Application Edition 10/03

micromaster

EMC Design Guidelines

SIEMENS

Copyright

Definitions and Warnings

Qualified personnel

In the sense of this documentation, qualified personnel are those who are knowledgeable and qualified to install, mount, commission, operate and service/maintain the MICROMASTER 4 and SINAMICS G110 products to be used. He or she must have the appropriate qualifications to carry-out these activities, for example:

- Trained and authorized to energize and de-energize, ground and tag circuits and equipment according to applicable safety standards.
- Trained or instructed according to the latest safety standards in the care and use of the appropriate safety equipment.
- Trained in rendering first aid.

There is no explicit warning information in this documentation. However, reference will be made to warning information and instructions in the Operating Instructions for the particular product.

User group

These EMC Guidelines were drawn-up to support customers and employees of Siemens AG when engineering plants and machines.

Exclusion of liability

The application examples are provided at no charge. They may be used under the clear understanding that the party using them does so at his own risk. They may only be passed-on to third parties, completely unchanged, maintaining all of the confidential property notices. These application examples may only be commercially passed-on after prior authorization in writing from Siemens Aktiengesellschaft.

Siemens does not accept any liability for recommendations which are provided or implied by the following description. The following description does not represent any additional guarantee, warranty or liability which goes beyond Siemens general conditions for supply. Any other claims are completely excluded. The authors and owners are only liable for deliberate and gross negligence. It is especially important to note that the authors are not liable for possible defects and subsequent damage.

Information regarding trademarks

MICROMASTER ® is a Siemens registered trademark
SINAMICS® is a Siemens registered trademark

Revisions/author

Version	Date/change	Author
V.1.0.	09/2003, first german edition	M.Uhlig
V.1.1.	10/2003; first english edition, small changes Cap. 3.1..1	M.Uhlig

Table of contents

1 Introduction

Various known phenomena - such as radio interference, harmonics, overvoltages, electromagnetic effects, parasitic interface etc. come under the collective term electromagnetic compatibility (EMC). Recently, this subject has become more and more important as a result of the increased use of power equipment, microelectronics in automation technology, the increasing number of radio-based services etc. In order to ensure disturbance-free operation of a plant or system, the earlier that the issue of EMC is taken into consideration then the associated costs are that much more favorable. This is the reason that EMC should always be included in the planning phase. In the individual planning phases, for example, EMC zones should be defined, cable types determined and filters adapted.

Contents

These EMC Configuring Guidelines are not intended to be a Manual about EMC. The main emphasis is to describe the measures to be carried-out to ensure a correct EMC design and operation of MICROMASTER 4 and SINAMICS G110 drive converters in machines and plants.

The following subjects are handled in the individual sections:

⇒ Legislation and Standards

⇒ EMC relating to AC drive converters

⇒ Design Guidelines for disturbance-free operation

⇒ Functional EMC faults, troubleshooting and removing disturbances

Target group

⇒ Personnel who plan and engineer machinery and plants with MICROMASTER 4 and SINAMICS G110 to control electric drives

⇒ Cabinet builders and installation companies/personnel

⇒ Service engineers who provide support for fast troubleshooting and resolving problems

2 EC Directives and EN Standards

General

EC Directives are published in the Official Journal of the European Union and must be included in the national legislation of EC Member States. The goal is to make it easier for the free movement of goods and personnel within the European Common Market. Within the European Common Market, published EC Directives and their implementation through national legislation form the legal basis.

The following subjects are principally handled within the Directives:

⇒ Applications, area of validity

⇒ Selling/marketing and commissioning

⇒ Essential requirements, protective goals which have to be maintained

⇒ Evaluating conformance, proof of conformance

⇒ CE marking

⇒ Coordinating the implementation, regulations for transition times etc.

Examples for EC Directives that have already been published and their implementation in national German legislation are listed in Table 2-1.

EC Directive	National legislation, e.g. Germany
Low-Voltage Directive 73/23/EEC	1. Regulations regarding the equipment safety law
EMC Directive 89/336/EEC	EMC law
Machinery Directive 98/37/EC Safety component according to 98/37/EC	9. Regulations regarding the equipment safety law

Table 2-1 Examples of EC Directives and their implementation

2.1 CE marking

The CE marking confirms that all of the EC Directives, which are applicable, are actually maintained. Different Directives must be considered depending on the type of the product / system and the way in which it is used.

The company/body who sold/marketed the product/system is responsible for the CE marking and checking that the EC Directives are also maintained. There are three different ways for manufacturers/machinery construction companies to certify that they comply with the particular EC Directive:

⇒ **Own declaration**
The manufacturer declares that all of the European Standards have been maintained, which are applicable for the equipment and for the electrical environment in which it is intended to be used. Only Standards may be

listed in the manufacturer's declaration (EC Declaration of Conformance) which are officially published in the Official Journal of the EC.

⇒ **Technical description of the design**
In specific cases a piece of equipment/system only partially fulfills existing Standards or there are still no applicable European Standards. In this particular case a "certified body" must issue a Declaration of Conformance. The "certified body" does not carry-out measurements itself. It refers to technical descriptions and information in existing test reports from certified test laboratories in order to evaluate the conformance. In this case, it is not permissible that the manufacturer/machinery construction company issues its own Declaration of Conformance.

⇒ **Type test certificate**
This method only applies for radio equipment.

The correctness of the CE marking is checked by various trade authorities within the various states. Trade Associations as well as the Ministry for Telecommunications. If a CE marking has been attached but there is no compliance, the product must be subsequently improved. Otherwise it will be prohibited from being "marketed" or the product will have to be withdrawn from the market. Violations associated with CE marking regulations are treated as regulatory offences.

2.1.1 EMC Directive: 89/336/EEC

From January 1996 all electrical equipment which has an autonomous, intrinsic function and which is marketed in the European Common Market to end users as specific individual devices and equipment has to fulfill the regulations laid-down in the EC Directive 89/336 /EEC.

It can be proven that the EMC Directive is maintained by applying the corresponding EMC Standards, e.g. EN 61800-3 (CE marking according to a manufacturer's own declaration). In this case, the regulations laid-down in the Product Standard have priority over the Generic Standards. When a specific product is installed in a final product, for which there is a special EMC Product Standard, then the EMC Product Standard of the end product should be applied.

Generally, drive converters are considered to be component of a complete plant/system. This means that similar to a motor, control etc., the manufacturer of the drive converter is not responsible in certifying that the EMC Directive is maintained. This means that the body "marketing" the complete plant/system is responsible for ensuring that the EMC Directive is maintained, i.e. the appropriate EMC Standards.

Manufacturers of components such as e.g. drive converters, control systems, power supplies etc. are responsible in providing information about the EMC characteristics of the equipment, its correct use and installation.

Note

The titles and reference data of the harmonized Standards in the sense of the EMC Directive are published in the Official Journal of the European Union under "Information from the Commission within the scope of implementing the Directive 89/336/EEC of the Council" in the Internet under http://europa.eu.int/eur-lex/de/index.html.

2.2 Standards

General

The contents of the Standards should be orientated to the requirements of the general public. The Standards must take into account state-of-the-art technology and create a reference for perfect technical characteristics and features. Standards are drawn-up in a multi-stage democratic procedure taking into account all of the groups involved.

Standards are drawn-up by the International Committees (IEC/CISPR), European Committees (e.g.: CENELEC) and the National Committees (e.g. Germany: DKE). The individual Technical Committees (TC) work on the various subjects within the International and European Committees. Individual Working Groups (WG) work within these committees.

After a request to draw-up a Standard, the European Standards Organization is responsible through the Commission to draw-up European Standards. Frequently, existing IEC Standards can be included in the European Standards. Member States are responsible in incorporating these, unchanged in their national Standards; and the associated national Standards must be retracted. The Deutsches Institut für Normung e.V. (DIN) [German Institute for Standards] is responsible for this task in Germany and for electrical issues, the Deutsche Kommission Elektrotechnik Elektronik Informationstechnik in DIN and VDE (DKE). Every EN Standard is transitioned, as result, into a harmonized German DIN EN or DIN VDE Standard.

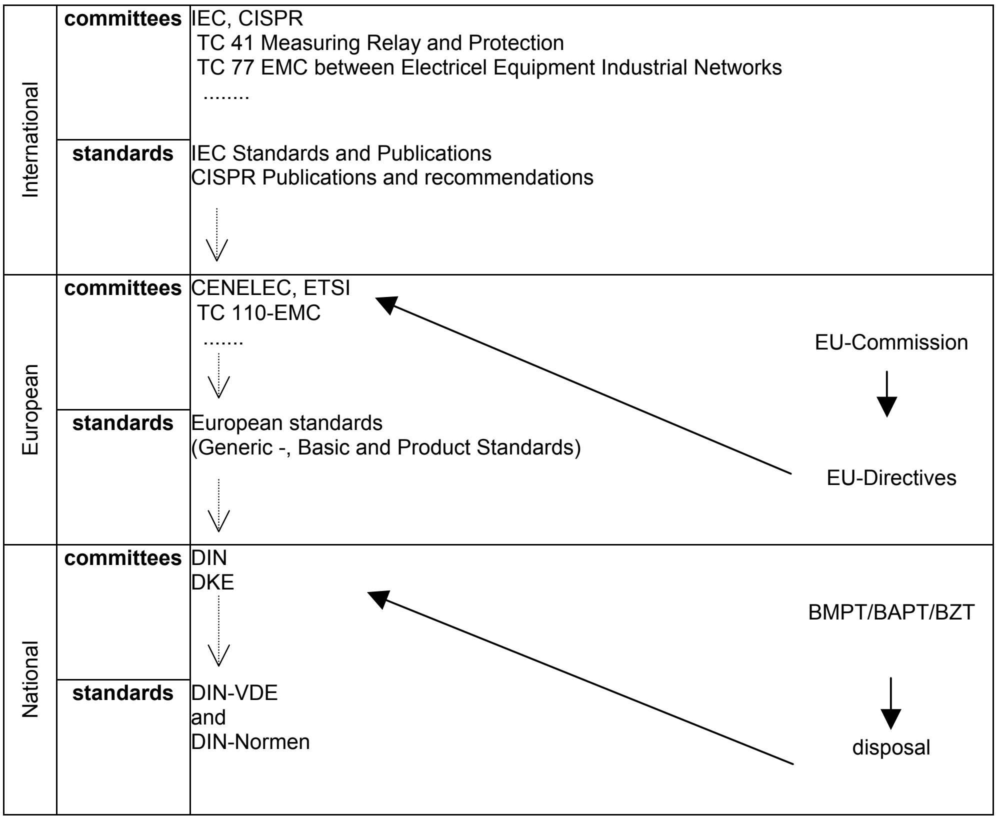


Fig. 2-1 Structure of the International and National Standards Associations

Classification of the Standards

The IEC, European and harmonized national Standards are, as far as the contents are concerned, sub-divided into 3 classes:

⇒ **Basic Standards** describe measuring and test techniques, referred to specific phenomena, to prove the required technical behavior and characteristics. They neither define limit values nor performance criteria.

⇒ **Generic Standards** define the minimum requirements for emission and immunity, in conjunction with the location where the equipment and systems are to be used. The limit values permissible for the individual physical phenomena are defined in the Generic Standards. The measuring techniques to be used are defined with reference made to the Basic Standards.

⇒ **Product Standards** only apply for products and product families. They include detailed information on

- Measuring and test techniques with reference to Basic Standards,
- Limit values based on Generic Standards,
- Configuration of test objects
- Specific operating conditions of the test object when making measurements,
- Specific evaluation criteria for the performance when noise or disturbances are present etc.

The following diagram shows the interrelationship between the Standards and a classification of the European Standards as example.

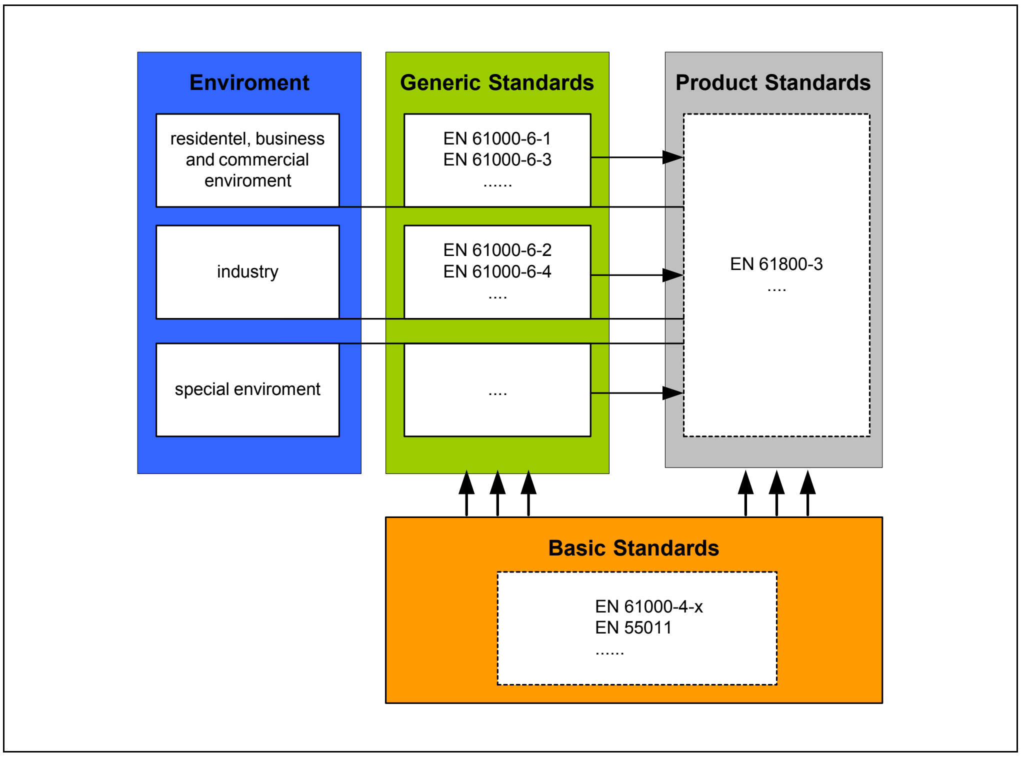


Fig. 2-2 Interrelationship between EN Standards

Product Standards and Generic Standards are published in the Official Journal of the European Community. This means that all EC Member States must apply them.

2.2.1 EMC Product Standard: EN 61800-3

General

The revised EMC Product Standard EN 61800-3/A11 for **P**ower **D**rive **S**ystems (PDS) has been valid since 01.01.2002.

The EMC Product Standard EN 61800-3/A11 does not directly refer to an AC drive converter, but to a complete drive system. In addition to the drive converter it also encompasses the complete circuit as well as motor and cables.

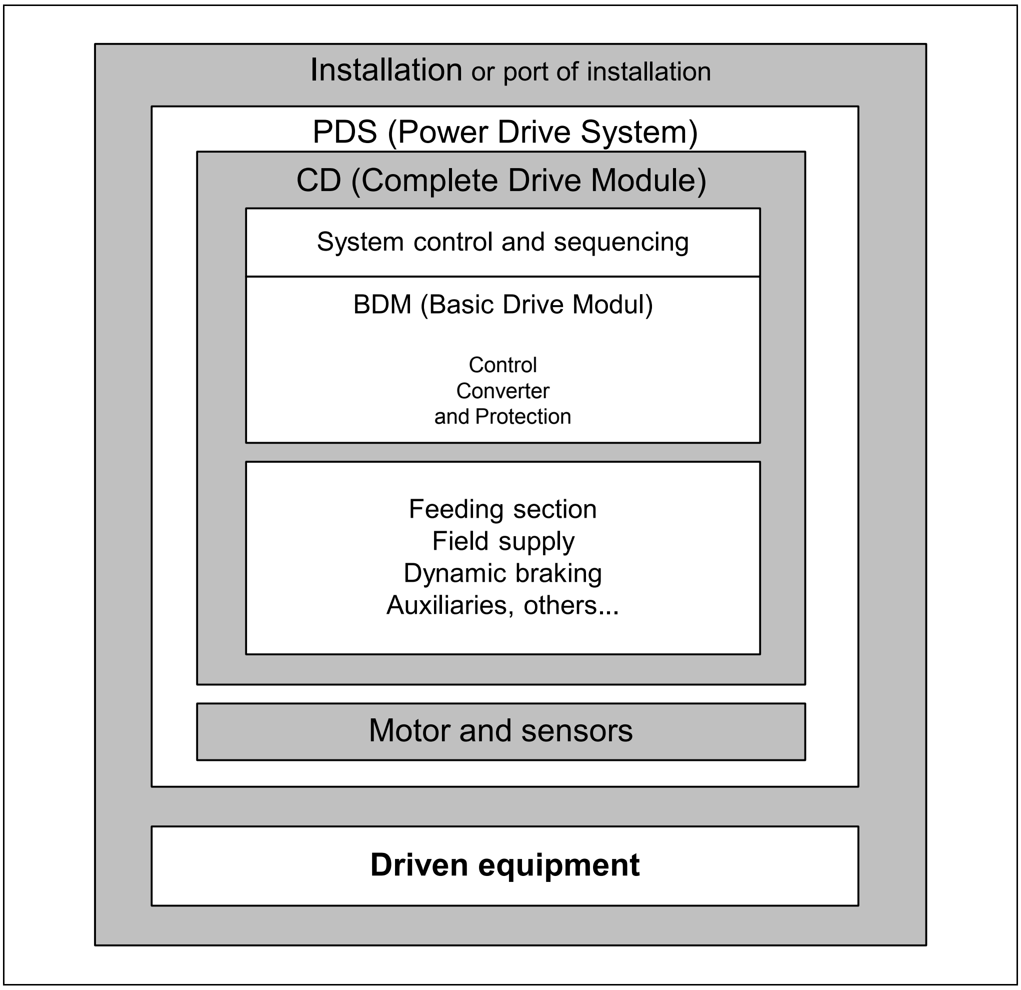


Fig. 2-3 Power Drive System (PDS) according to EN 61800-3

Evaluation criteria for the performance when disturbances occur are defined in the Standard and the immunity requirements and emission limit values are defined corresponding to the conditions that exist at the location where the equipment is used.

Classification of the drive systems

In the EN 61800-3/A11 Standard, which is presently valid, power drive systems are classified according to different sales channels and environments.

Environment	1st environment (residential, business and commercial environments)		2nd environment (industry)	
Sales channel	General availability	Limited availability	General availability	Limited availability

Table 2-2 Classification of the Power Drive Systems according to EN 61800-3/A11

Sales channel:

General availability
Sales channels to market/sell the product independent of the EMC know-how of the customer or user.

Limited availability:
Sales channels where the product is just marketed to distributors, customers or users who either individually or together are knowledgeable about EMC. A person/company knowledgeable about EMC installs and commissions the equipment.

Environment:

1st environment (domestic, business and commercial environments)
All "environments" which are directly supplied through a public low-voltage line supply, for example:

- Domestic areas, e.g. houses, apartments etc.
- Retailers, e.g. business, supermarkets
- Public facilities, e.g. petrol stations, parking lots
- Outdoor areas, e.g. petrol stations, parking lots
- Light industry, e.g. workshops, laboratories, small production operations

2. Environment (industry)
Industrial environment with its own line supply network which is isolated from the public low-voltage line supply via a transformer.

Power Drive Systems were re-classified in the last revised Draft Standards for EN 61800-3 which were published. PDS are now classified in four Categories C1 to C4 as a function of the line supply voltage and currents, the various environments and the EMC knowledge of the person/company installing the drive system (PDS). The definition of the sales channel, provided in previous Editions of the Standard, has been eliminated.

Category	C1	C2	C3	C4
Enviroment	1st environment (residential, business and commercial environments)		2nd environment (industry)	
Voltage/ Current	<1000 V			>1000V or > 400A
EMC-knowledge	No request	PDS that is intended to be installed and commissioned only by a professional.		

Table 2-3 Classification of the drive system according to the new EN 61800-3

Category C1: PDS with rated voltage < 1000V , used in the 1st environment

Category C2: PDS with rated voltage < 1000V , used in the 1st environment and installation and commissioning by persons/companies with EMC know-how

Category C3: PDS with rated voltage < 1000V, used in the 2nd environment

Category C4: PDS with rated voltage >= 1000V or rated currents >=400A or used in a total plant/system, 2nd environment

Comments to the requirements specified in EN 61800-3 regarding emission

EMC phenomena relating to noise emission in low-frequency and high-frequency areas are classified in the Standard. A description of the phenomena, their causes and possible remedies associated with EMC of the AC drive converter are discussed in Section 3.1 Emission.

a) <u>Low-frequency range < 9kHz</u>

As far as maintaining the limit values of line harmonics, the EMC Product Standard EN 61 800-3/A11 refers to maintaining and complying with Standards EN 61 000-3-2 and EN 61 000-3-12 for PDS.

b) <u>High-frequency [radio frequency] range > 9 kHz</u>

Product Standard EN 61 800-3/A11 specifies, for the various categories, that the following emission limits are maintained regarding high-frequency emission.

Category C1 - specified limit values, Class B, Group 1 according to EN 55 011

Category C2 - specified limit values, Class A, Group 1 according to EN 55 011, installed by persons/companies with EMC knowledge and the appropriate warning information:
"This is a product of Category C2 according to EN 61800-3. In a domestic environment, this product can cause radio interference. In which case, mitigation measures may be required."

Category C3 - specified limit values, Class A, Group 2 according to EN 55 011, whereby these limit values lie below Class A, Group 1 - and, in addition the following warning information:
"This type of PDS is not intended to be used on a low-voltage network which

supplies domestic premises. Radio frequency interference is expected if used on such a network."

Category C4 - essentially the same limit values apply as for Category C3. If, as a result of high nominal values or specific technical requirements, these cannot be maintained, then the user and manufacturer must agree on special EMC design measures.

Category	C1	C2	C3	C4
Limit values according EN 55011	Classe B	Classe A +Warning information	Classe A Group 2 + Warning information	Classe A Group 2 or special EMC design measures

Table 2-4 Emission limits > 9kHz

In order to maintain the specified limit values, appropriate EMC filters are available for the MICROMASTER 4 / SINAMICS G110 series of drive converters.

Options

Ordering Data for Variant Dependent Options

The options listed here (filters, chokes, brake resistors, gland plates, fuses and circuit breakers) are inverter specific.

The inverter and the associated options have the same voltage ratings.

All options are certified to ®, except fuses. The fuses 3NE1 comply with ® (corresponds to ®).

Mains operating voltage	Rated output kW	Inverter **without** filter	Order No. of the options **EMC filter Class A**	**EMC filter Class B**	**Filter Class B with low leakage**
200 V to 240 V 1 AC	0.12	6SE6440-2UC11-2AA1	–	–	6SE6400-2FL01-0AB0
	0.25	6SE6440-2UC12-5AA1	–	–	
	0.37	6SE6440-2UC13-7AA1	–	–	
	0.55	6SE6440-2UC15-5AA1	–	–	
	0.75	6SE6440-2UC17-5AA1	–	–	
	1.1	6SE6440-2UC21-1BA1	–	–	6SE6400-2FL02-6BB0
	1.5	6SE6440-2UC21-5BA1	–	–	
	2.2	6SE6440-2UC22-2BA1	–	–	
	3.0	6SE6440-2UC23-0CA1	–	–	–
200 V to 240 V 3 AC	0.12	6SE6440-2UC11-2AA1	6SE6400-2FA00-6AD0	6SE6400-2FB00-6AD0	–
	0.25	6SE6440-2UC12-5AA1			–

Fig. 2-4 Excerpt from the MICROMASTER 4 Catalog DA51.2 2002

<u>In order to achieve the specified limit values, when installing EMC filters, the appropriate EMC Design Guidelines must be carefully observed and the max. permissible motor feeder cable lengths.</u>

Comments regarding the requirements of EN 61800-3 for immunity

Depending on where the drive system is being actually used, the Standard defines different test limit values with the appropriate evaluation criteria. Higher limit values are specified for applications in industrial environments (2^{nd} environment) and when used in domestic areas (1^{st} environment).

The EMC phenomena described in the Standard together with the appropriate test Standards are explained in Section 3.2. Immunity.

3 EMC of AC drive converter

EMC stands for "Electromagnetic compatibility" and essentially describes the requirement that when electrical equipment is operated it can neither interfere with other equipment nor be significantly influenced by other equipment. The criteria for the electromagnetic compatibility of a piece of equipment is on one hand that specific emission limit values are maintained and on the other hand specific emission limit values can be tolerated.

The EMC model is used as basis to describe and investigate electromagnetic phenomena:

⇒ **Interference source**
The cause of the disturbance is known as the interference source. Disturbances or their effects, emitted by interference sources, must be removed or at least dampened by applying the appropriate measures.

⇒ **Paths through which the interference is coupled-in**
The coupling path is the path along which the disturbance, generated by an interference source, is propagated. Disturbances can propagate themselves from the interference source to the interference receiver along these paths. There are various mechanisms by which interference can be coupled-in.

⇒ **Interference receiver**
An interference receiver is a piece of electrical equipment whose function can be impeded (negatively influenced) as a result of disturbances.

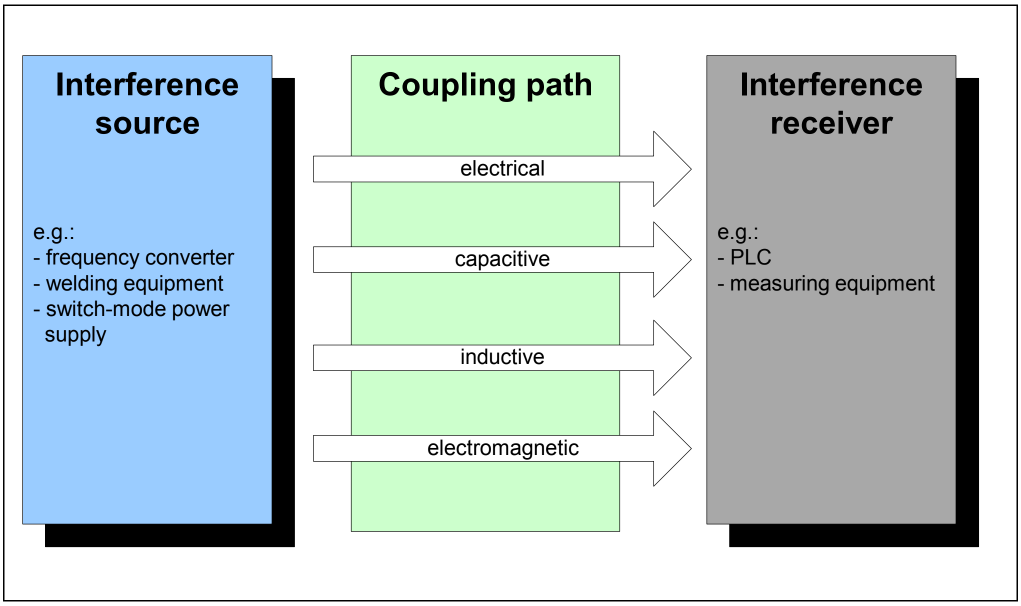


Fig. 3-1 EMC model

Electromagnetic disturbances can only influence equipment and plants if all three components of the EMC model are present. After localizing the individual components, the mutual electromagnetic compatibility can be increased by

⇒ **Suppressing the interference source:** Minimizing or eliminating the emission,

⇒ **Increasing the interference immunity of the interference receiver:** Minimizing the negative impact on the function or avoiding the negative impact on the function caused by disturbances,

⇒ **Reducing the coupling-in paths:** The disturbance is either dampened or suppressed.

3.1 Emission

Emission includes all types of electrical and magnetic disturbance which is emitted from an interference source. In this case the causes and coupling paths essentially depend on the prevailing frequencies.

3.1.1 Low-frequency emission < 9kHz

General

Cable-borne harmonics are important in the low-frequency area. In this case, the following phenomena are involved with the appropriate test Standards.

⇒ Voltage distortion as a result of superimposed harmonic currents; EN 61000-3-2/ -12

⇒ Periodic voltage dips caused by commutation operations in the input circuits of the drive converters; EN 60146-1-1

⇒ Voltage fluctuations/flicker caused by fast load changes (especially reactive power); EN 61000-3-3/ -11

Causes

As a rule, the incoming circuit of a MICROMASTER 4 / SINAMICS G110 drive converter comprises an uncontrolled rectifier (e.g. B6 diode bridge) and electrolytic capacitors are used in the DC link.

If the line supply voltage exceeds the DC link voltage the diodes conduct and the capacitors are charged. High current pulses briefly flow which means that a non-sinusoidal current is drawn from the line supply.

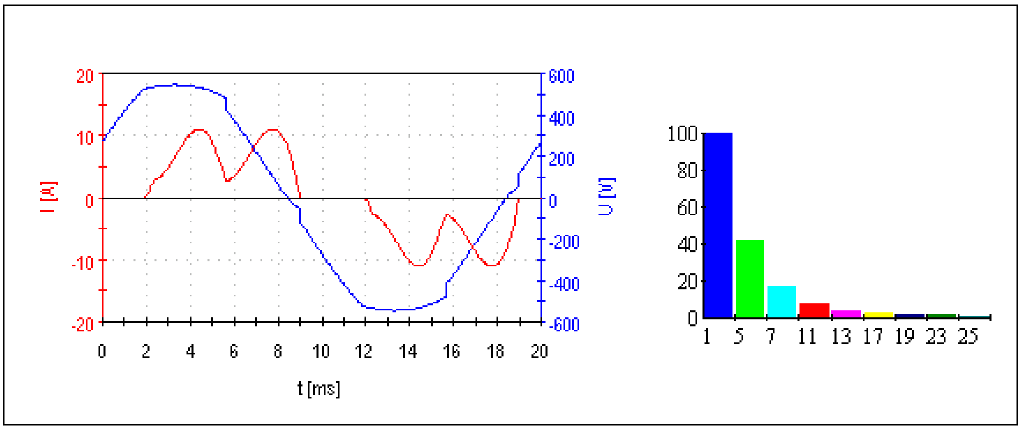


Fig. 3-2 Line supply voltage and current of a B6 rectifier

The non-sinusoidal line current can be emulated using Fourier analysis as the sum of a basic fundamental current and several harmonic currents with different amplitudes and frequencies. For a 6-pulse diode bridge, typically only uneven harmonic currents, which cannot be divided by 3, occur. The amplitudes of these harmonic currents decrease with the increasing harmonic Order Number.

Line harmonics are also caused by other loads, for example, PCs, equipment with clocked power supply, dimmers etc.

If a fully-controlled thyristor bridge is used in the input circuit - e.g. for high-rating drive converters - then the line supply is additionally stressed as a result of the periodic voltage dips (commutation dips). These are directly caused by the commutation operations and are therefore also known as commutation dips. If uncontrolled diode bridges are used, commutation is always close to the natural firing instant. The voltage gaps which can be observed are extremely narrow and in practice can be essentially neglected.

Effects

The functional disturbances that occur in the line supply are not directly related to the harmonic currents, but to the voltage drops which are caused by the various harmonic frequencies across the line impedance. These voltages distort the line supply voltage characteristic.

This means that the line harmonics which actually occur mainly depend on the line supply characteristics at the connection point.

The line supply impedance essentially comprises the ohmic and inductive components of the cables and transformers. Users are guaranteed (through legislation) a minimum line supply impedance which is normally significantly better. The line supply impedance is not a constant value but changes when loads and transformers are switched-in and switched-out. When the line supply impedance is doubled, the harmonic currents also increase but not directly to twice the value. The reason for this is that the current harmonics change at the same time. From the perspective of the drive converter, a higher line supply impedance means that the current pulses to re-charge the capacitors are no longer so high which means that this must be compensated using longer current conduction times. The pulses become wider and the current harmonics decrease.

Frequently the term **"Weak line supply"** is used to describe a high line impedance and low system fault level and **"Stiff line supply"**, i.e. a low line supply impedance and a high system fault level.

Harmonic currents essentially only generate reactive power. However this means that the apparent current is increased which is decisive when dimensioning cables and the line supply transformer. Typical disturbing effects of harmonics include:

- Cables, contactors and circuit-breakers are overloaded
- The power factor is reduced
- Measuring equipment and devices do not function correctly

Further, harmonic currents in the line supply feeding the AC drive converter can cause parallel resonance excitation. There is a high probability that these effects occur, if, for example, reactive power compensation is used in the line supply with unchoked capacitors.

Counter-measures

In order to reduce the voltage distortion for other loads, the line supply impedance at the connection point should be as low as possible. However, from the perspective of the drive converter, for low line supply impedances, the harmonic currents in the line feeder cables increase. A line reactor has proven itself to be the simplest method to adapt the line supply feeder impedance of the drive converter.

Line supply impedance

$$X_{line} = \frac{V_{line}}{\sqrt{3} * I_{k\_line}}$$

Apparent system fault level

- single-phase, e.g. 1-ph 230V AC $S_{k\_line} = V_{line} * I_{k\_line}$
- three-phase, e.g. 3-ph 400V AC $S_{k\_line} = \sqrt{3} * V_{line} * I_{k\_line}$

V_{line}.....rated line supply voltage
I_{k_line}...short-circuit current of the line supply

Apparent short-circuit power
at the secondary side of a transformer

$$S_{k\_trans} = \frac{S_{trans}}{u_k}$$

S_{trans}.....transformer rating (e.g. 400 kVA)
u_k........per unit short-circuit voltage of the transformer (e.g. 4%)

A line reactor must be used with MICROMASTER 4 frame size A-F and SINAMICS G110 drive units if the following applies for the system fault level at the connection point:

<u>SINAMICS G110 / MICROMASTER 4 frame size A-F:</u>

$$S_k \geq 100 * S_{conv}$$

<u>MICROMASTER 4 frame size FX-GX:</u>

$$S_k \geq 33 * S_{conv}$$

It`s a line reactor be used with **MICROMASTER 4 frame size FX-GX**, the following condition for the system fault level at the connection point must in addition be met.

$$S_k \leq 100 * S_{conv}$$

- single-phase, e.g. 1-ph 230V AC $\boxed{S_{conv} = V_{conv} * I_{conv}}$
- three-phase, e.g. 3-ph 400V AC $\boxed{S_{conv} = \sqrt{3} * V_{conv} * I_{conv}}$

S_k........*apparent system fault level at the connection point (e.g. 10MVA)*

S_{conv}.....*apparent drive converter power*

V_{conv}.....*rated drive converter voltage*

I_{conv}.....*rated drive converter input current*

Further, in practice, the drive converter load should only be between 15 and 25% of the total supply power. If drive converters are the predominant load connected to the line supply and the other linear loads can be neglected, then a high level of voltage harmonics occur even when upstream line reactors are used. In this case, the drive converter should be supplied through a separate transformer. This means that the transformer used can be dimensioned as a special drive converter transformer so that the corresponding line reactors of the individual drive converters can be eliminated.

Additional measures:

⇒ If there are significant problems relating to line harmonics, special LC circuits can be used which are harmonized to the frequency of the disturbing harmonics.

⇒ For higher converter power ratings, input circuits with a higher number of pulses should be used. For example, 12-pulse supplies. In this case, the harmonics with low order numbers are almost completely eliminated.

⇒ Drive converters should be used which are capable of regenerative feedback with self-commutated rectifiers and special incoming filters which result in almost sinusoidal line currents, e.g. MASTERDRIVES **A**ctive**F**ront**E**nd (AFE).

Additional commutating reactors are not required for MICROMASTER 4/ SINAMICS G110 drive converters. If these units already have an line reactor, then this has the function of a commutating reactor.

3.1.2 High-frequency emission > 9kHz

General

High-frequency (radio frequency) emission includes the following:

⇒ Cable-borne disturbances, 10 kHz to 30 MHz
corresponding to EN 55011

⇒ Radiated disturbances, 30 MHz to 1 GHz
corresponding to EN 55011

Causes

The output circuit of an AC drive converter typically comprises fast-switching IGBT modules. These operate with switching frequencies of between 2 and 16 kHz. The DC link voltage is switched to the motor windings by appropriately "switching" the IGBTs.

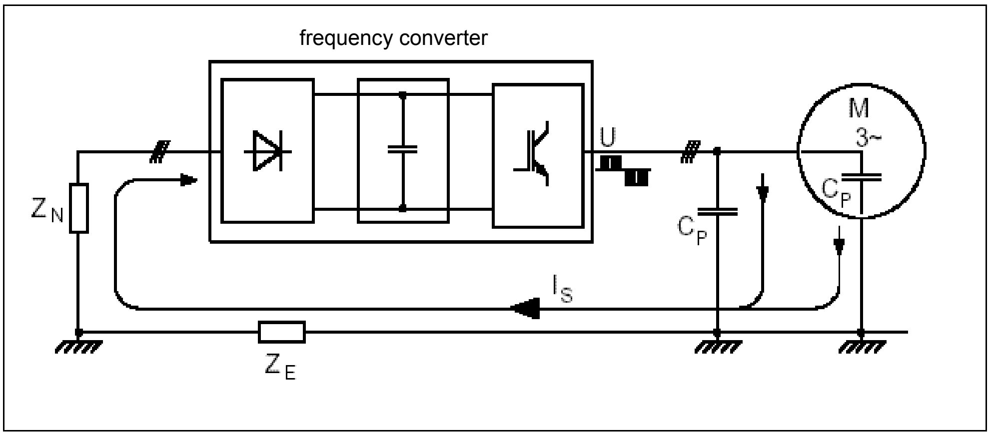


Fig. 3-1 Interference current I_s for unshielded motor feeder cables

The parasitic capacitances C_P are charged and discharged as a result of the pulsed AC drive converter output voltage. An interference current I_s flows.

The drive converter and especially the motor feeder cables radiate high-frequency electromagnetic fields (HF radiation).

Effects

The interference current must flow back to its source which in this case is the DC link of the AC drive converter. If unshielded cables are used, the interference current flows in an undefined fashion back through the impedances of the ground Z_E and the line feeder cable Z_N as well as, e.g. foundation grounder, cable trays etc. The interference current and the interference voltages that it generates can have a negative impact on plants and equipment and even damage these.

The electromagnetic fields radiated from the drive converter and the motor feeder cable transmit energy and can interfere other pieces of equipment, e.g. this can cause a radio to crackle.

Counter-measures

The following measures should be used in order to reduce the radio-frequency emission:

⇒ Use shielded motor feeder cables

⇒ Use a special EMC filter on the line side of the drive converter

Shielded motor cables must be used to dampen radio-frequency radiation and in order that the interference current is fed back to its source in a defined fashion (in this case the source is the AC drive converter). We recommend that special EMC motor cables are used - for example Siemens Protoflex EMC cables - which have a high shielding factor and low parasitic capacitances. The cable shield must be connected to the drive converter housing and the motor frame through the largest possible surface area. It is not permissible that the cable shield is interrupted!

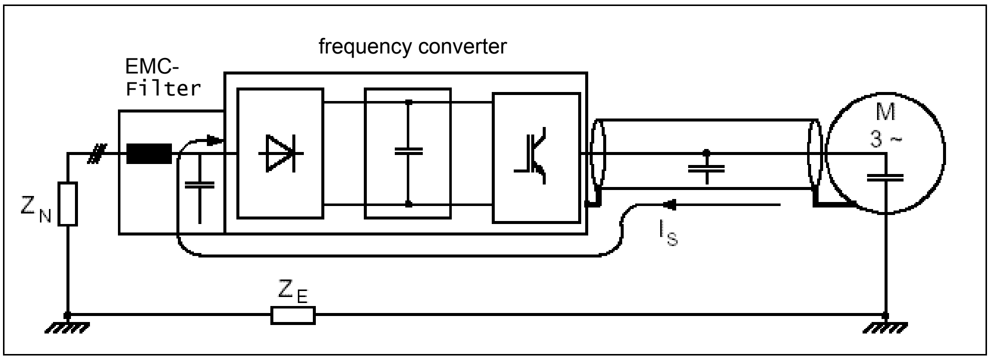


Fig. 3-2 Interference current when using shielded motor feeder cables and an EMC filter

In order that the radio-frequency interference current can flow back to the drive converter DC link through the lowest possible impedance, discharge capacitors and **special EMC filters** are used to establish a capacitive coupling. MICROMASTER 4 / SINAMICS G110 drive converter already include as standard basic interference suppression - the so-called Y capacitors.

The better solution is to use special EMC filters at the line supply input of the AC drive converter. EMC filters as sub-chassis filter or a Class A/ B filter in compliance with EN 55011, which are already integrated in the unit, are available for MICROMASTER 4 / SINAMICS G110 drive units.

It is important to have a good connection between the drive converter housing and the housing of the EMC filter. The most favorable solution is to mount the EMC filter directly onto the drive converter as sub-chassis filter. Another possibility is to mount the filter and drive converter on a common, well-grounded mounting plate with a good conductivity.

<u>The connecting cable between the drive converter and EMC filter should be shielded and be kept as short as possible!</u>

Note

It is not permissible to connect MICROMASTER 4 / SINAMICS G110 drives equipped with EMC filters to ungrounded line supplies (IT line supplies). If a non-filtered drive converter is connected to an IT line supply, then the basic interference suppression elements (Y capacitors) should be removed (refer to the Operating Instructions).

3.2 Interference immunity

General

Every piece of equipment must have a certain degree of interference immunity as a function of where it is being used. Interference immunity describes the immunity to individual emissions from neighboring interference sources. In this case, immunity means that a certain level of disturbances can result in a specified level of interference. If the interference level is exceeded, then it can result in failures which can no longer be tolerated. This disturbance can also cause the destruction of equipment.

Typical disturbances

a) in the low-frequency range <9 kHz

⇒ Harmonics corresponding to EN 61000-2-2/-4

⇒ Commutation dips corresponding to EN 60146-1-1

⇒ Voltage changes, fluctuations, dips and interruptions corresponding to EN 61000-2-1

⇒ Voltage imbalance and frequency changes corresponding to EN 61000-2-2/-4

b) in the high-frequency range > 9 kHz

⇒ ESD: Electrostatic discharge corresponding to EN 61000-4-2

⇒ HF radiation corresponding to EN 61000-4-3

⇒ Burst: Fast transient disturbances corresponding to EN 61000-4-4

⇒ Surge: Transients with high energy levels corresponding to EN 61000-4-5

⇒ Cables exposed to HF corresponding to EN 61000-4-6

⇒ Influence of homogenous magnetic fields with high energy levels (DC and AC fields) corresponding to EN 61000-4-8

The Product Standard EN 61800-3 and the Generic Standards EN 61000-6-1/ -2 specify, for the individual disturbances, appropriate test values and evaluation criteria.

MICROMASTER 4 and SINAMICS G110 drive units fulfill the limit values listed in the following table.

EMC-Phäenomenon		criteria	Limit value
ESD immunity EN 61 000-4-2	ESD through air discharge	Test level 3	8 kV
	ESD through contact discharge	Test level 3	6 kV
Electrical fields immunity EN 61 000-4-3	Electrical field applied to unit	Test level 3 26 MHz bis 1 GHz	10 V/m
Burst interference immunity EN 61 000-4-4	Applied to all cable terminations	Test level 4	4 kV
Surge immunity	Applied to mains cables	Test level 3	2 kV

EN 61 000-4-5			
Immunity to RFI emissions, conducted EN 61 000-4-6	Applied to mains, motor and control cables	Test level 4 0,15 MHz bis 80 MHz 80 % AM (1 kHz)	10 V

Table 3-1 Limit values for immunity to interference

3.3 Coupled-in disturbances

General

Coupled-in disturbances describe the way in which disturbances are coupled-in from an interference source to an interference receiver. In this case the various coupling mechanisms can occur both in parallel as well as in stages.

3.3.1 Electrical coupling

Cause

Electrical or metallic coupling always occurs if two circuits use a common conductor (e.g. ground and earthing connections).

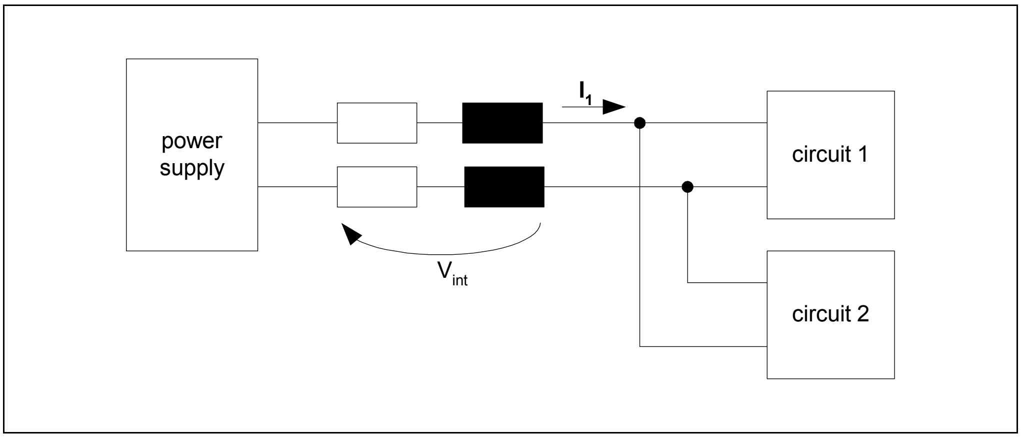


Fig. 3-3 Electrical coupling

These interference voltages V_{Int} result in, for example, different voltage levels or a voltage shift for pieces of equipment with a common power supply.

Counter-measures

⇒ Dedicated outgoing and incoming cable should be used for each circuit.

⇒ Short, common reference cables

⇒ Connection to a common reference point in a star-type configuration

⇒ Electrical isolation between the various systems (transformer, relay, opto-coupler..)

3.3.2 Capacitive coupling

Cause

Capacitive or electrical coupling occurs between two cables which are mutually insulated from one another and which are at different potentials (voltage levels). As a result of the voltage difference there is an electrical field between the conductors that is represented using capacitance C_K in Fig. 3-4. An interference current I_{Int} is coupled-into the interference receiver via C_K, which results in an interference voltage across impedance Z.

⇒ Disturbances coupled-in through cables running in parallel (power/signal cables)

⇒ Static discharge from humans

⇒ When contactors or inductance is switched

⇒ High voltage rate-of-change dv/dt

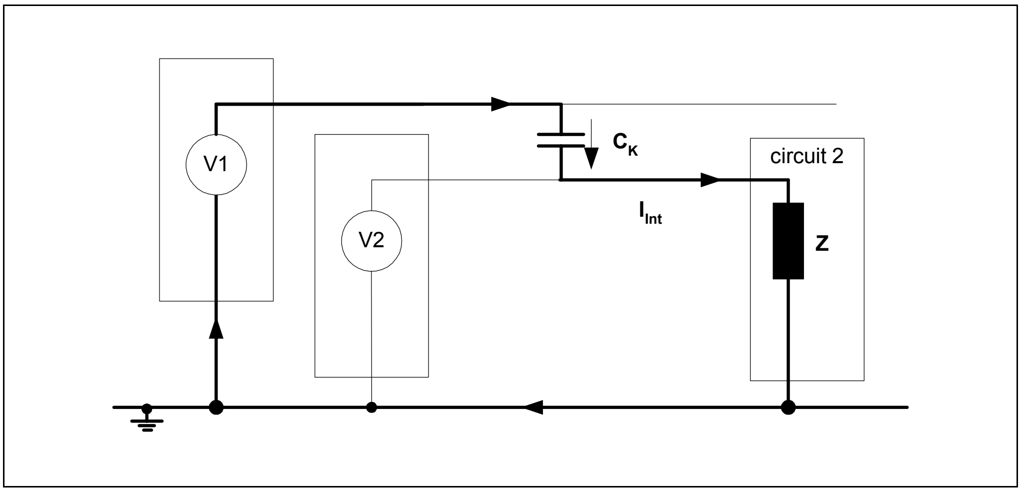


Fig. 3-4 Capacitive coupling for cables running in parallel

The magnitude of the interference current depends on the magnitude of the electric field. In turn the electrical field strength depends on the voltage difference and the distance between cables.

Counter-measures

The simplest measure is to carefully route cables and conductors. The following rules should be taken into consideration:

⇒ Increase the distance between cables and conductors

⇒ Reduce the lengths of cables running in parallel

⇒ Use shielded cables

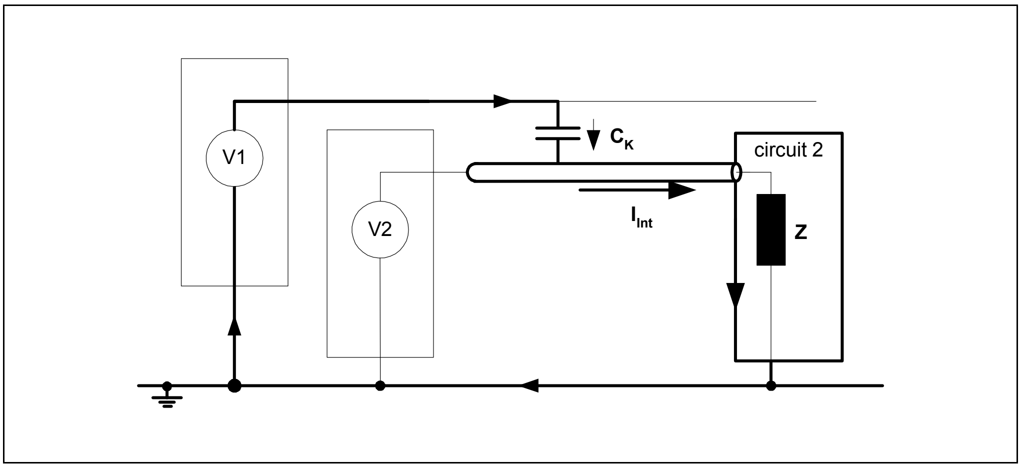


Fig. 3-5 Discharge interference current I_S

When shielded signal cables are used and there is a good shield connection, the interference current Is is discharged to ground through the enclosure. This means that it has no effect on the internal circuits. It would be sufficient to connect the cable shield at one end to shield against interference being capacitively coupled-in.

3.3.3 Inductive coupling

Cause

Inductive or magnetic coupling occurs between conductors through which current is flowing. The AC current flowing through the conductor generates a magnetic field which induces an interference voltage in an adjacent conductor or circuit.

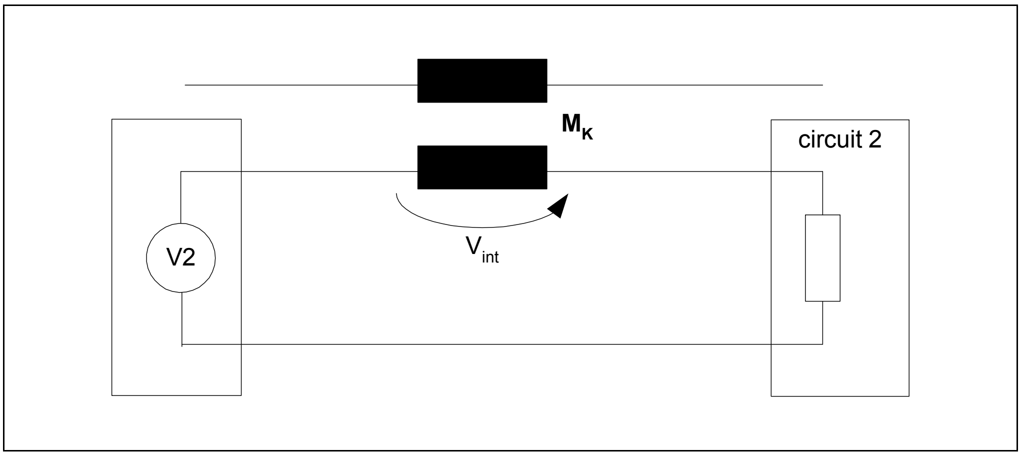


Fig. 3-6 Inductive coupling

The coupling is not influenced if there is a direct connection between the two conductors or not. Typical sources of interference include:

⇒ Transformers, motors, electrical welding equipment

⇒ When high currents are switched

⇒ High current rates of change di/dt

⇒ Signal cables with high frequency

⇒ Undampened coils

Counter-measures

Inductive and capacitive couplings are present at the same time between non-shielded cables. In order to provide shielding against inductive noise, the shields must be grounded at both ends.

Additional measures to reduce the effect of interference include:

⇒ Twisted signal cables

⇒ Provide contactors with interference suppression (damping elements)

⇒ Increase the distance/clearance between cables

3.3.4 Radiation

Cause

Radiation, also known as electromagnetic coupling, is where inductive and capacitive coupling are superimposed in the form of a radiated electromagnetic field.

Typical sources of interference include:

⇒ Transmitters which are in the vicinity (e.g. mobile radio equipment)

⇒ Radio-frequency equipment

⇒ Arcing gaps (firing plugs, welding equipment)

Counter-measures

Essentially the same measures apply as have already been described. However, it should be noted that radiated electromagnetic fields mainly lie in the radio-frequency range. Suitable shielding materials and shielding braids must be used in order to provide a good shielding effect. "Radiating" cables should be routed as close as possible to a surface at ground potential, i.e. to reduce the effective antenna height.

4 Correct EMC design

General

The most favorable interference suppression measure from a cost standpoint is to spatially separate interference sources and interference receivers. This assumes that these issues have already been taken into account when designing a drive system or a plant. The first question that has to be answered for each piece of equipment used is whether it is a potential interference source or interference receiver:

⇒ **Interference sources** in this sense are, e.g. AC drive converters, braking choppers, contactors.

⇒ **Interference receivers** include automation equipment, transmitters and sensors.

The complete drive system is then classified according to EMC zones and the various pieces of equipment/devices are allocated to these zones. The zone concept will now be explained using the following diagram:

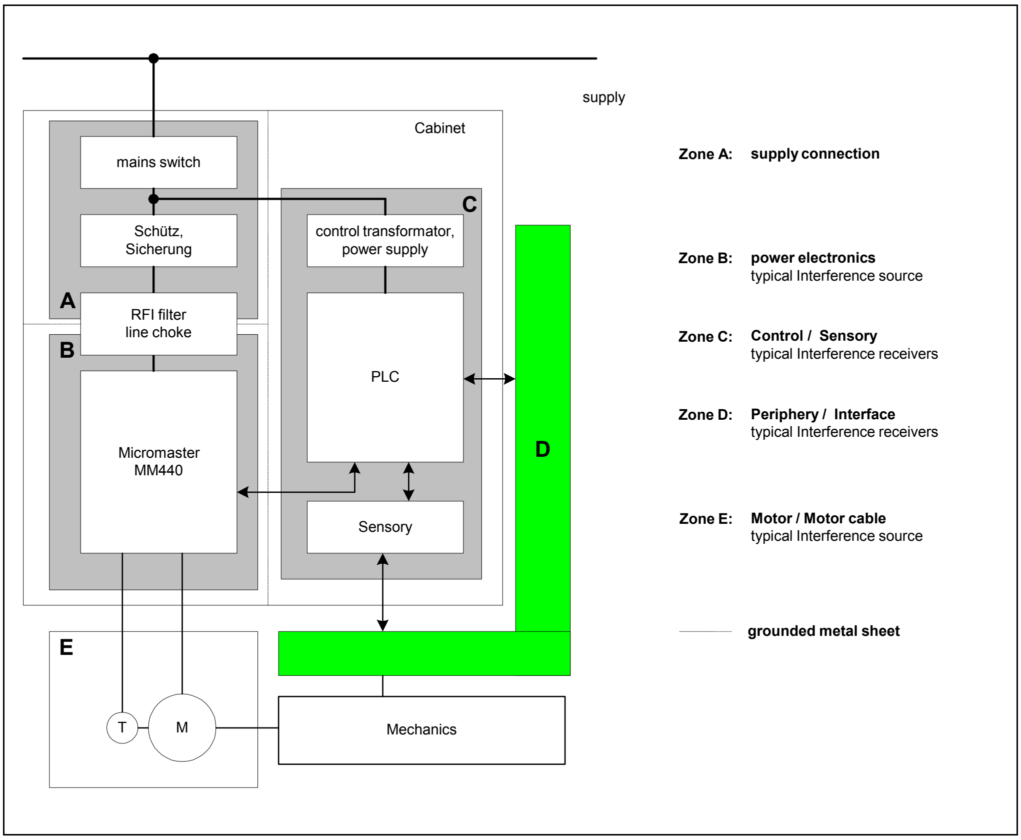


Fig. 4-1 Example for classifying a drive system according to various zones

There are specific requirements regarding emission and immunity in each zone. The zones should be spatially separated. This is best done using a metal enclosure or within a cabinet by using grounded metal partitions. If required, filters should be used at the interfaces between the zones. Cables from the different zones should be separately routed or mutually shielded from one another.

4.1 Design of electrical cabinets

General

The electrical cabinet is often a "housing" to accommodate a wide variety of electrical equipment and devices. These can include for example, controls, contactors, display elements and AC drive converters. A good shielding effect between external and internal interference is achieved by appropriately designing the cabinet components. The main aspects which should be taken into account is to use the appropriate conductive materials, good contacts between all of the housing parts and to avoid any large openings in the cabinet panels. Special EMC cabinets can be used if especially high demands are placed on the shield damping effect.

Inadmissible mutual interference can be avoided by correctly mounting the components within the electrical cabinet in the defined EMC zones. Further, it is important to correctly route the cables and correctly use shields.

4.1.1 Electrical cabinet components

General

For a standard electrical cabinet manufactured out of painted sheet steel good shield damping can be achieved by observing some simple rules. The most important basic principle is to design the electrical cabinet as Faraday cage.

Basic rules

⇒ All metal housing parts and mounting plates of an electrical cabinet must be connected to the cabinet frame through the largest possible surface area to ensure a good electrical connection.

⇒ Cabinet covers such as side panels, rear panels, roof assembly and baseplates should be connected to one another at suitable intervals.

⇒ All of the screw connections at painted or coated metal components must either use special serrated contact washers or the insulating protective layers between the parts and components must be removed before assembly.

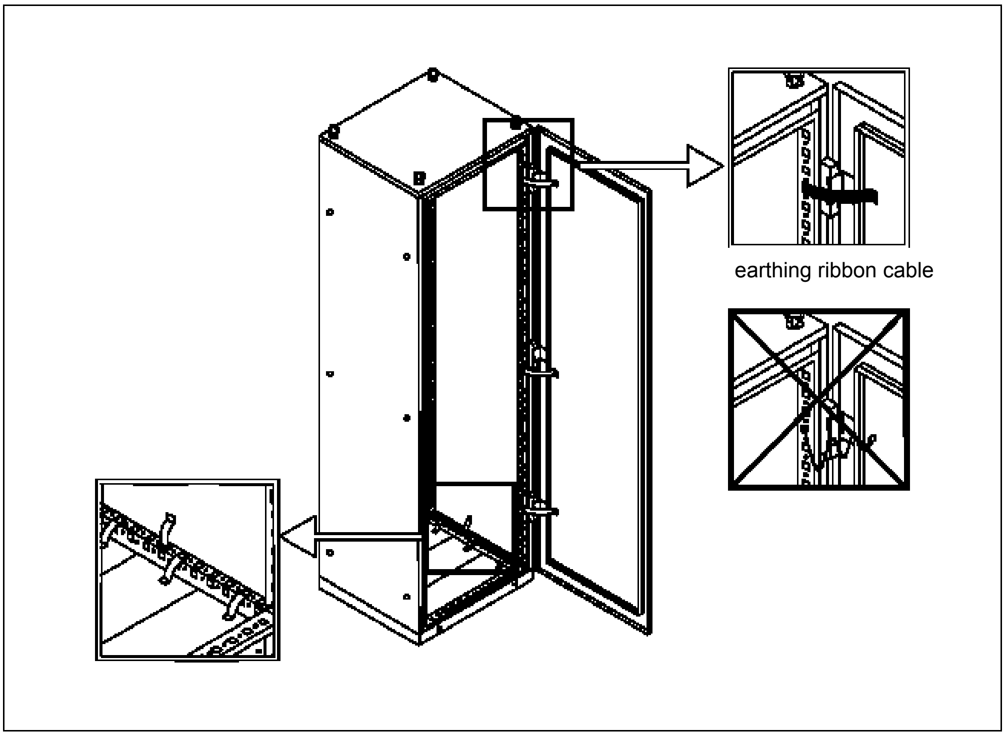


Fig. 4-2 Connecting housing parts

⇒ The material for the parts to be connected including the connecting elements (screws, serrated washers, rivets etc.) should be located close to one another in the electrochemical voltage series.

4.1.2 Openings in the cabinet panels

General

Ventilation holes, windows and operator elements have a negative impact on the shielding effect of the electrical cabinet. Every opening with a size of half of the wavelength λ of the noise frequency acts just like an antenna and radiates an electromagnetic field. In practice, the **slot lengths should be less than λ/20**.

Ventilation slots

If ventilation openings are required in the electrical cabinet, then offset holes or HF meshes are certainly better than slots. It is better to have many small holes than just a few large holes.

Operator elements

When mounting/installing operator elements and operator panels it must be ensured that there is a good contact between the edges of the panels and the metal mounting frames.

Otherwise is may be necessary to use additional EMC seals / covers.

Cable entries

The best way of connecting the shields to ground is to use cable entries which establish a good contact around the shield and provide a good HF seal with the housing itself (cabinet panel). This measure also prevents interference that is generated in the cabinet from being radiated to the outside via the shielded cable. This is the reason that for all shielded cables, the outer shield must be connected to the cabinet housing through the largest possible surface area at the point where it enters the cabinet.

4.1.3 Components in the electrical cabinet

General

⇒ The component should be arranged corresponding to the classification in the various EMC zones. This means for example that the power components (e.g. transformers, drive equipment) should always be separated from the control components (e.g. SIMATIC S7).

⇒ The effect of the disturbance decreases with increasing distance between the interference source and interference receiver.

⇒ It is also possible to reduce disturbances by installing sheet metal partitions.

⇒ All of the components/devices should be connected with one another through the largest possible surface area to ensure a good electrical connection.

Drive converters and options

The drive converter, EMC filter, line reactors, shield connections and braking resistors are best mounted on a bare conductive mounting plate. A low-ohmic (low-resistance) connection for the interference currents is achieved using the mounting plate. If it is not possible to mount the equipment on a plate or there is no plate, then a good conductive path for the interference current must be established using the appropriate connections (preferably a flat cable with a large contact surface).

The following points should be observed when mounting MICROMASTER Size A or SINAMICS G110 drive converters on a mounting rail:

⇒ There must be a good electrical connection between the mounting rail and the ground of the electrical cabinet

⇒ <u>The shields of the motor cables must be connected to the drive converter housing using the shield connecting plate!</u>

⇒ If an additional external EMC filter is used, this should be mounted on a bare mounting plate which is grounded through a low-ohmic connection. The cable shields of the connecting cable between the filter and the drive converter and the motor feeder cables should be connected to the shield connection plate of the drive converter. In addition, the shields of the motor cables should be connected to the shield rail of the cabinet or connected to the mounting plate using shield clamps.

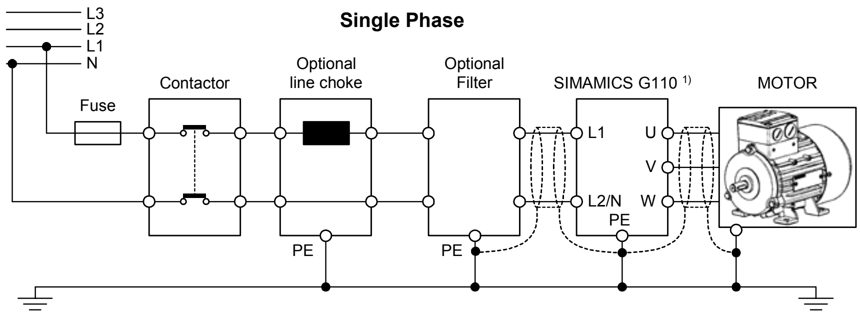
<u>We do not recommend this configuration for EMC reasons!</u>
It makes more sense to mount the EMC filter and the drive converter directly on a common mounting plate without using a mounting rail.

EMC filters are available as accessories for the MICROMASTER 4 / SINAMICS G110 drive converters. Refer to, for example, Catalog DA 51.2.

When using EMC filters it is especially important to ensure a good radio-frequency connection between the filter and drive converter housing, motor cable shield and ground.

When arranging filters and reactors, the following installation information/ instructions apply. These correspond to the Operating Instructions of the drive units.

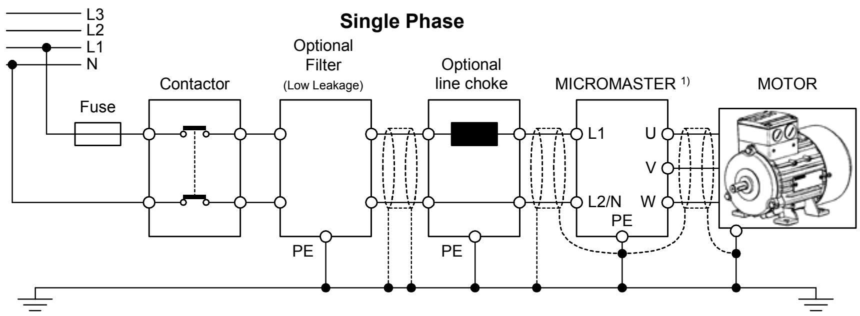
SINAMICS G110



1) with and without integrated filter

Fig. 4-3 Schematic diagram of the motor and line supply connections

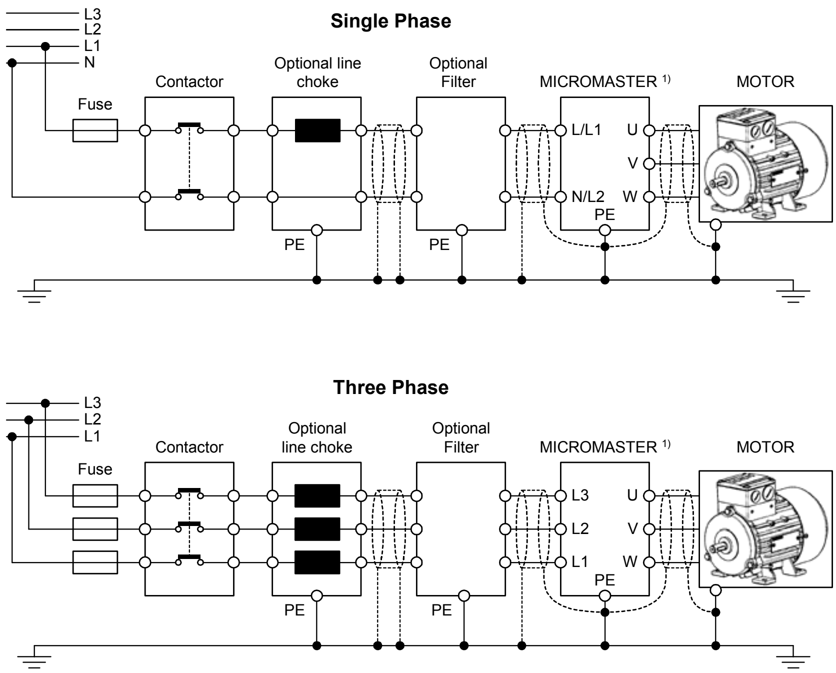
MM410, Sizes AA and AB



1) with and without integrated filter

Fig. 4-4 Schematic diagram of the motor and line supply connections

MM420/430/440, Sizes A to F

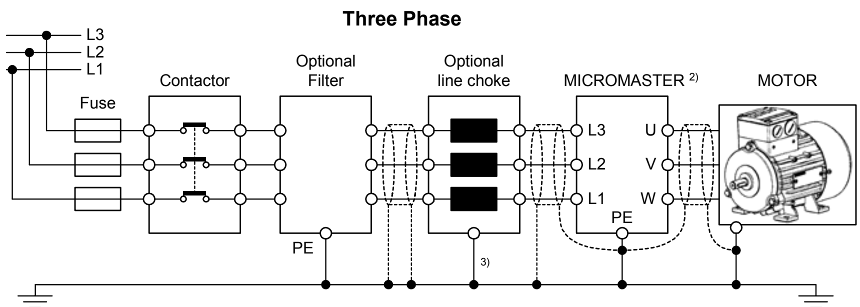


1) with and without integrated filter

Fig. 4-5 Schematic diagram of the motor and line supply connections

MM440, Sizes FX and GX

A line-commutating reactor is required when an EMC filter is used. The cable shield is retained to the metal mounting surface as close as possible to the components.



1) without integrated filter
2) the line choke is to be earthed using the designated point

Fig. 4-6 Schematic diagram of the motor and line supply connections

Shield and protective conductor rail

The shield, potential bonding and protective conductor rails are connected to the electrical cabinet ground. This means that they have the same reference potential within the electrical cabinet.

Shields conduct interference currents to avoid undesirable mutual interference. The shield rail is used to connect the cable shields where the cable enters the electrical cabinet. They must be connected through the largest possible surface area and with a low-ohmic connection at radio frequencies to the common electrical cabinet ground (mounting plate).

The protective conductor (PE = Protective Earth) only conducts current under fault conditions. The central protective conductor rail must be connected to the grounding rail. The central grounding rail must be electrically connected to the electrical cabinet ground (this is a metal-metal connection). Only then can fault and noise currents be reliably discharged to ground.

The reference conductor (neutral conductor, circuit ground, 0V) conduct current under normal operating conditions.

The protective and reference conductors must be dimensioned according to the relevant Standards and Directives.

It must be ensured that the grounding, protective conductor and shielding concepts are harmonized and coordinated with one another in order to avoid any undesirable voltage shifts and noise currents.

In order to achieve optimum EMC it is necessary to have a good (at both low and high frequencies) potential bonding of all of the metallic housings/enclosures, cabinets, machinery and plant/system parts.

Relays, contactors

Extremely high interference voltages are generated when coils are de-energized (e.g. when relays, contactors are de-energized). This is the reason that the appropriate interference suppression elements must be connected as shown below.

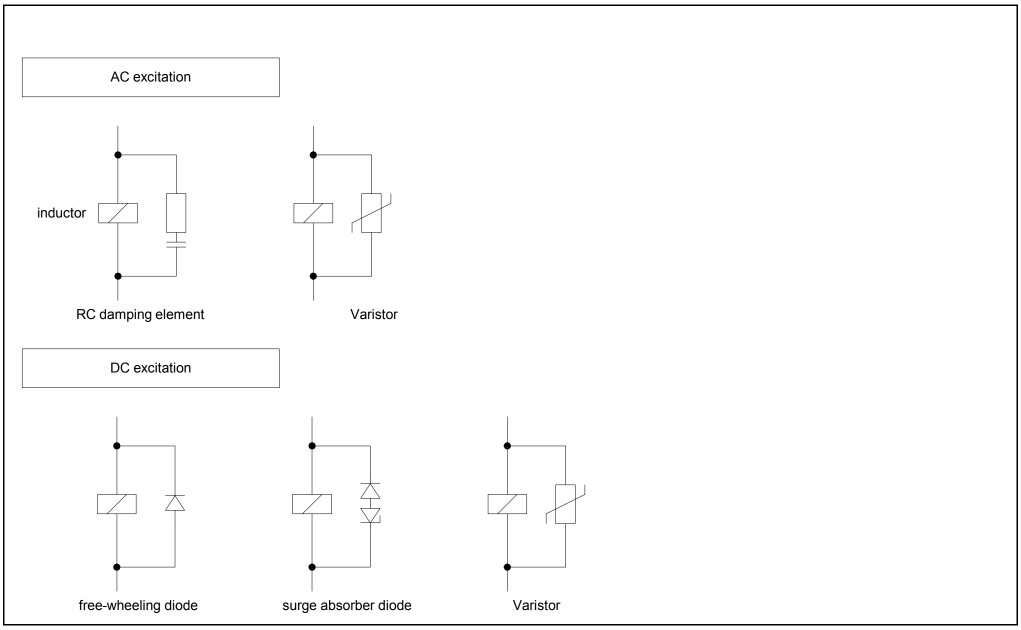


Fig. 4-7 Noise suppression elements

4.1.4 Routing cables in the electrical cabinet

General

Power and signal cables must always be separately routed. To realize this, we recommend that the various cables are classified according to cable groups. The cables associated with a group can be combined in a common cable assembly and the various groups can be routed with the necessary clearance between them.

Basic rules

⇒ Signal cables/data cables should, if at all possible, only enter the cabinet at one particular location.

⇒ All of the cables/conductors inside the electrical cabinet should be routed as close as possible to housing parts and components (e.g. cabinet panels, mounting plates, support frames, metal rails). If cables are simply routed a distance away from metal parts in free space this results in increased interference being coupled-in and also radiated interference (antenna effect).

⇒ If it is absolutely necessary signal and power cables can cross each other however they should never be routed in parallel close to one another.

⇒ Signal cables / data cables should be routed separated from power cables and power supply cables (avoid cable runs where interference can be coupled-in). Minimum clearance in the electrical cabinet: 20cm.
If required, use a grounded sheet metal partition.

⇒ Control circuits for contactors (230 V AC) should be routed as far as possible separated from signal cables.

⇒ Cables associated with one another (outgoing and incoming conductors) should be routed together.

4.1.5 Shielding

General

The quality of the shielding concept is predominantly influenced by the correct shield connection and the shield configuration/materials being used.

Basic rules

⇒ The first shield contact must be made directly where the cable enters the electrical cabinet.

⇒ Special shield rails must be provided to ensure a low impedance contact between the shield and the shield rail.

⇒ The shield must be connected to ground through the largest possible surface area to ensure a good electrical connection. Shield clamps and screw connections can be used.

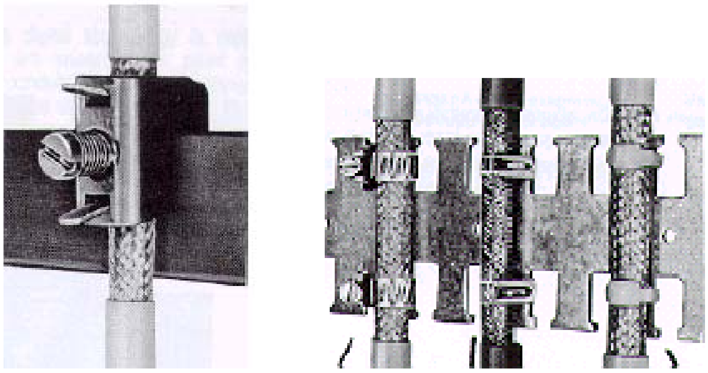


Fig. 4-8 Examples for connecting shields to a shield rail

⇒ Shields with nickel-plated copper braiding should be preferably used. These are better than foil-type shields.

⇒ Never interrupt shields

⇒ Shields may not assume the function of an N or PE conductor. Always ensure that there is a good potential bonding between the electrical cabinet and the complete plant/system!

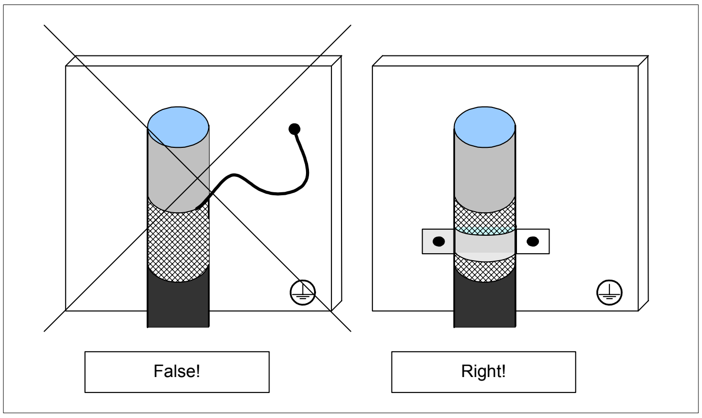


Fig. 4-9 Connecting the shield

⇒ Never extend the shield using a wire (pigtail) to the shield connecting point.

4.2 Cables for optimum EMC

General

⇒ Always use shielded cables and ensure a low shield resistance of these cables.

⇒ Separately route motor cables away from line supply, control and signal cables/conductors.

⇒ Non-shielded signal cables belonging to the same circuit (outgoing and incoming conductors) should be twisted; the surface area between the outgoing and incoming conductors should be kept as low as possible in order to avoid unnecessary frame-antenna effects.

⇒ Unnecessary cable lengths should be avoided. This keeps coupling capacitances and coupling inductances low.

⇒ Reserve cables should be as short as possible. The conductors/cores of reserve cables should be connected to at least one or better still at both cable ends to the equipment ground.

4.2.1 Motor cables

⇒ Motor cables radiate a high degree of interference. In order to limit the emission level, shielded, low-capacitance, 4-conductor motor cables should be used (U, V, W, PE conductors and outer shield). Suitable cables include, for example, SIEMENS PROTOFLEX. The cable shield must be connected at both ends to the housings/frame (ground) through the largest possible surface area. Cables with a YCY copper braiding provide a good shielding effect. They are better than cables with SY steel armor.

⇒ <u>Feeder cables for motor temperature monitoring (PTC or KTY) must be routed separately away from the motor cables!</u> We recommend that shielded signal cables are used.

⇒ If it is absolutely necessary to interrupt motor feeder cables to connect reactors or terminals, then the non-shielded cable should be kept as short as possible.

⇒ If it is absolutely necessary to interrupt the motor feeder cable to connect contactors, switches, terminals then these must be separately mounted away from other terminal strips, switches etc.

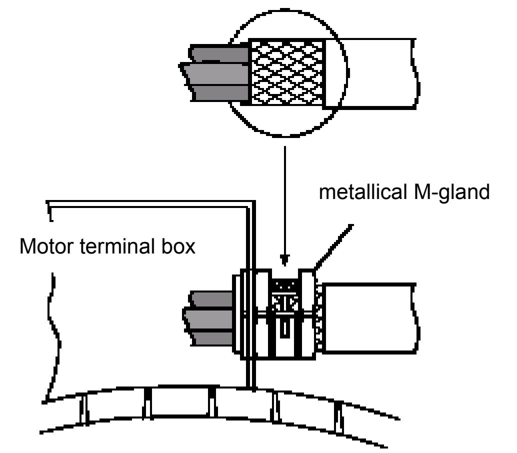


Fig. 4-10 Connecting the cable shield at the motor

⇒ A suitable M gland with shield contact can be used to connect the cable shield to the motor. It must be ensured that there is a low-impedance connection between the motor terminal box and motor frame (ground).

⇒ The motor terminal boxes should be manufactured out of metal and be electrically conductive (gray cast iron / aluminum alloy). It must be ensured that the terminal box cover is flush with the terminal box so that there are no gaps which could result in an antenna effect.

Max. motor feeder cable lengths for non-filtered drive units

The values specified in the table apply for a 4 kHz pulse frequency.

Type	Size	Line supply voltage +- 10%	Without output choke		With output choke	
			Shielded	Non-shielded	Shielded	Non-shielded
G110	A-C	200-240V	**25m**	**50m**	**-**	**-**
MM410	AA/ AB	100-240V	30m	50m	-	-
MM411	CS B	380-480V	5m	-	-	-
	CS C	380-480V	5m	-	-	-
MM420	A	200-240V	50m	100m	200m	300m
		380-400V			150m	225m
		401-480V			100m	150m
	B	200-240V			200m	300m
		380-400V			150m	225m
		401-480V			100m	150m
	C	200-240V			200m	300m
		380-400V			200m	225m
		401-480V			100m	150m
MM430	C	380-480V	50m	100m	200m	300m
	D					
	E					
	F					
MM440	A	200-240V	50m	100m	200m	300m
		380-400V			150m	225m
		401-480V			100m	150m
	B	200-240V			200m	300m
		380-400V			150m	225m
		401-480V			100m	150m
	C	200-240V			200m	300m
		380-400V			200m	300m
		401-480V			100m	150m
		500-600V			100m	150m
	D	200-600V			200m	300m
	E	200-600V				
	F	200-600V				
	FX	380-480V	200m	300m	-	-
	GX	380-480V			-	-

Table 4-1 Max. permissible motor feeder cable lengths for non-filtered drive units

If the drive converter is used to feed several motors (group drive) then the total cable length as a sum of the individual motor cables is decisive.

Max. motor feeder cable lengths for filtered drive units

The permissible motor feeder cable lengths are reduced to the following values in order to maintain the specified limit values when using EMC filters:

<table>
<tr><th></th><th></th><th colspan="2">Integrated filter</th><th colspan="3">Additional filter</th></tr>
<tr><th>Type</th><th>FS</th><th>Class A</th><th>Class B</th><th>Class A</th><th>Class B</th><th>Class B (low leakage currents)</th></tr>
<tr><td rowspan="2">G100</td><td>A</td><td>10m</td><td rowspan="2">5m</td><td rowspan="2">- / -</td><td rowspan="2">25m</td><td rowspan="2">5m</td></tr>
<tr><td>B-C</td><td>25m</td></tr>
<tr><td>MM410</td><td>AA-AB</td><td>- / -</td><td>5m / 10m[1]</td><td>- / -</td><td>- / -</td><td>5m</td></tr>
<tr><td>MM411</td><td>CS B-C</td><td>- / -</td><td>5m</td><td colspan="3">- / -</td></tr>
<tr><td rowspan="3">MM420</td><td>A</td><td rowspan="3">25m</td><td rowspan="3">- / -</td><td rowspan="2">25m</td><td rowspan="3">25m</td><td rowspan="2">5m</td></tr>
<tr><td>B</td></tr>
<tr><td>C</td><td>- / -</td><td>- / -</td></tr>
<tr><td rowspan="4">MM430</td><td>C</td><td rowspan="4">25m</td><td rowspan="4">- / -</td><td rowspan="4">- / -</td><td>25m</td><td rowspan="4">- / -</td></tr>
<tr><td>D</td><td>50m</td></tr>
<tr><td>E</td><td>30m</td></tr>
<tr><td>F</td><td>25m</td></tr>
<tr><td rowspan="8">MM440</td><td>A</td><td rowspan="6">25m</td><td rowspan="8">- / -</td><td rowspan="2">25m</td><td rowspan="3">25m</td><td rowspan="2">5m</td></tr>
<tr><td>B</td></tr>
<tr><td>C</td><td rowspan="6">- / -</td><td rowspan="6">- / -</td></tr>
<tr><td>D</td><td>50m</td></tr>
<tr><td>E</td><td>30m</td></tr>
<tr><td>F</td><td>25m</td></tr>
<tr><td>FX</td><td rowspan="2">- / -</td><td rowspan="2">- / -</td></tr>
<tr><td>GX</td></tr>
</table>

1) low-capacitance motor feeder cable with conductor/conductor <75pF/m, conductor/shield <150pF/m

Table 4-2 Max. permissible motor feeder cable lengths for filtered drive units

4.2.2 Signal cables

General

Signal cables should be protected against possible interference being coupled-in. This is the reason that shielded cables should also be used here.

Digital signal cables

The shields of digital signal cables, e.g. 24 V control signals, encoder cables, should be connected at both ends to ground through the largest possible surface area to ensure a good electrical connection. If there is a poor potential bonding between the shield connections then in order to reduce the current flowing through the shield, an additional bonding conductor – minimum 10 mm² – should be routed in parallel to the shield. It is permissible to connect the shield several times to ground. We do not recommend foil-type shields. Braided shields have a shielding effect which is 5 times better than foil-type shields.

Analog signal cables

In order to establish good potential bonding the shields of analog signal cables should be connected to ground at both ends.

When the shields of analog signal cables are connected at both ends this can result in signal noise – the so-called ground loops (hum). In this case, one of the two ends is grounded through a capacitor (0.01÷0.1 µF) which has a very low impedance at high frequencies.

4.3 Routing cables outside the electrical cabinet

General

The largest possible clearance must be maintained between signal and power cables. If an adequate separation is not possible, then the shielded cables should be separately routed in shielded, grounded cable ducts (metal).

Basic rules when routing cables

⇒ Signal, control and data cables should be routed so that they are not interrupted.

⇒ When shielded cables are interrupted, then it should be ensured that the shield is still kept intact.

⇒ Route cables using metal, grounded cable trays or cable ducts.

⇒ Signal and power cables which run in parallel with one another should be separated by an appropriately high clearance or a grounded shield plate should be used

⇒ The longer that cable lengths run together then the higher must be the distance between them.

⇒ Cable tray/duct sections should be connected with one another through the largest possible surface area to ensure a good electrical connection.

⇒ Non-shielded cables/conductors belonging to the same circuit (outgoing and incoming conductors) should, if possible, be twisted and the distance between the outgoing and incoming conductors should be kept as low as possible.

⇒ Signal cables and the associated potential bonding cables should be routed with respect to another with the smallest distance between them.

⇒ Signal cables should not be routed close to equipment which generate strong magnetic fields (e.g. motors, transformers).

⇒ Unnecessary cable lengths (also for reserve cables) should be avoided.

⇒ Lightening protection (internal and external lightening protection) and grounding measures should be carried-out in compliance with the applicable Standards.

5 Summary of the basic EMC rules

Cabinet design

⇒ All of the metallic parts (e.g. side panels, support frames, mounting plates) of the electrical cabinet should be connected to one another through the largest possible surface area so that a good electrical connection is established

⇒ The cabinet door should be connected to the cabinet frame using short, wide grounding straps (top, center, bottom).

⇒ Shield rails and potential bonding rails should be connected to cabinet ground through the largest possible surface area.

⇒ All connections should be permanent and rugged. When making screw connections at painted and coated metal parts, either special contact washers (serrated washers) should be used or the insulating protective coating (e.g. paint) should be removed.

⇒ All metallic enclosures/housings of the components installed in the cabinet (e.g. filter, drive converter) should be connected through the largest possible surface area to the electrical cabinet ground in order to establish a good electrical connection. The best solution is to mount the various components on a bare, grounded mounting plate which has good conductive properties (e.g. galvanized steel).

⇒ The coils of contactors, relays, solenoid valves and motor holding brakes should be provided with the appropriate interference suppression elements, for instance, RC elements, varistors etc.

Cable routing

⇒ Signal/data cables must be routed, spatially separated from motor cables. In the electrical cabinet there should be a minimum clearance of approx. 20-25 cm between the cables or the cables should be separated by a grounded shielding plate.

⇒ Filtered line supply feeder cables should be routed separately away from non-filtered line supply feeder cables and motor feeder cables.

⇒ Control/data cables and line supply cables should, as far as possible, not be routed in parallel to motor feeder cables. The longer that the cables are routed next to one another, then the higher the distance between cables must be.

⇒ Control/data cables and line supply cables should cross, where necessary, motor feeder cables at 90°.

⇒ Avoid unnecessary cable lengths

⇒ Cables should be routed as close as possible to grounded housing components, for example, mounting plates, support frames, cable ducts and trays etc.

⇒ Signal cables and the associated potential bonding conductors should be routed with the shortest distance between them.

⇒ Ground reserve conductors at both ends. This provides an additional shielding effect.

⇒ Signal cables/data cables should, if at all possible, enter the cabinet at one level (e.g. only from below).

⇒ Signal cables, especially setpoint and actual value cables, should be routed without any interruption. If cables do have to be interrupted then the shield should be kept intact and continuous.

Cables

⇒ Shielded, low-capacitance, 4-core motor feeder cables should be used.

⇒ Separately route motor feeder cables and PTC/ KTY cables. PTC/ KTY cables must be connected to the drive converter through a separate cable. From the EMC perspective, PTC/ KTY cables are treated just like control cables.

⇒ Signal/data cables should preferably be shielded in order to minimize disturbances being coupled-in.

Shields

⇒ Foil-type shields are not suitable. Braided shields have a shielding effect which is 5 times better than foil-type shields.

⇒ Shields should be grounded at both ends through the largest surface area and connected through the largest possible surface area to grounded enclosures/housings. This is the only way in which they are effective against electromagnetic disturbances.

⇒ Cable shields should be directly connected to a shield rail after the cable enters the cabinet. The shields should then be continued from there.

⇒ Never interrupt shields!

⇒ Metal cable clamps are preferably used to retain and connect braided shields. The cable clamps must wrap around the shield through the largest possible surface area ensuring a good electrical contact.

⇒ Only metallic or metallized connector housings should be used at plug connections.

Potential bonding

⇒ Adequately dimensioned potential bonding conductors must be used to equalize potentials (voltage levels) between parts and components of a plant/system.

⇒ In the electrical cabinet, all of the potential bonding cables are connected to the central grounding rail or to a separate potential bonding rail grounded through a low-ohmic connection.

⇒ Cross-section of the potential bonding cables > $10 mm^2$.

⇒ Flat straps should be used to connect plant/system parts to ground.

6 EMC troubleshooting

General

In-depth knowledge about EMC and physical and electrical basics are necessary to successfully troubleshoot and remove faults and disturbances. It is also important to be knowledgeable about circuitry, and the effects of ground and shield connections etc. The engineer/technician is responsible in carrying-out a theoretical and practical system analysis. Due to the very nature of EMC problems, faults have to be precisely observed and documented and various measures tried out. The objective is to identify sources and receivers of interference and the corresponding coupling paths. This then allows the appropriate counter-measures to be implemented to increase the level of EMC.

Examples

⇒ Disturbed AOP/BOP displays due to electrostatic discharge

⇒ RS485 communication disturbances as a result of strong electromagnetic radiation

⇒ Brief speed fluctuations due to frequent phase failures or significant voltage dips on the line feeder cables

⇒ High shield currents due to poor potential bonding connections between the individual devices / equipment sections

6.1 Localizing EMC problems

General

Localizing EMC problems is made that much easier by precisely analyzing and documenting the faults which have occurred and trying-out the appropriate counter-measures. Localizing EMC problems can be that much more specific the more precise the fault description is.

Localizing the source of interference

⇒ Is the functional disturbance continuous or only occasional (sporadic)?

⇒ Is there an interrelationship between the fault occurring, fault rate and operating modes of the faulted equipment and the operation of other equipment?

⇒ Can the source of interference be identified by shutting down other equipment step-by-step?

⇒ Check the ground and potential bonding connections!

Localizing the interference receiver

⇒ Can hardware and software faults/errors be absolutely ruled-out as far as the functional disturbances are concerned?

⇒ Use the diagnostic functionality of the systems in order to identify the faulted equipment (LEDs, fault displays, fault counters, ...).

⇒ In order to localize the faulted equipment it helps to specifically shutdown / isolate / replace parts of the system.

Identifying where disturbances are coupled-in

After the source of the interference and interference receiver have been localized, then the possible coupling paths must be found and reduced. In some cases, it is extremely time consuming to identify coupling mechanisms – especially if several mechanisms are simultaneously effective and are essentially cascaded. Some ways of looking for interference coupling paths include:

⇒ Electrical coupling paths can be proven/confirmed by electrically isolating systems. For example, using separate power supply cables, supply through isolating transformers etc.

⇒ Induced voltages are transferred as a result of strong magnetic fields, e.g. switched inductances which are located close to cables.

⇒ If the fault still remains after the faulty cables have been disconnected at the device, then this indicates electromagnetic interface. This can be checked by moving the device a considerable distance away from the source or it can be located in a shielded enclosure. A check should also be made as to whether the specific interference immunity of the device or devices match the actual environmental conditions.

⇒ Cable-coupled disturbances can be tracked down using clip-on ammeters and probes.

As troubleshooting continues, it can be extremely helpful to simulate individual "EMC phenomena" using the appropriate generators to create disturbances. This procedure can be used to investigate the specific EMC characteristics of a plant or a piece of equipment.

6.2 Removing disturbances

General

In order to remove functional faults and disturbances arising from insufficient EMC, the various remedial measures must be carried-out on a system-for-system basis. The remedial measures taken can either be combined or individually applied:

⇒ Remove or reduce the level of disturbance emitted from the source of interference (connecting interference suppression elements to coils, using filters, shielding plates, ...)

⇒ Increase the interference immunity of the equipment being disturbed (using filters, shielded enclosures, ...).

⇒ Remove coupling paths, e.g. increase the distance between power and signal cables, use shielded cables, route cables along metal surfaces, etc.

⇒ Check that the EMC Guidelines have been maintained and the measures specified in the documentation associated with the product have been applied.

A Appendix

A.1 Abbreviations

CE	European Community; French: **C**ommunauté **E**uropéenne
DKE	Deutsche Kommission Elektrotechnik Elektronik Informationstechnik im DIN und VDE [German Commission for Electrical Engineering, Electronics, Data Processing in Din and VDE]
DIN	Deutsches Institut für Normung e.V.
EMC	Electromagnetic Compatibility
EN	European Standard
EU	European Union
EEC	European Economic Community
IGBT	Insulated Gate Bipolar Transistor
PDS	**P**ower **D**rive **S**ystem
PTC	Positive Temperature Coefficient
VDE	Verband der Elektrotechnik Elektronik Informationstechnik e. V. [Association of Electrical Engineering, Electronics, Data Processing]

A.2 EC Directives

73/23/EEC	Directive of the Council to harmonize the legislation of the Member States for electrical equipment to be used within specific voltage limits
89/336/EEC	Directive of the Council to harmonize the legislation of the Member States for electromagnetic compatibility

A.3 EMC Standards listed acc. to European Standards

- EN 55011:1998 Amendment A2:2002
  Industrial, scientific and medical radio-frequency equipment (ISM equipment) — Radio interference — Limit values and measuring techniques
- EN 60146-1-1: 1991 Amendment A1: 1996
  Semiconductor converters – General requirements and line-commutated converters – Part 1-1: Specifications of basic requirements
- EN 61000-2-2: 1993
  Electromagnetic compatibility (EMC) – Part 2: Environment – Section 2: Compatibility levels for low-frequency conducted disturbances and signaling in public low-voltage power supply systems
- EN 61000-2-4: 1998
  Electromagnetic compatibility (EMC) – Part 2: Environment – Section 4:

Compatibility levels in industrial plants for low-frequency conducted disturbances

- EN 61000-3-2:2000
  Electromagnetic compatibility (EMC) — Part 3-2: Limits — Limits for harmonic current emissions (equipment with input current up to and including 16 A per phase)
- EN 61000-3-3:1995 Amendment A1:2001
  Electromagnetic compatibility (EMC) — Part 3-3: Limits — Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current ≤ 16 A per phase, which are not subject to special connection conditions
- EN 61000-3-11:2000
  Electromagnetic compatibility (EMC) — Part 3-11: Limits — Limitation of voltage fluctuations and flicker in low-voltage supply systems — Equipment and devices with a rated current ≤ 75 A which are subject to special connection conditions
- EN 61000-4-2:1995
  Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 2: Electrostatic discharge immunity test – Basic EMC publication
- EN 61000-4-3: 1995 Amendment A1:1998
  Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 3: Radiated, radio-frequency, electromagnetic field immunity test – Basic EMC publication
- EN 61000-4-4: 1995
  Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 4: Electrical fast transient/ burst immunity test – Basic EMC publication
- EN 61000-4-5: 1995
  Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 5: Surge immunity test
- EN 61000-4-6: 1996
  Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 6: Immunity to conducted disturbances, induced by radio-frequency fields
- EN 61000-4-8: 1993
  Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 8: Power frequency magnetic field immunity test – Basic EMC publication
- EN 61000-4-9: 1993
  Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques; Section 9: Pulse magnetic field immunity test – Basic EMC publication
- EN 61000-4-10: 1993
  Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 10: Damped oscillatory magnetic field immunity test – Basic EMC publication
- EN 61000-6-1:2001
  Electromagnetic compatibility (EMC) — Part 6-1:
  Generic Standards — Immunity to disturbances — Domestic environments, business and trade areas as well as small companies

- EN 61000-6-2:2001
  Electromagnetic compatibility (EMC) — Part 6-2:
  Generic Standards — Immunity to disturbances — Industrial environments
- EN 61000-6-3:2001
  Electromagnetic compatibility (EMC) — Part 6-3:
  Generic Standards — Emissions — Domestic environments, business and trade areas as well as small companies
- EN 61000-6-4:2001
  Electromagnetic compatibility (EMC) — Part 6-4:
  Generic Standards — Emissions — Industrial environments
- EN 61800-3:1996 Amendment A11:2000
  Power drive systems — Part 3:
  EMC Product Standard including special testing techniques

A.4 Internet links

⇒ International Standards Associations:
http://www.iec.ch/index.html
http://www.iso.ch/iso/en/ISOOnline.frontpage

⇒ European Standards Association:
http://www.cenorm.be/
http://www.cenelec.org/Cenelec/Homepage.htm
http://www.etsi.org/

⇒ German Standards Associations:
http://www.dke.de/
http://www2.din.de/
http://www.vde.de/vde/

⇒ German Regulatory Bodies
http://www.regtp.de/

⇒ List of the published Council Journals of the EC
http://www.newapproach.org/
http://europa.eu.int/eur-lex/de/index.html

⇒ Standards
http://www.vde-verlag.de/
http://www.iec-normen.de/

⇒ EMC Compendium
http://www.EMC-online.de/

A.5 References

⇒ Elektromagnetische Verträglichkeit: Grundlagen – Praxis; Arnold Rodewald; 2.Auflage; Vieweg Verlag; ISBN: 3-528-14924-8

⇒ Elektromagnetische Verträglichkeit; Adolf J. Schwab; 4.Auflage; Springer Verlag; ISBN: 3-540-60787-0

⇒ EMC nach VDE 0100; Wilhelm Rudolph, Otmar Winter; VDE Verlag 2000; ISBN 3-8007-2532-0

⇒ CE-Konformitätskennzeichnung: EMC-Richtlinie und EMC-Gesetz, Anforderungen an Hersteller und Auswirkungen auf Produkte; Anton Kohling; Publicis-MCD-Verl. 3. Auflage; ISBN: 3-89578-051-0

⇒ EMC von Gebäuden, Anlagen und Geräten: Praktische Umsetzung der technischen, wirtschaftlichen und gesetzlichen Anforderungen für die CE-Kennzeichnung, Anton Kohling (Hrsg.), Ger Balzer..; VDE-Verlag 1998; ISBN: 3-8007-2261-5

Siemens AG
Automation and Drives
Standard Drives
Postfach 3269, D – 91050 Erlangen
Federal Republic of Germany

MM4App_008

www.ad.siemens.de

Printed in the Federal Republic of Germany