant range of applications. It should not be concealed, that the use of variable speed drive systems require additional measures to ensure reliable operation as well as conformity to standards.

These effects are for example:

- A device trips due to long motor cables.
- The motor cable is longer than the specified maximum length to keep the limits of a certain EMC category (C1…C3 according EN 61800-3).
- The motor is not qualified for inverter operation
    - The generated voltage peaks at the motor terminals are higher than permitted for the motor.
    - The non-fundamental losses inside the motor lead to a thermal overload.
    - The motor generates noise.
    - Bearing currents arise.
- Shielded cables are necessary to keep conformity to EMC standards. There are some cases, where the use of a shielded motor cable is not possible.
- When connected to the public network: the harmonics on the mains side are higher than specified by the standard.

The reasons for these unwanted effects can mostly be found in the field of electromagnetic compatibility (EMC). In most cases they are caused by

- conducted emissions
- radiated emissions
- distortion of the mains voltage because of harmonics
- leakage currents generated by filtering measures or the shield of the motor cable
- reflections on the motor cable because of the inverter output voltage

This application note has not to be understood as a science-based document. It should enable the reader to understand the correlations in the field of EMC. It describes the phenomena and the required mitigation measures to deal with them. However, much more important is the statement, that the user can/must take preventive measures to create an EMC-compatible system. This is a basic condition to reduce the unwanted effects and also necessary for the effectiveness of additional measures, which are possibly required.

2 EMC-compatible setup – an important preventive measure

For many users the electromagnetic compatibility is something like the “mystical part of the electro-technology”.

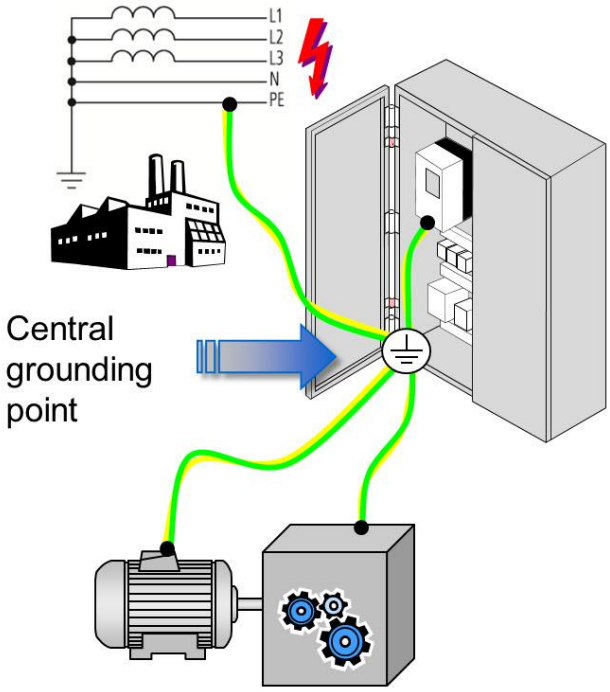
- The effects are verifiable.
- They can only be measured badly.
- Even systems, which are built according to the same drawings, show different behavior.
- ……

At a first glance this sounds quite unlikely and is based on the fact, that there are higher frequencies in voltage and current involved, which influence the behavior of the drive system. One is well advised to consider the principle of an EMC compatible setup, to exclude possible parasitic effects from the very beginning, or at least to reduce them.

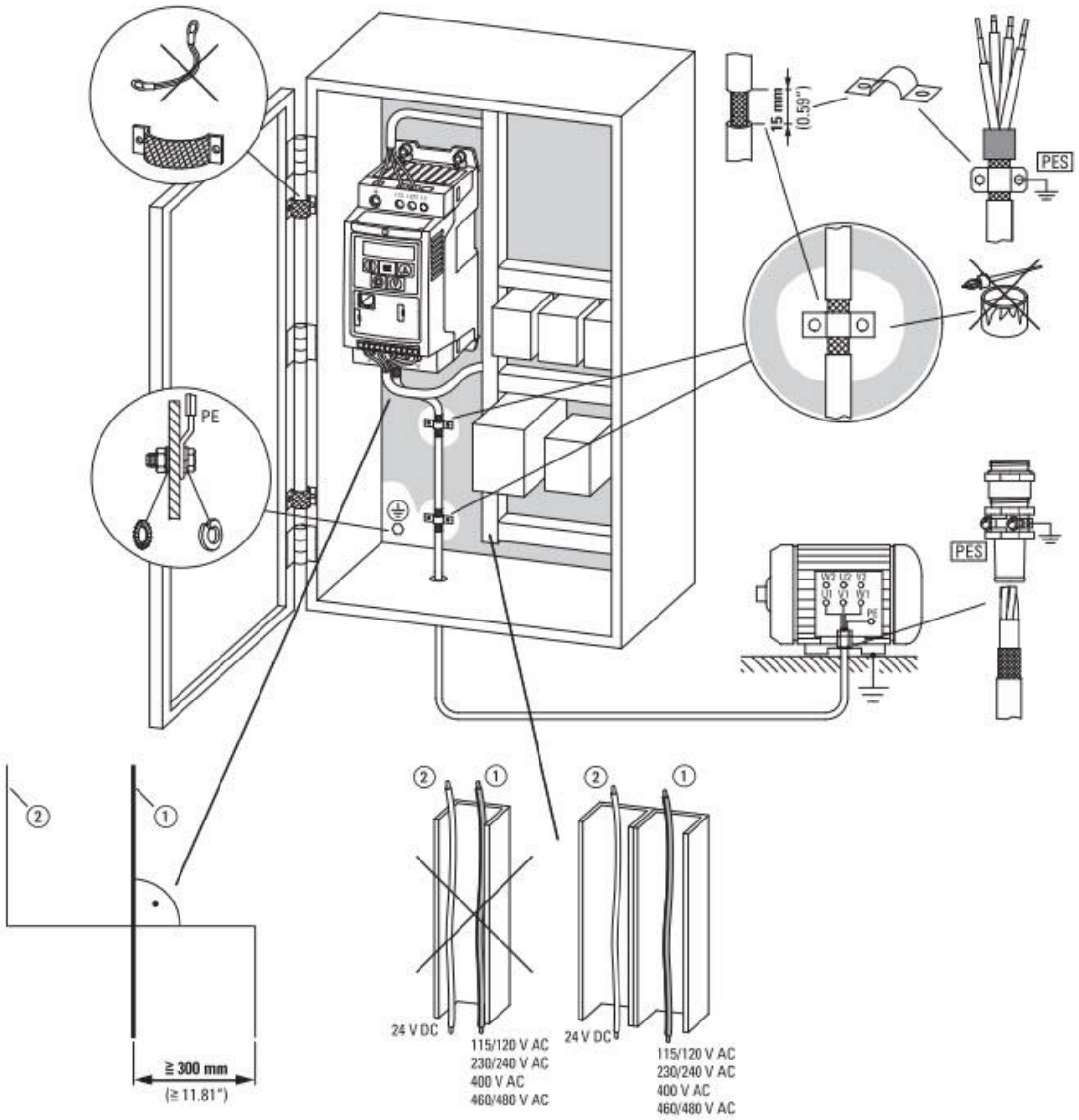
2.1 Grounding connections

A proper setup of the grounding system is the alpha and the omega of EMC. The following must be considered:

- The grounding inside a control cabinet must be done at one point only.
- The cross section of the earth conductor in the mains connection must be as least as big as the one of the phase conductors. Recommendation: $\geq$ 10 mm²
- The devices to be grounded must be connected to one single grounding point (like a star). Looping the earth connector from device to device is not allowed.
- The ground loop impedance must correspond to the effective local requirements.

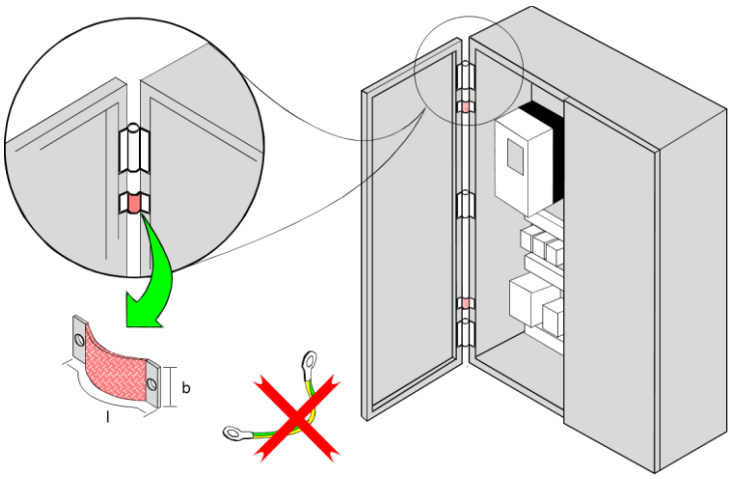


2.1.1 Overview

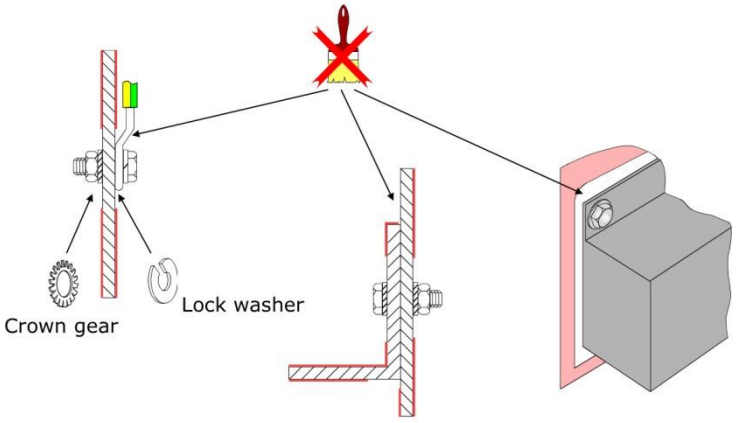


2.1.2 Setup of the control cabinet

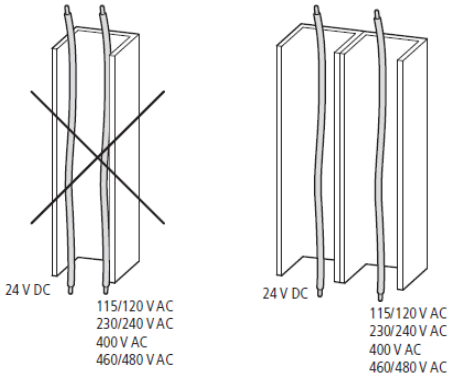
A control cabinet made out of metal offers an additional shielding of radiated emissions in the range of 10 dB µV.



The earth connection between the control cabinet itself and the door should be done with an earthing strap (ratio between length and width; l / b < 3) and not with a normal conductor to discharge disturbances of higher frequencies.



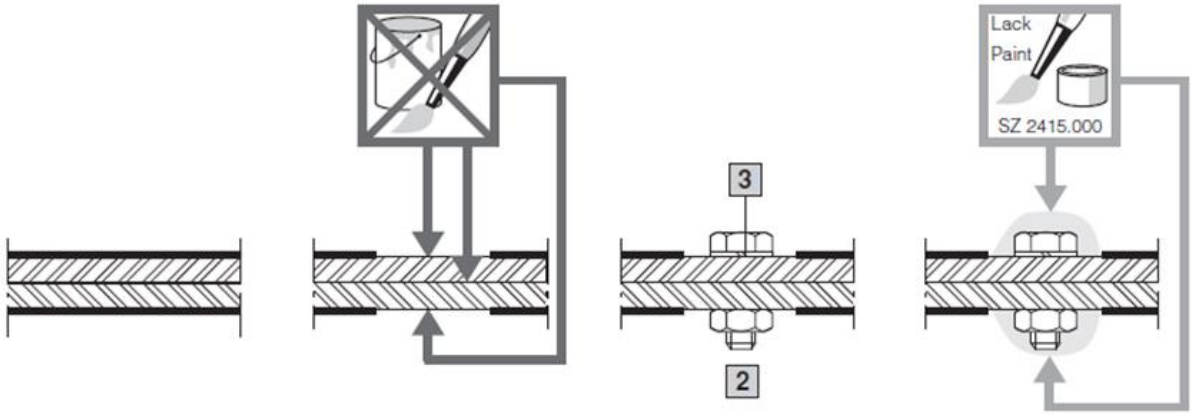
The mounting plate used should preferably NOT be painted or coated. However in cases, where the mounting plate is painted or coated, the paint and coat has to be removed at places, where it is necessary for EMC reasons to ensure an extensive metal contact.



Power cables and control cables have to be located in different cable ducts, where the mains supply cable and the motor cable of variable speed starters and variable frequency drives have to be separated too, to avoid a coupling of disturbances between these two cables. Where necessary, power cables and control cables should be crossed in a rectangular way (90 °) to avoid paralleling of cables as much as possible.

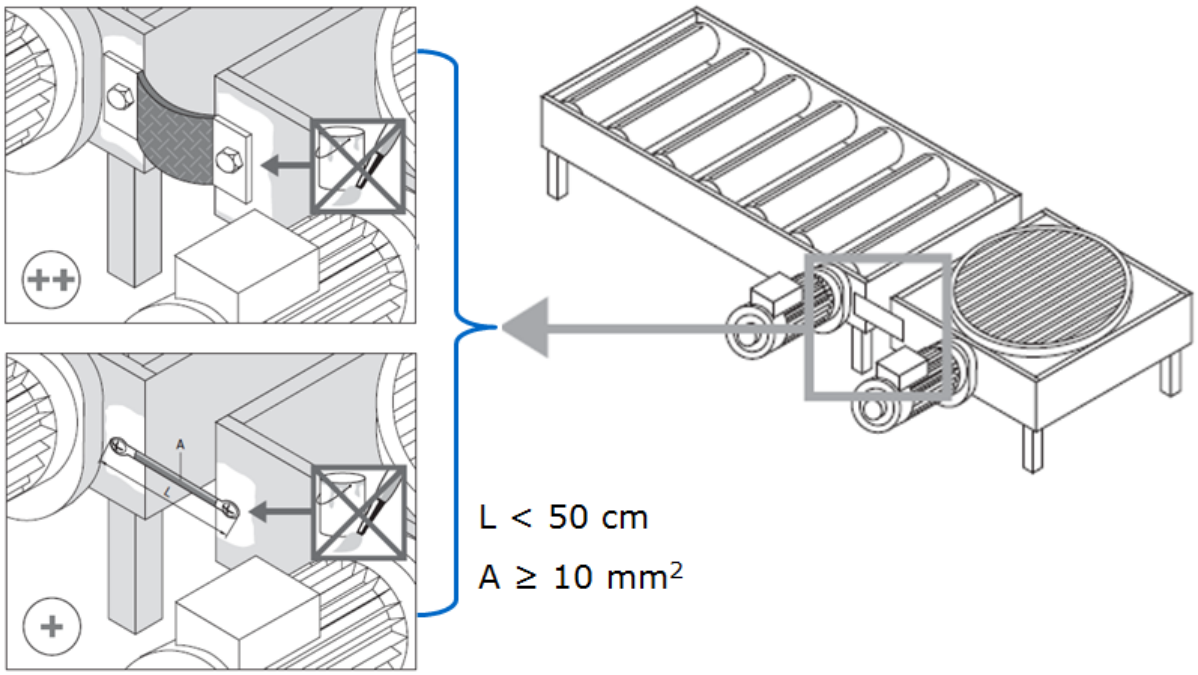
2.1.3 Installation

The parts of the machine itself must also be included into the EMC examination. Also here: have an extensive area of metal contact to keep the contact resistance as small as possible.



Picture: Rittal

The single parts of the machine have preferably to be connected with copper straps. In case wires are used instead of straps, these must not be longer than 50 cm and their cross section shall not be less than 10 mm² in copper. The respective area at the machine MUST be free from paint and coating.

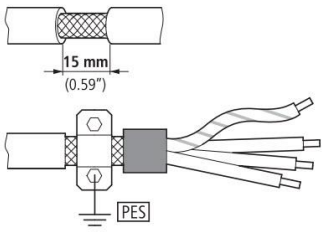


Picture: Rittal

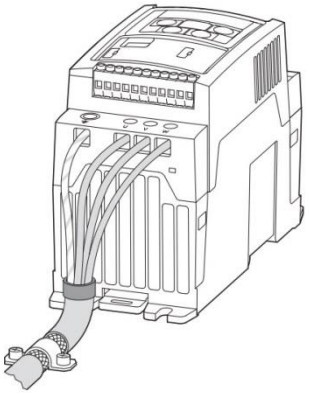
2.2 Screening of cables

2.2.1 Motor cables

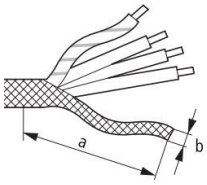
Due to the principle used, variable speed starters and variable frequency drives emit disturbances. To limit the disturbances locally and to prevent influences between devices, the motor cable has to be screened and grounded on both ends. Most important is the way, how the grounding is done and the selection of the right type of motor cable.



To achieve a large scale grounding of the screen, the insulation of the motor cable has to be peeled on a length of about 15 mm. The use of a respective cable clamp enables a 360° grounding of the screen. The grounding should be done in a short distance to the variable speed starter respectively the variable frequency drive and also inside the motor terminal board.



The cable screen should have a grommet at the end to prevent a fan out of the screen. On one hand it is reasonable from the EMC point of view and prevents on the other hand an unintended short circuit respectively ground loops.



In practice it is usual, to twist the ends of the cable screen and to ground this twisted end, instead of using a clamp as described above. From an EMC point of view this has to be prevented. Local circumstances sometimes do not allow the optimal solution and one has to fall back to the twisted end (pigtail) for grounding. In this case, the length “a” of the pigtail should be as short as possible and the cross section “b” as large as possible. Rule of thumb: $b \geq 1/5\ a$.

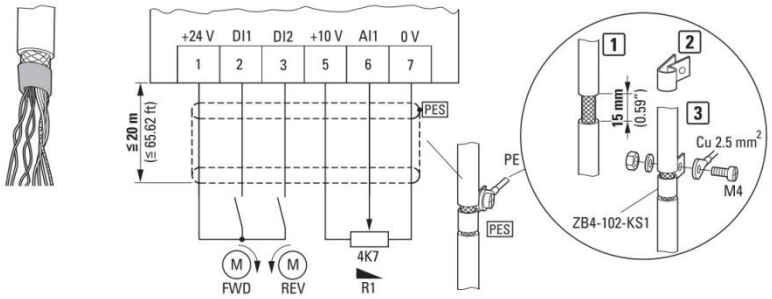
The type of the used motor cable plays an important role. The cable manufacturer, e.g. Helu or Lapp, offer special types for the use in variable speed drive systems. They should have a shield coverage of at least 80 % to ensure a good shielding, also for radiated emissions.

2.2.2 Control wiring

Other than with the motor cable, the control wires are screened not because of emissions, but for immunity reasons. Disturbances coming from outside should not influence the control signals. In a “normal” environment it is thinkable to resign on the screening of short control wires, because the inputs of the control filter most disturbances. Nevertheless we recommend a screening and in in two cases it is mandatory to use screened control wires:

- In a polluted environment with a high level of EMC disturbances
- In cases where EMC category C1 according EN 61800-3 is required (see 3.2)

The screen is grounded on one side near the variable speed starter respectively variable frequency drive. The statement given in chapter “Motor cables” concerning the use of “pigtails” applies also here: prevent them as much as possible and in case you have to use them: keep them short.

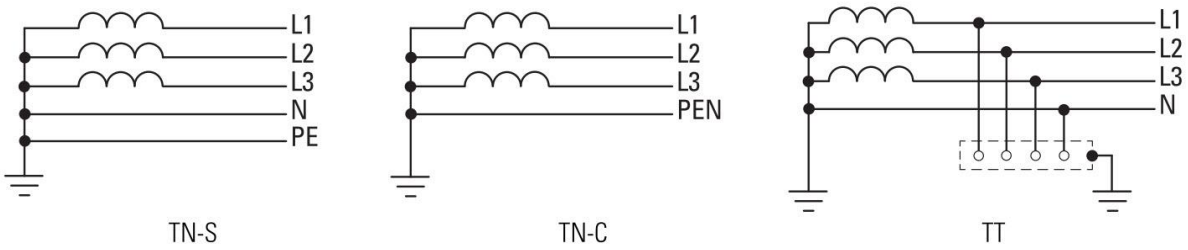


Example for the connection of control wiring to a variable frequency drive of the series DC1

2.3 The mains supply

2.3.1 Configuration of the supply network

Variable speed starters and variable frequency drives may only be operated at supply networks in which the star point is earthed (TN-S, TN-C, TT). The effectiveness of filters incorporated into the devices is only given with one of the mentioned configurations, because the components convey the interference current to ground.



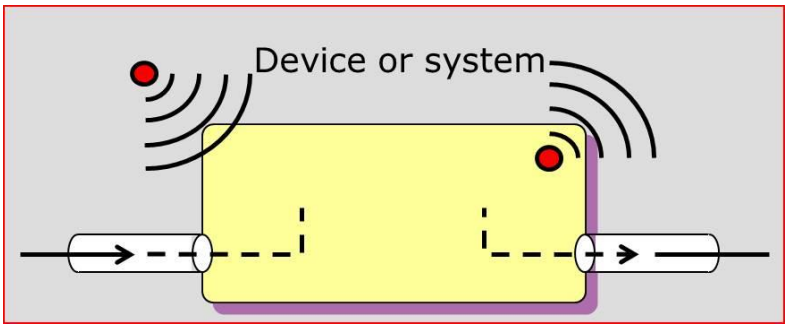
At variable speed starters of the series DE1 and many series of variable frequency drives the connection of the filter to ground can be disconnected by removing jumpers or screws. This possibility is used, when the devices are connected to an ungrounded network (IT network). It has to be noted, that the effectiveness of the filtering is much reduced. The connection to an IT network is one of the criteria to use the EMC category C4 according IEC/EN 61800-3. This category does not require to keep certain emission limits. It is necessary to set up an EMC plan, where it is laid down, how it can be achieved that other devices are not disturbed by the operation of a variable speed drive system (see also 3.2).

2.3.2 Connected to an emergency generator

In some applications, e.g. in hospitals, it can be necessary to operate variable speed drive systems also in case of mains power failure. In this case the supply is commuted to an emergency generator. Such generator should be loaded symmetrically. This means to avoid the connection of single phase devices as much as possible. Because of the higher impedance compared to the normal supply network the harmonics generated by variable speed starters and variable frequency drives on the supply side have a stronger impact. It has to be noted, that only a certain percentage of the generator's load may be nonlinear loads like variable speed starters of variable frequency drives. As a guideline one can assume a percentage of 20 %, and in case mains chokes are used, something more up to about 30 %.

3 EMC from directives' and standards' point of view

Electromagnetic compatibility means the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to other equipment in that environment.



Picture: ZVEI

Beside a reliable operation the conformity to standards and directives is an important topic of the electromagnetic compatibility.

The declaration of conformity with the EMC Regulation 2014/30/EU can be based on:

- the conformity to standards listed in the Official Journal of the EC under the EMC directive (e.g. EN 61800-3 for PDS (PDS = Power Drive System))
- a declaration of a „Competent Body"
- a self certification, laid down in a technical construction file, where the risk assessment and the test results have to be documented.

Non-compliance is culpable.

3.1 Which EMC standard is the right one for my application?

There are different hierarchical levels of standards

- Application related standards
  - Describe application specific requirements
- Product related standards (Product standards)
  - Describe product specific requirements
- Generic standards describe phenomena in general
  - They are used, where no product standard and application related standard exists.
  - Product standards and application related standards very often refer to generic standards.

The priority is as follows:

- 1st priority: Application related standard
- 2nd priority: Product standard
- 3rd priority: Generic standard

Does an application related standard exist (e.g. for lifts or a special kind of machine?)

- YES → Use application related standard
- NO → Check for product standard

Does a product standard exist?

- YES → Use product standard
- NO → Use generic standard

The EMC product standard for variable speed drives is IEC/EN 61800-3. This standard follows a system approach and takes the complete Power Drive System (PDS) from the power supply to the motor shaft into account. At the end the user is responsible for the compliance with the EMC Directive. Background is, that a proper installation (cabling etc.) from the EMC point of view is of essential importance and the manufacturer of variable frequency drives and variable speed starters has a much limited influence on that. However, the device manufacturer is obliged to state inside the documentation, which measures are necessary in normal cases (typical PDS), to permit a compliant operation.

In practice the installer or user of the machine or system keeps the guideline of the manufacturer but doesn't do EMC measurements on site. In many cases this isn't possible in a senseful way, because also disturbances coming from other parts of the installation are measured.

An exception from this kind of approach are small machines, which are sold as standard ones and where the location, where they are operated, is not known at the time of production. In this case an EMC test in a test laboratory is performed. In many cases this type of machines has small dimensions, which allow a measurement inside a test chamber, what is not possible with larger installations.

Variable speed starters and variable frequency drives are built and tested according to IEC/ EN 61800-3.

3.2 Which limits are decisive for me?

Inside the standards different limits for emission as well as for immunity exist, which have to be kept. The values to be used depend on the power supply network the device is connected to.

Public mains

- low emissions required
- low immunity accepted

Industrial mains (own mid voltage transformer):

- higher emission values accepted
- higher immunity required

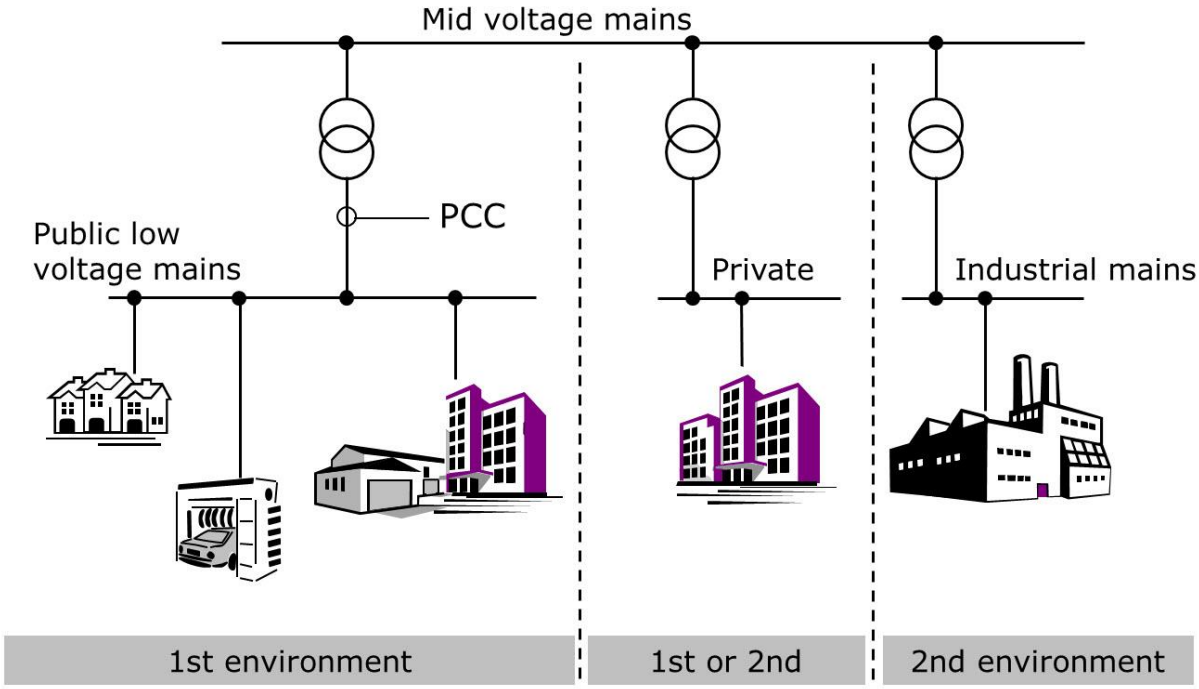
In cases, where the device is operated at the public mains as was as at the industrial one, this means:

- low emissions
- high immunity

The following statements refer to IEC/EN 61800-3, the product standard for variable speed drive systems-

Definitions according IEC/EN 61800-3:

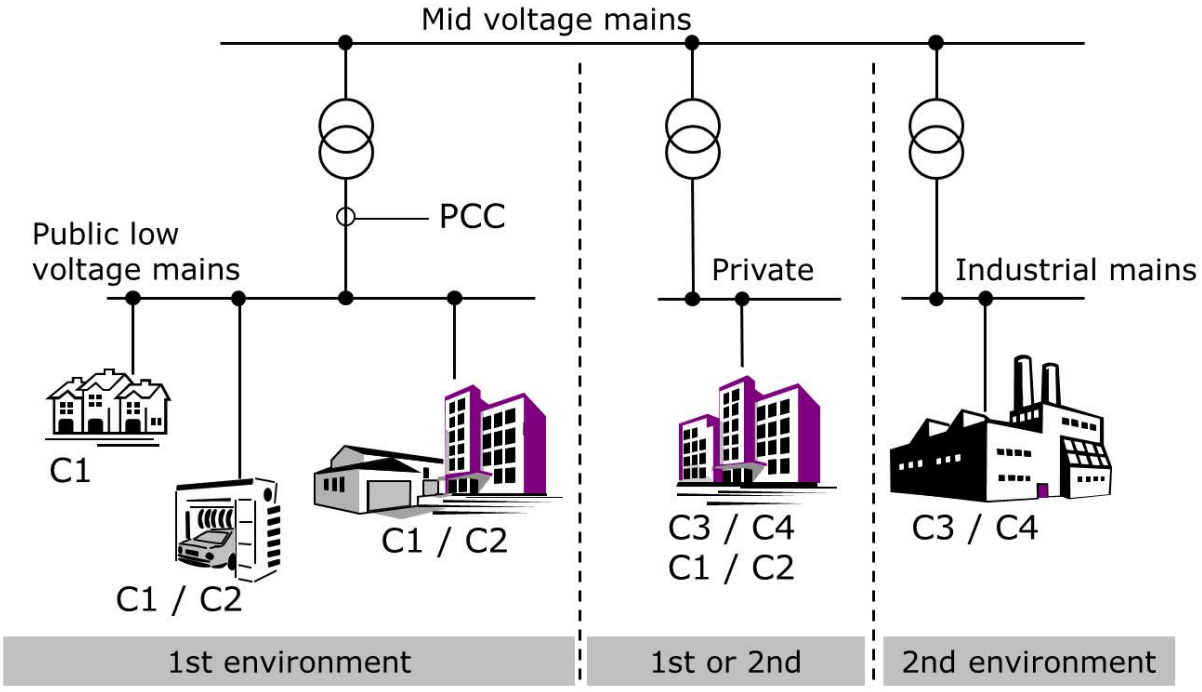
- First environment
  - Environment that includes domestic premises, it also includes establishments directly connected without intermediate transformers to a low-voltage power supply network which supplies buildings used for domestic purposes.
- Second environment
  - Environment that includes all establishments other than those directly connected to a low-voltage power supply network which supplies buildings used for domestic purposes. (own mid voltage transformer)
- Private power supply network
  - A private network is characterized by its own mid voltage transformer. It doesn‘t supply domestic premises. Typically a private network supplies administration buildings, office buildings, shopping centers etc. It is up to the operator to decide if the network will be performed according first or second environment.



The minimum requirements concerning immunity and the permitted emission limits are divided into the categories C1 … C4. Their application depends on the environment.

Definitions according IEC/EN 61800-3:

- PDS (Power Drive System) of category C1
  - PDS of rated voltage less than 1000 V, intended for use in the 1st environment
- PDS of category C2
  - PDS in 1st environment, fulfilling all following criteria
    - Rated voltage less than 1000 V
    - No plug in device
    - No movable device
    - Intended to be installed and commissioned by an EMC professional only
  - Warning necessary („In a domestic environment, this product may cause radio interference, in which case supplementary mitigation measures may be required.“)
- PDS of category C3
  - PDS of rated voltage less than 1000 V, intended for use in the second environment and not intended for use in the first environment.
  - Warning necessary („This type of PDS is not intended to be used on a low-voltage public network, which supplies domestic premises. Radio interference is expected if used on such a network.“)
- PDS of category C4
  - PDS intended to be connected in the second environment fulfilling at least one of the following criteria:
    - Voltage above 1000 V
    - Current above 400 A
    - Connected to IT-networks (isolated from earth or connected with high impedance)
    - Where required dynamic performance will be limited as a result of filtering
  - An EMC plan has to be set up.



Some resulting take aways:

- Devices, which are connected to the mains with plug and socket ("Schukoplug") are assigned to category C1. In addition the leakage current (touch current) must not be higher than 3.5 mA AC respectively 10 mA DC. Background is, that the devices are moveable and one doesn't know at which location they are used. Most likely they are operated by laymen. To use category C2 at a public mains, the installation has to be done by an EMC professional, who can take mitigation measures in cases, where the C2 limit values lead to disturbances at other devices. The costs are borne by the user.
- Smaller handicraft and industrial enterprises very often don't have an own mid voltage transformer. In this case the emission limits of category C2 are allowed as a maximum.
- Under certain conditions category C4 may be used at the industrial mains. It has to be noted, that anm EMC plan has to be set up. Examples can be found in the annex of the standard IEC/EN 61800-3

How does Eaton treat the different environments?

- Immunity
    - The immunity of Eaton's variable speed starters and variable frequency drives is generally suitable for industrial environment and therefore also sufficient for a connection to the public mains.
- Emissions
    - The level of emissions depends amongst others on the length of the motor cable. There is different information about the maximum motor cable length available, depending on the EMC category. For example: the permissible length for category C1 is shorter than for category C3, because the maximum emission level at public mains is lower than at industrial ones.
    - If the maximum cable length stated inside the technical data is not sufficient, the length can be extended by the use of external EMI filters. In this case the internal filter has to be deactivated (remove screws or jumpers, which connect the internal filter with ground potential).

BUT:

It has always to be checked, if an application related standard exists, which requires other (more strict) limits. The following table compares the limits for conducted emissions of IEC/EN 61800-3 with the ones of the generic standard EN 55011.

	EN 61800-3 (= IEC 61800-3)	EN 55011 (= IEC/CISPR 11)
Public mains	C1 (correlates with EN 55011, Class B)	Class B
	C2 (correlates with EN 55011, Class A, Group 1)	
Industry	C3 (correlates with EN 55011, Class A, Group 2)	Class A, Group 1
	C4 (EMC-Plan)	

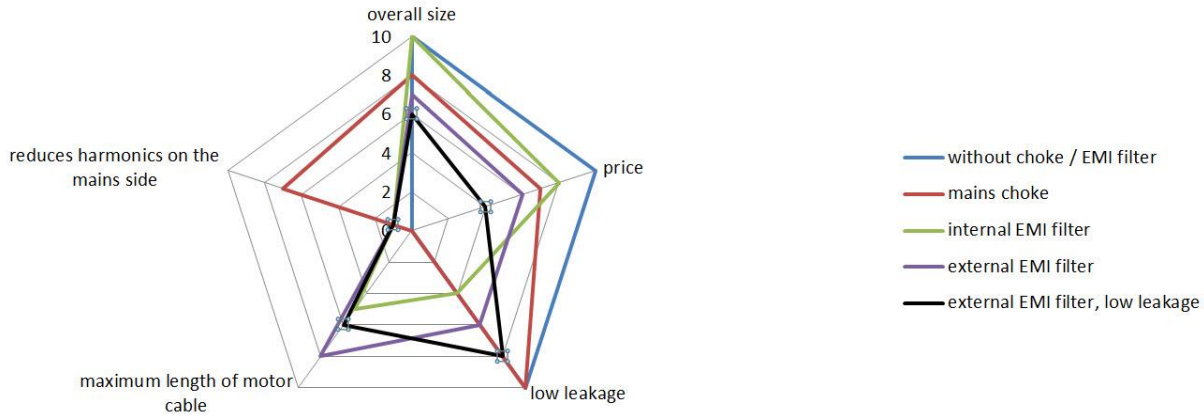
4 When are additional EMC measures required / reasonable?

In chapter 1 cases are described, in which additional measures have to be taken to achieve a higher reliability of the system or to become conformal to standards or directives. The components used, mostly do nor influence only one phenomenon.

The diagrams below illustrate the effectiveness of the single measure. They are scaled from 0 to 10, where “10” is always the best ranking.

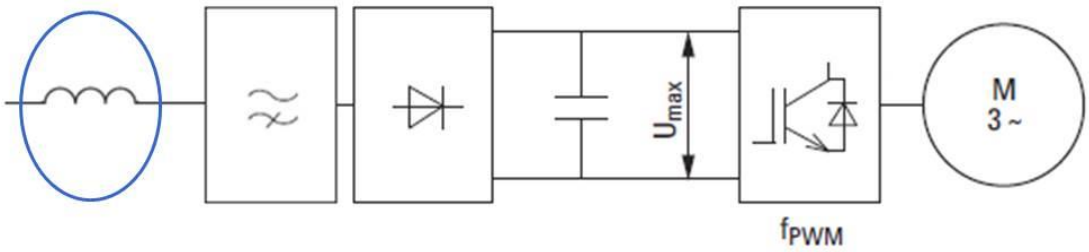
Hint: inside the category “Price” “10” means the lowest price.

4.1 Measures on the mains side



4.1.1 Mains choke

As the name implies, mains chokes are located on the mains side of variable speed starters and variable frequency drives. (Eaton-Type: DX-LN…)



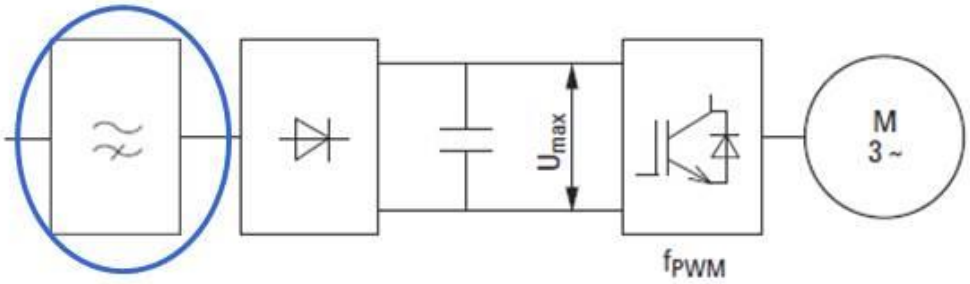
Achievements when using a mains choke:

- Reduction of the current harmonics on the mains side (perturbation). Range: up to 30 %
- Protection of the variable speed starter / variable frequency drive against over voltages in the mains
- Increase in life time of variable speed starter / variable frequency drive (DC link capacitors) and of switchgear on the mains side by limiting current peaks.

The dimensioning is done according to the input current of the devices. In many cases, data of the supply network (short circuit capability, inductance…) at the installation site are not known. In practice a value of 2.5 … 4 % for u_k is proved. A choke inside the DC link fulfills the same purpose but doesn’t protect against over voltages on the mains side.

4.1.2 EMC filters

EMC filters reduce the conducted emissions, which predominantly occur because of the chopper principle of the inverter. They are located on the mains side.



The level of emissions depends on different factors, for example on the length of the motor cable. The expenditure for the filter increases with the length of the motor cable. In many cases the devices have internal filter. They are designed to be sufficient for a plurality of applications. The maximum length of the motor cable, which can be achieved with an internal filter and compliance to the standards and directives at the same time, depend on the EMC category respectively the location.

When a longer motor cable is needed, an external filter is used (DX-EMC…). In these cases devices without internal filters are used to prevent interactions between internal and external EMC filter. If the used device has an internal filter, the filter has to be deactivated by unscrewing the EMC screw or removing the jumpers. Guidelines can be found inside the manual for the respective device line.

The following table shows the maximum length of the motor cable with compliance to the EMC categories C1…C3 for conducted emission according IEC/EN 61800-3 (screened motor cable). The values shall show, what the influence of an external filter can be. The real values have to be taken from the respective user manuals. They depend on the type of filter used, the rating of the device and if the filter is one with a low leakage current, which leads to a reduction of the possible cable length.

Device line	internal filter			external filter		
	C1[1)]	C2	C3	C1	C2	C3
DE1	5 m	10 m	25 m	5 … 50 m	25 … 100 m	50 … 100 m
DC1	1 m	5 m	25 m	5 … 25 m	25 … 100 m	50 … 150 m
DA1	1 m	5 m	25 m	5 … 25 m	25 … 75 m	50 … 75 m
DG1	-	10 m	50 m	5 … 25 m	25 … 50 m	50 … 75 m

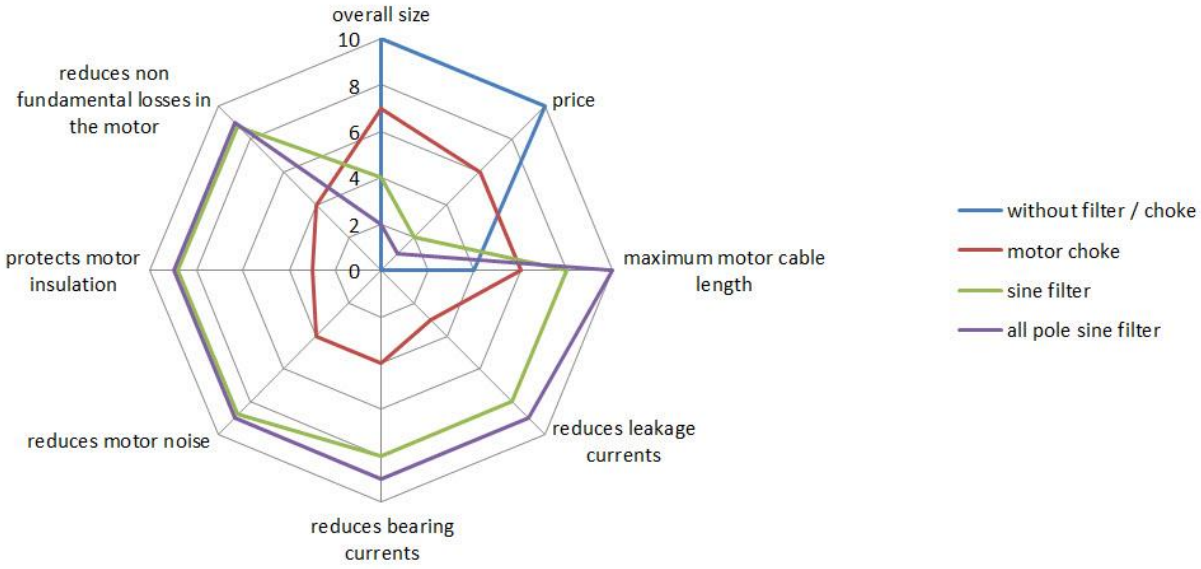
1) With single phase supply voltage only

In most cases EMC filters lead the interference current via capacitors to ground and generate leakage currents. It has to be noted, that in case of a plug and socket connection (“Schukoplug”) to supply variable speed starters and variable frequency drives from the mains, the leakage current (touch current) may not be higher than 3.5 mA AC or 10 mA DC (IEC/EN 61800-5-1 and IEC/EN 62477-1). A connector for industrial use according IEC 60309 (CE plug) is seen as a fixed connection. If the leakage current is too high, it can be reduced by using an external EMC filter with low leakage current (DX-EMC…L).

Hint: EMC filters are designed in a way, that there is only a low leakage current flowing to ground during normal operation. The leakage current is increased if there is an imbalance of voltages in the supply (e.g. 230 V and 225 V against Neutral) and in case the contacts of a switching element on the

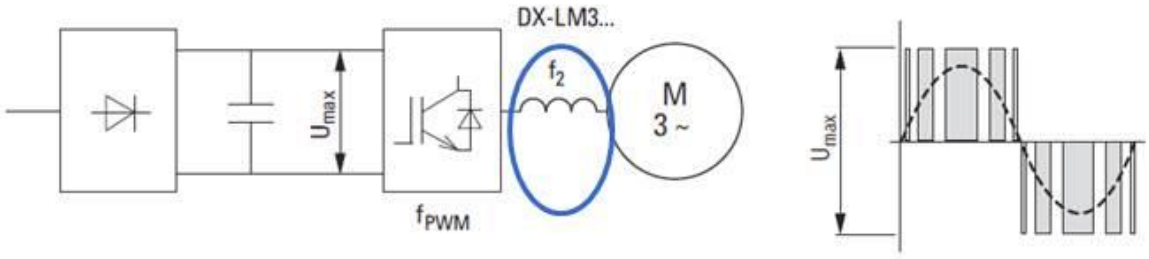
mains side (e.g. cam switch or contactor) do not open or close simultaneously. This can also lead to a trip of an RCD located upstream.

4.2 Measures on the motor side



4.2.1 Motor choke

Variable speed starter and variable frequency drives use the fast switching PWM technology to generate voltage and frequency at the output of the devices. The fast switching operations in connection with long motor cables may lead to reflections, which can reach three times the value of the output voltage with very short rise times. Motor chokes, also called output chokes, help to reduce the voltage peaks and to extend the rise time. They reduce the motor stress (additional losses, bearing currents, noise) and prevent a damage of the isolation.



The use of motor chokes is recommended,

- when the connected motor is not suitable for a direct connection to a variable speed starter or a variable frequency drive
- when a motor cable with a high capacity is used
- in case multiple motors are connected in parallel at the output of one device
- in case the length of the motor cable exceeds the one stated inside the manual of the respective device (see table under 4.1.2) or 150 % of this value in case of unshielded motor cable.

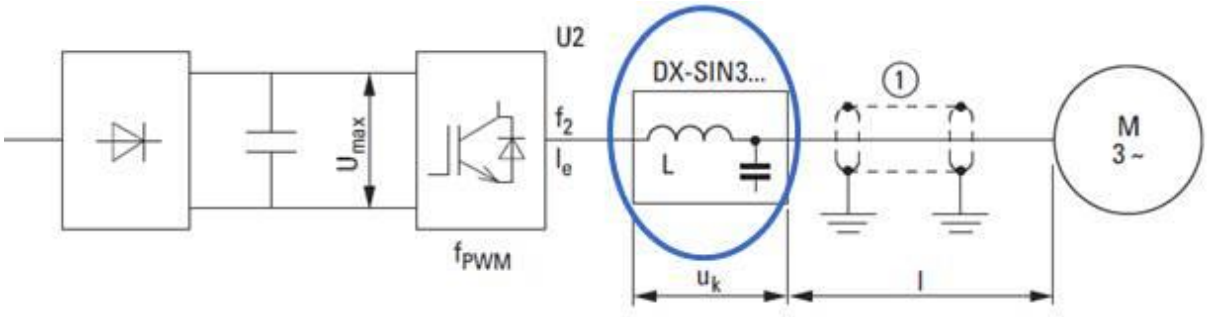
By using a motor choke the length can be extended up to 200 % of the stated one for shielded cables or in case of an unshielded cable up to 300 %.

- Note: with a motor choke and an unshielded motor cable it is not possible to achieve conformity to the categories C1…C3 according IEC/EN 61800-3!

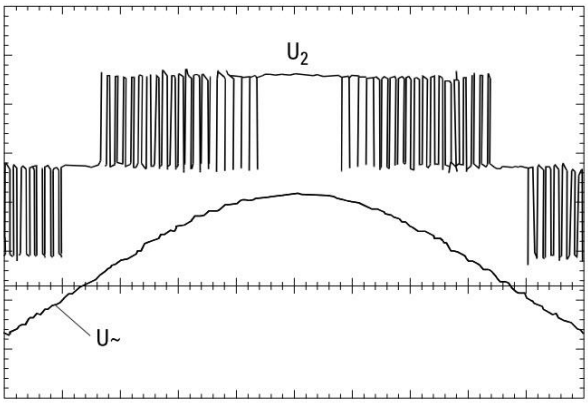
Example for a device, in whose manual a 25 m length for a shielded cable is given:

- 25 m shielded cable
- 37.5 m unshielded cable (= 150 % of 25 m)
- 50 m shielded cable with a motor choke
- 75 m unshielded cable with a motor choke

4.2.2 Sine filter



Sine filters detract the higher frequencies of the output voltage signal U_2 at variable frequency drives. Because of the filtering, the voltage at the output of the sine filter is almost sinusoidal with a typical superimposed ripple of 5…10 %.



Working principle of a sine filter:

Voltage U_2 at the output of the variable frequency drive

Voltage U~ after the sine filter (= motor voltage)

The use of sine filters

- reduces the peak voltage, which may occur because of reflections on long motor cables, which can damage the motor isolation.
- reduces the leakage currents due to the capacity of the motor cable.
- enables the use of longer motor cables without a trip of the device
- reduces bearing currents and noise inside the motor generated by the switching frequency

Note:

- When using sine filters, a voltage drop at the filter in the range of 5…10 % of the motor nominal voltage can be anticipated
- Additional losses inside the filter are partly compensated by the reduced motor losses. In general a 5 % increase of the current can be estimated. This has to be taken into account when selecting the right variable frequency drive.
- Sine filters may not be used in connection with variable speed starters of the DE1 series and variable frequency drives of the DC1 series (exception: DC1…E1).

There are two different types of sine filters

- (normal) sine filters, filtering the differential mode disturbances only
- all pole sine filters, which filter differential mode as well as common mode disturbances.

	sine filter (DX-SIN3…)	all pole sine filter (DX-SIN3…A)
filters differential mode disturbanes (phase / phase)	yes	yes
filters common mode disturbanes (phase / PE (N))	no	yes
located	between variable frequency drive and motor	between variable frequency drive and motor with feedback to the DC link
typical length of the motor cable with an internal EMC filter and a sine filter at the output	approx. 200 m in category C2 according EN 61800-3	in theory: unlimited. recommended: up to 500 m
motor cable	shielded. (It is also possible to use an unshielded cable. It is recommended to resign this solution, because coupling between parallel cables can be expected.)	unshielded
cable between variable frequency drive and sine filter	Unshielded, as short as possible (approx. 30 … 50 cm maximum)	
Permitted range of switching frequency	4 up to 8 kHz Because of possible resonances, the switching frequency may not be outside the specified range. Care has to be taken in cases, where the switching frequency is changed automatically, e.g. to reduce losses at higher temperatures of the heat sink. The given values refer to the real switching frequency. In case a variable frequency drive of the DA1 series is used, the values stated inside this table have to be multiplied by 2 to get the permissible setting range. (double edge modulation)	4 up to 16 kHz

Example 1: device of the series DA1

- Setting of the switching frequency with P2-24
  - permissible range with DX-SIN3… → 8 up to 16 kHz
  - permissible range with DX-SIN3…A → 8 up to 32 kHz
- Minimum switching frequency (P6-02) at automatic adaptation → 8 kHz

Example 2: device of the series DG1

- Setting of the switching frequency with P8-10
  - permissible range with DX-SIN3… → 4 up to 8 kHz
  - permissible range with DX-SIN3…A → 4 up to 12 kHz (12 kHz is the maximum switching frequency at DG1)
- The sine filter mode must be enabled with P8-11 = 1. This means that the switching frequency remains unchanged at the value set with P8-10.

5 Checklist EMC

To judge, if/which additional EMC measures are necessary, at least the following information is required:

- Mains
  - Mains configuration (TN-S / TN-C / TT / IT / other (which one?))
  - Mains voltage
  - Mains frequency
  - Kind of mains connection? (fixed connection / plug and socket connection))
  - Is an RCD required?
    - to protect persons? (30 mA)
    - for fire protection? (300 mA)
- Environment
  - First environment (public mains, respectively no own mid voltage transformer
  - Second environment (industry)
  - Private power supply network (owner can define, if the limits of the first or the second environment apply)
- Motor
  - Is the motor suitable to be operated with a variable frequency drive?
  - Is there only one motor connected to the variable frequency drive or are multiple ones connected in parallel?
  - Length oft he motor cable
    - With multiple motors connected in parallel: length of the single motor cables
- Which standard has to be used for the limits?
  - application specific standard (please provide name / number))
  - product standard EN 61800-3
  - generic standard EN 55011
- Specialties?
  - Possible limits (operated at a generator, dimensions ….)
  - ……..