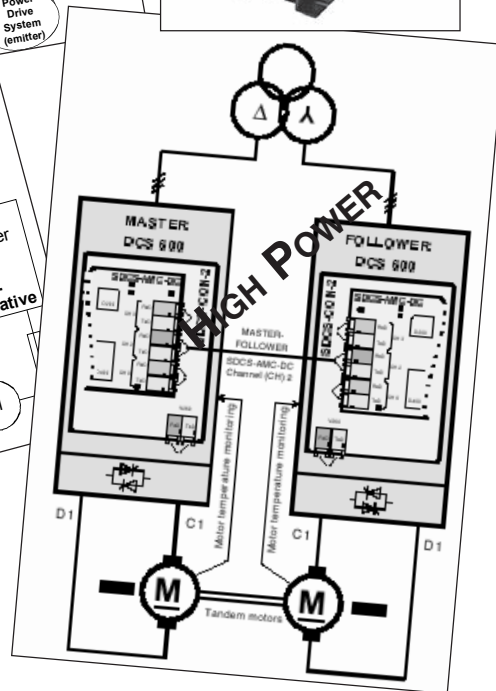
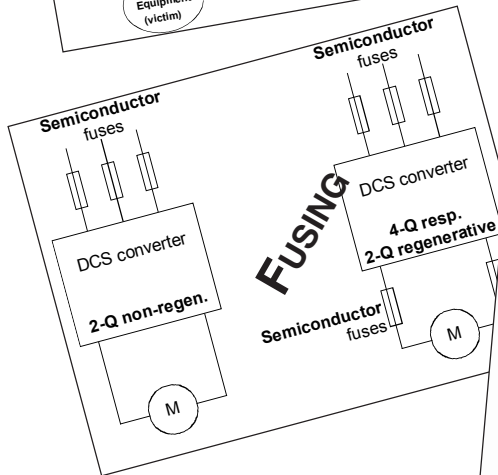
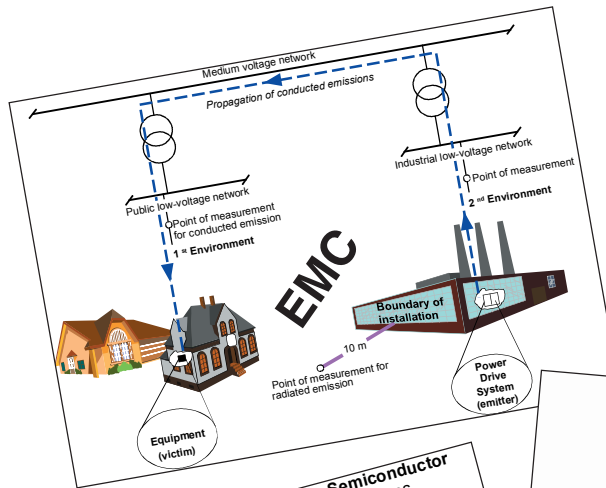


DCS Thyristor Power Converters for DC Drive Systems

Technical Guide



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1.1 Introduction

When using DC drives from ABB or any other supplier there is always basic knowledge required to enable you to understand:

- How your drive needs to be configured and engineered.
- How does your drive installation interact with any other installations surrounding the drive.
- What types of components need to be added to the converter and why to guarantee the correct functionality.
- How need components to be matched.
- What needs to be done to be inline with existing laws and technical standards.

To have some support in to find solutions for all these problems ABB offers this type of documentation for your assistance.

All other documentation related to ABB's drives program apart from this will be found in the dedicated product documentation like *System Description*, *Technical Data*, *Operating Instruction* etc. and is generally available with every single drive delivered.

1.1.1 How to use this description

The purpose of this documentation is to provide profound general information about drives, their engineering including additional requirements for special accessories, their technical environment as well as basic information of how to handle modernization of old installations.

1.1.2 Target group

All users having basic knowledge as well as experience in practical exercises with DC-Drives.

2 Technical environment

2.1 EMC Compliant Installation and Configuration for a Power Drive System

2.1.1 Introduction

General

This guide assists the design and installation personnel when intending to achieve compliance with the requirements of EMC Directive in the user's systems and installations, when using DCS converters.

The purpose of this chapter

The purpose of this chapter is to guide Original Equipment Manufacturers (OEM), System Integrators and Panel builders in designing and installing DCS converters and their auxiliary components into their own installation and systems. The auxiliaries include EMC filters, line reactors, fuses, etc. If these instructions are followed, it is possible to fulfil EMC requirements and give CE marking when necessary.

Definitions

The **EMC Product Standard for Power Drive Systems, EN 61800-3 (or IEC 1800-3)** is used as normative standard for variable speed drives. The terms and definitions applied in the standard are also used in this manual. The different types of equipment used in this guide (refer to *section 2.1.2 Definitions*) are the same as defined in the EMC Directive.

Practical Installations and Systems

This manual gives a brief insight of EMC in terms of definitions and offers practical EMC solutions and a connection example with essential remarks and hints for the EMC compliance of power drive systems. The solutions can be directly used or applied by OEM or Panel builder.

The Directives concerning Drives

There are three directives that concern variable speed drives. They are Machinery Directive, Low Voltage Directive and EMC Directive. The main objective of the **EMC Directive** is to guarantee the free movement of apparatus and to create an acceptable electromagnetic environment in the European Economic Area (EEA).

Product-specific Manuals

The detailed information of the installation and use of products can be found in product-specific manuals included in the product package. This guide is meant to be used together with product-specific manuals.

2.1.2 Definitions

Electromagnetic Compatibility (EMC)

EMC stands for Electromagnetic Compatibility. It is the ability of an electrical/electronic equipment to operate satisfactorily within an electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment (International Electrotechnical Vocabulary, IEC 50 Chapter 161). This is a legal requirement for all equipment taken into service within the European Economic Area (EEA).

The terms used to define compatibility are shown in fig. 2.1/1.

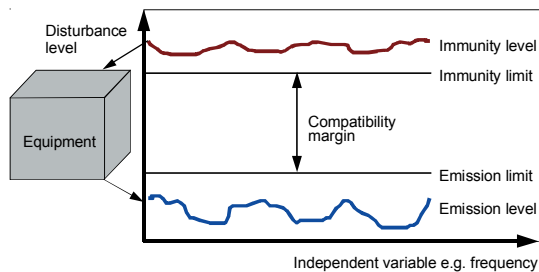


Fig. 2.1/1 Immunity and emission compatibility.

As the variable speed drives are described as a source of interference, it is natural that all parts that are in electrical or airborne connection within the Power Drive System are part of the EMC compliance. The concept that a system is as weak as its weakest point is valid here.

Immunity

Electrical equipment should be immune to high frequency and low frequency phenomena. High-frequency phenomena include electrostatic discharge (ESD), electrical fast transient (Burst), radiating electromagnetic field, conducted radio frequency disturbance and electrical surge. Typical low-frequency phenomena are mains voltage harmonics, notches and unbalance in 3-phase networks.

Emission

The source of high-frequency emission of thyristor converters is the fast switching of power components such as thyristors and control electronics. This high-frequency emission can propagate by conduction and radiation.

Power Drive System (PDS)

According to the EMC Product Standard EN 61800-3 a variable speed drive, which controls a driven equipment, constitutes part of an installation. The standard defines a drive as a Power Drive System (PDS).

It is recommended that design and installation responsible personnel have this standard available and are familiar with this standard. All standards are available from the national bodies on standardisation and from CENELEC, rue de Stassart, 35, 1050 Bruxelles.

The machine or system made by OEM or Panel builder consists more or less of the PDS parts or many PDSs in a configuration. The installation guidelines for EMC compliance described in this manual are used within the definition of Power Drive Systems, but the same guidelines can, or in some cases, should be extended to all installation. This manual gives principles and a practical EMC connection example, which can be applied to user's system.

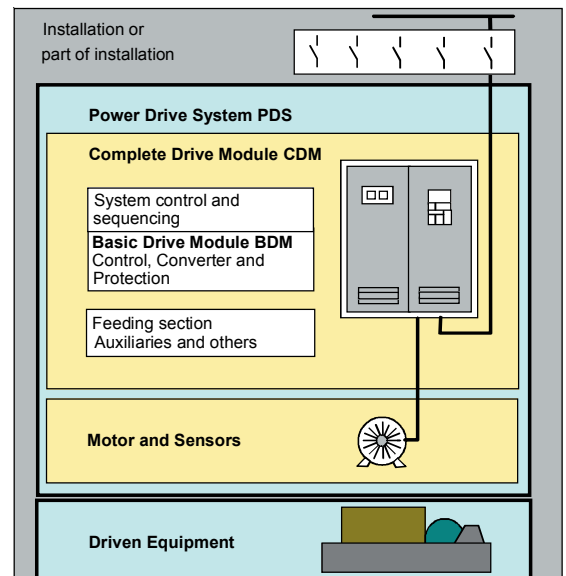


Fig. 2.1 /2 Terms and abbreviations used in Drives.

Types of Equipment

EMC Directive applies to "all electrical and electronic appliances together with installations containing electrical and/or electronic components liable to cause electromagnetic disturbance or the performance of which is liable to be affected by such disturbance".

The interpretation of EMC Directive for different configuration in the area of drives can be divided into several levels:

Component

In this content the interpretation of component can be divided into several categories. If a component performs a direct function, as the variable speed drives do, they are considered equivalent to apparatus.

Direct function:

Any function which meets the needs of a user and which can be directly used by such a user, without the need to make any further adjustments other than any connections essential for its electrical power supply or for the exchange of analogue or digital signals.

Apparatus

A finished product containing electrical and/or electronic components and intended to be placed on the market and/or taken into service as a single commercial unit.

System

Several items of apparatus combined to fulfil a specific objective and intended to be placed on the market as a single functional unit.

Installation

A combination of items of apparatus, equipment and/or components put together at a given place to fulfil a specific objective but **not** intended to be placed on the market as a single functional unit.

CE Marking for EMC

Components with direct functions, Apparatus and Systems have to be CE marked.

Components with **no direct function** for the final consumer are **not** CE marked.

Installations are required to satisfy various bases of the Directives, but are **not** required to be CE marked.



Fig. 2.1/3 The CE mark.

Installation Environments

The PDSs can be connected to either industrial or public power distribution networks. The environment class depends on the way the PDS is connected to the network.

The environment classes are First and Second Environment.

First Environment

The First Environment includes domestic premises. It also includes establishments directly connected without intermediate transformer to a low-voltage power supply network which supplies buildings used for domestic purposes.

Second Environment

Second Environment includes all establishments other than those directly connected to a low-voltage power supply network which supplies buildings used for domestic purposes.

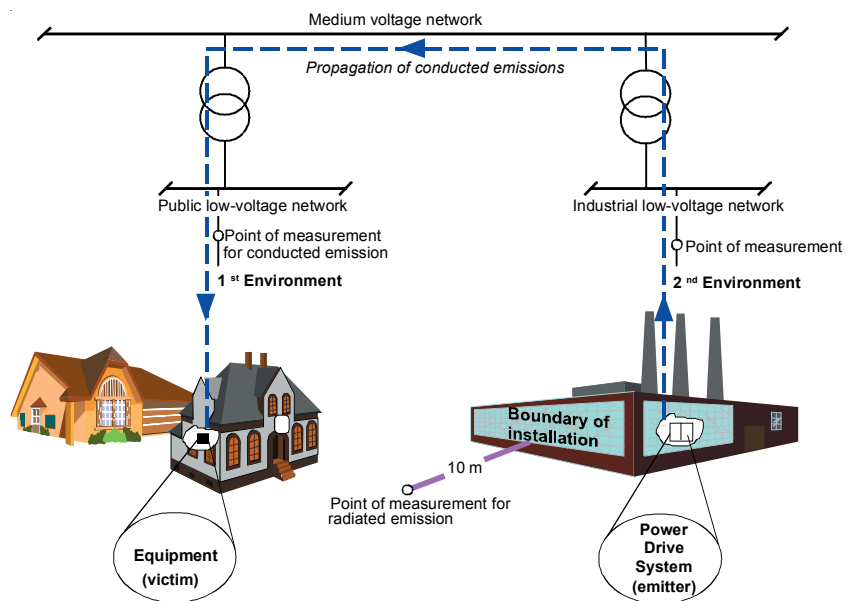


Fig. 2.1/4 Illustration of Environment Classes and propagation of disturbances.

Propagation

For PDSs in the second environment, the user shall ensure that excessive disturbances are not induced into low-voltage network, even if propagation is through a medium voltage network.

Note! Fig. 2.1/4 shows the case when a victim is in a 1st Environment. The situation is the same if a victim is in a 2nd Environment in another installation. The measurements are carried out in that case only in case of dispute.

2.1.3 EMC Compliant Installation Guidelines

Note

In order to make the description in this chapter as short and easily readable as possible, cross references in the form **1**, **2** ... are used.

General

Converters and the major part of the devices, which constitute a DC Drive, cannot fulfil the EMC requirements independently from each other. They must be installed and connected by skilled personnel according to the guidelines laid down in this manual. This restriction is related to the expression "restricted distribution" in the short description of EN 61800-3, which is the EMC product standard for a Power Drive System.



NOTE!

The conformity procedure is matter of responsibility of ABB Automation Products GmbH and of the machine manufacturers or the plant builders corresponding to their share of the extension of the electrical equipment.

Product Standard EN 61800-3

EMC standard for drive systems (PowerDriveSystem), interference immunity and emissions in residential areas, enterprise zones with light industry and in industrial facilities. This standard must be complied with in the EU for satisfying the EMC requirements for systems and machines!

For emitted interference, the following apply:

EN 61000-6-3 Specialised basic standard for emissions in **light industry** can be satisfied with special features (mains filters, screened power cables) in the lower rating range *(EN 50081-1).

EN 61000-6-4 Specialised basic standard for emissions in **industry** *(EN 50081-2)

For interference immunity, the following apply:

EN 61000-6-1 Specialised basic standard for interference immunity in **residential areas** *(EN 50082-1)

EN 61000-6-2 Specialised basic standard for interference immunity in **industry**. If this standard is satisfied, then the EN 61000-6-1 standard is automatically satisfied as well *(EN 50082-2).

* The old generic standards are given in brackets

Definitions



Earth, earthing for safety



Ground, grounding for EMC, connection with chassis or housing with low inductance



Important instructions for plants with line filters

Filter in an earthed line (TN or TT Network)

The filters are suitable for earthed lines only, for example in public European 400 V lines. According to EN 61800-3, filters are not compatible in insulated industrial lines with own supply transformers due to their safety risks in such floating lines (IT networks).

Earth fault detection

Filters (with internal discharging resistors), cables, the converter and the motor have together a considerable capacitance to ground, which can cause an increased capacitive earth current. The tripping threshold of an earth fault detector that measures this current must be adapted to this higher value.

High voltage test

Because of the capacitors of the line filter the high voltage test has to be done with dc voltage to protect the components.



Warning

Line filters contain capacitors, which can keep dangerous voltages at the terminals after the switch off of the mains voltage. The discharge by internal resistors takes some seconds. Therefore a waiting time of **at least 10 s** and a voltage check are obligatory before you begin your work at the equipment.



General safety instructions

Electrical machines or devices are items of equipment used in industrial power installations. During operation, parts of this equipment are live and bare, or moving, rotating, etc. These parts may cause great material damage and serious heavy injuries, if, for instance, their covers are removed or if they are not properly used or operated.

It must therefore be ensured that

- only qualified experts perform work at these machines and devices,
- these persons always have available - among other things - the operating instructions and other product-specific documentation supplied along when performing work, and are obliged to meet the requirements laid down in these documents,
- non-qualified persons are not authorised to perform any work at or near these machines and devices.

The operating instructions cannot take into consideration every possible case of configuration, operation or maintenance. Thus, they mainly give such advice only, which is required by qualified personnel for normal operation of the machines and devices in industrial installations.

If in special cases the electrical machines and devices are intended for use in non-industrial installations - which may require stricter safety regulations (e.g. protection against contact by children or similar) -, these additional safety measures must be carried out by the customer during assembly.

Earth connections must be made according to IEC 364!

1 Classification

First environment (residential area with light industry) with restricted distribution	
Not applied, since general distribution sales channel excluded	
Not applicable	satisfied
satisfied	

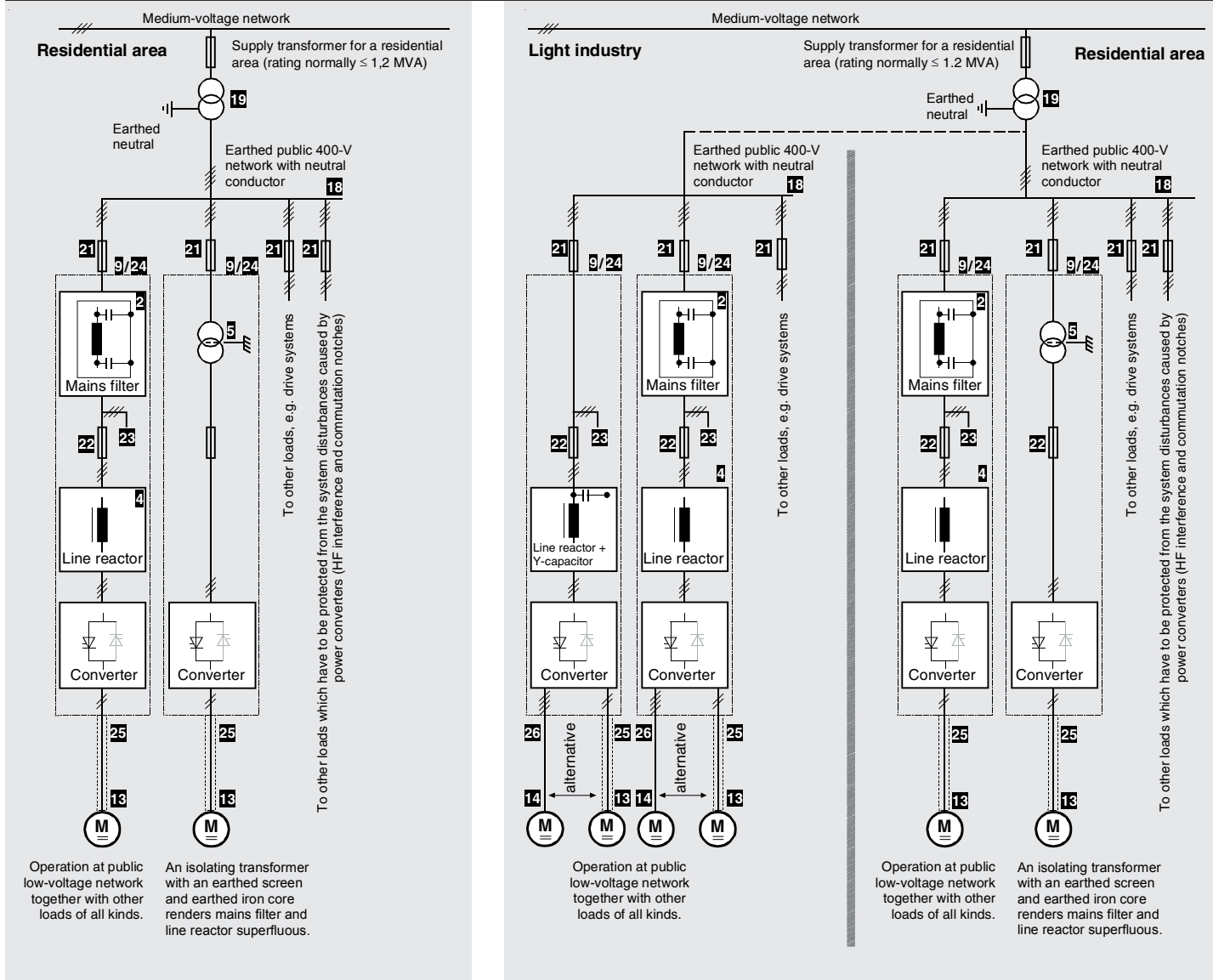
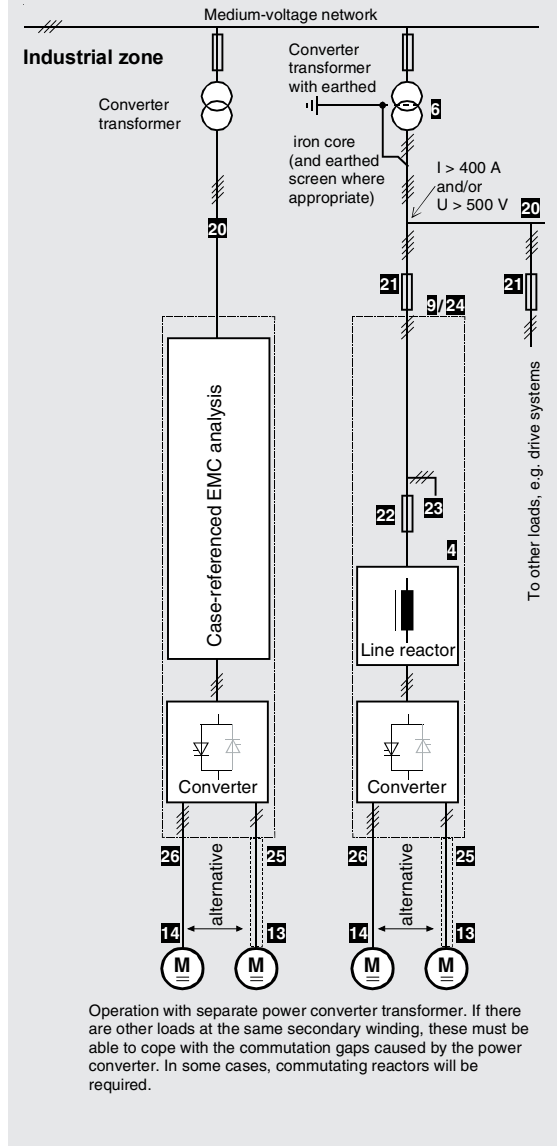
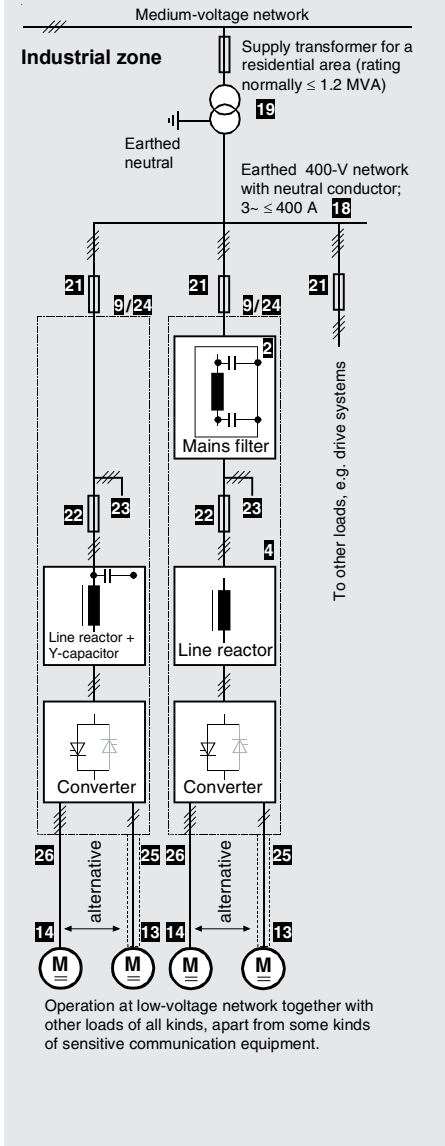


Fig. 2.1/5: Classification

Second environment (industry) with restricted distribution		
Not applicable		
satisfied	on customer's request	satisfied
satisfied		

Standards
EN 61800-3
EN 61000-6-3
EN 61000-6-4
EN 61000-6-2
EN 61000-6-1



The field supply is not depicted in this overview diagram. For the field current cables, the same rules apply as for the armature-circuit cables.

Legend

	Screened cable
	Unscreened cable with restriction

2 Three-phase filters

EMC filters are necessary to fulfil the standard for emitted interference if a converter shall be run at a public low voltage line, in Europe for example with 400 V between the phases. Such lines have an earthed neutral conductor. ABB offers suitable three - phase filters for 400 V and 25 A...600 A and 500 V filters for 440 V lines outside Europe (see *System description / Technical data*).

Lines with 500 V to 1000 V are not public. They are local lines inside factories, and they do not supply sensitive electronics. Therefore converters do not need EMC filters if they shall run with 500 V and more (see also 6).

3 Single-phase filters for field supply

Many field supply units are single - phase converters for up to 50 A excitation current. They can be supplied by two of the three input phases of the armature supply converter. Then a field supply unit does not need an own filter as shown at the connection example (24).

If the phase voltage to the neutral conductor shall be taken (230 V in a 400 V line) then a separate filter is necessary as shown below. ABB offers such filters for 250 V and 6...55 A (see *System description / Technical data*).

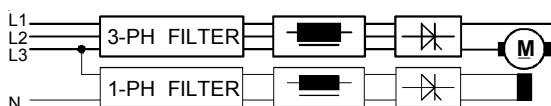


Fig. 2.1/6 Connection of single and three phase filters

4 Line reactors (Commutation reactors)

Converters cause short-duration short circuits at their AC inputs, so - called commutation notches. Such notches down to 0 V (100% depth) can be accepted at the secondary windings of converter (dedicated) transformers (operation without line reactors). However, their depth must be reduced if the same transformer shall supply more than one converter. In such case line reactors are necessary. They must cause about 1% relative voltage drop at rated current. So - called 1% reactors are also necessary if the power of the converter is very low compared with the available power of the transformer or supply line. ABB offers suitable 1%

reactors.

According to the European product standard EN 61800-3, the commutation notches must be kept below 20% of the line voltage in the first environment, whereas an upper limit of 40 % is specified for the second environment. This target can be achieved with the aid of line reactors. The inductance of these reactors to be applied in the first environment must have 4 times the value of the network inductance at the converter's connection point (point of common coupling, PCC) as shown in fig. 2.1/7. Therefore in many cases so-called 4% reactors are necessary, and therefore ABB offers also suitable 4% line reactors besides the 1% reactors (see *System description / Technical data*).

Due to the maximum power of public 400 V transformers (P_{MAX} = 1.2 MVA ⇒ I_{MAX} = 1732 A) and due to their relative short circuit voltage V_{SC} of 6% or 4% the maximum AC current which is available for a converter is 346 A or 520 A (I_{DC} ≤ 422 A or 633 A).

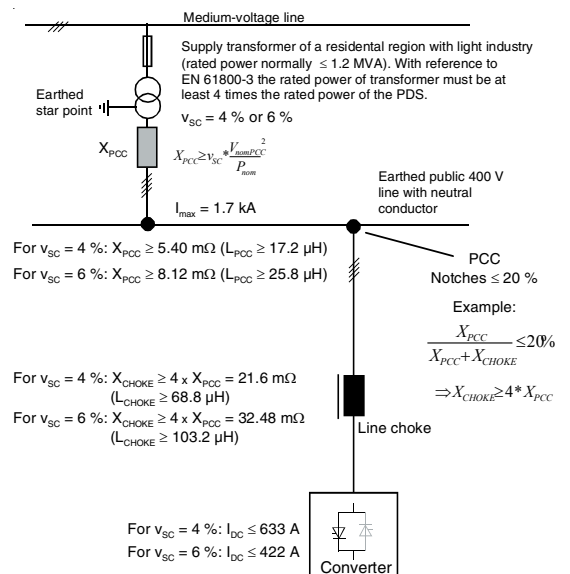


Fig. 2.1/7 Required minimum line reactor impedance for installation of converter in first environment

Often the maximum current is not limited by the transformer but by the power cable to the industry region. Therefore it is necessary to ask the energy supply company concerning the line impedance and the current which is available at the desired point of common coupling (PCC).

5 Separation transformers

A separation transformer makes line reactors unnecessary because of its leakage inductance, and a grounded screen between its windings saves an EMC filter, see 1 and 4. The screen and the iron core must be well connected with the mounting plate of the converter. If the transformer is located outside the converter cubicle the screen of a screened 3-phase cable must make this connection.

6 Converter (dedicated) transformers

A converter (dedicated) transformer transfers high power directly from a medium voltage line to a single large converter or to a local low voltage line for several converters (see 20). Furthermore it acts as separation transformer.

If such a converter transformer has no screen the EMC demands are nevertheless fulfilled in most cases because the RF interference energy can hardly get via the medium-voltage line and the transformer of the public line to the loads which must be protected against perturbances. In the case of a dispute a measurement must be done at the point of common coupling (public low - voltage line) according to EN 61 800-3.

7 Installation hints

8 Cabinets

All metal cubicles available on the market can be used; however, their mounting plates must have well conducting surfaces according to 9. If a drive system is placed in more than one cubicle their mounting plates must be connected by broad pieces of well conducting sheet metal.

9 Mounting plate

The mounting plate must be made from steel with zinc surfaces and without any painting. The PE copper bar must be mounted directly on the mounting plate without any insulating means between, and it must be connected with the plate by several bolts distributed in equal distances along its length.

10 Placement of devices

The converter, the line reactor, fuses, contactors and the EMC filter are to be placed on the mounting plate so that the connections can be

made as short as possible, especially those from the converter via the line reactor to the filter, and that the requirements in 15 can be fulfilled. The surface of the components to be mounted on the mounting plate has to be free of coating material (see 28).

11 Screening

12 Signal cables

The cables for digital signals, which are longer than 3 m and all cables for analogue signals, must be screened. Each screen must be connected at **both** ends by metal clamps (see fig. 2.1/8) or comparable means directly on clean metal surfaces, if both earthing points belong to the same earth line. Otherwise a capacitor must be connected to earth on one end. In the converter cubicle this kind of connection must be made directly on the sheet metal as close as possible to the terminals (see 27) and if the cable comes from outside also on the PE bar (see 25 and 26). At the other end of the cable the screen must be well connected with the housing of the signal emitter or receiver.

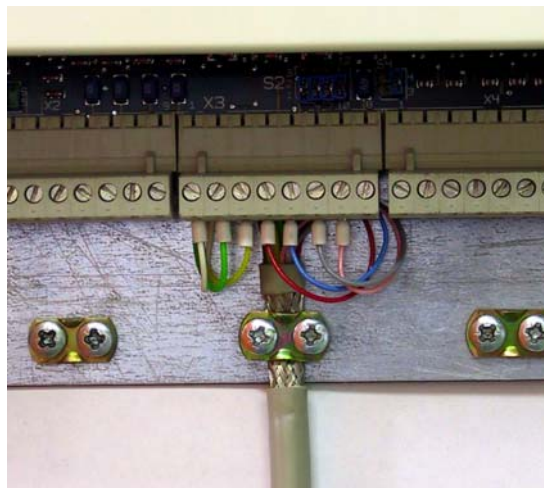
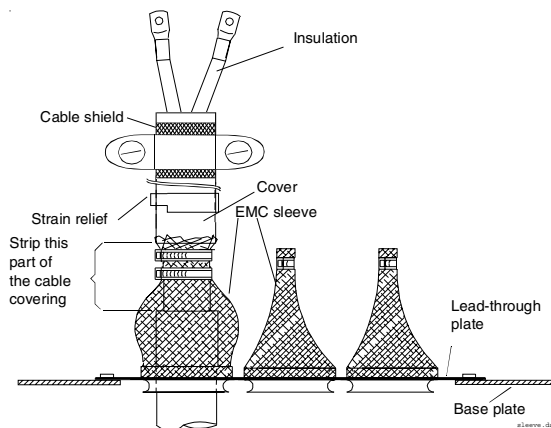


Fig. 2.1/8 Connection of a cable screen with the aid of metal clamp to the metal surface of the PCB carrier at a DCS converter

13 Power cables with screens

Power cables with screens are necessary, if they run over long distances (>20 m) where they are susceptible to EMC environmental conditions. The cable may have e.g. either a braided or spiral screen made preferably of copper or aluminium. The transfer impedance Z_T of the

power cable must be less than $0.1 \Omega/m$ in the frequency range up to 100 MHz, in order to ensure an effective reduction of emission and a significant increase of immunity. The screen must be pressed by a well conducting metal clamp directly against the mounting plate or the PE bar of the converter cubicle (see 24). Another connection option is via **EMC sleeve**.



There the contact surface shall be clean and as large as possible. The PE wire can be connected with a normal cable socket at the PE bar. Screened cables to the armature and to the excitation winding cause the lowest noise level.

14 Power cables without screens

If a screen is not necessary (see 13) the armature current cable must be a four-wire cable because two wires are needed as conductors for the parasitic RF currents from the motor to the RF filter in the cubicle. The unscreened field current cable **F** must be installed directly along the armature cable **A** as shown in fig. 2.1/9. A 2-wire cable is sufficient.

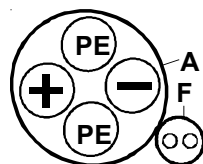


Fig. 2.1/9 Cross-sectional view of arrangement of field current cable **F** and armature cable **A**.

The arrangement according to 26 has been tested with a 20 m long motor cable with the result that the conducted emission requirements are fulfilled. If the connections to the armature are made from single-wire cables, especially if n parallel wires are necessary for higher currents, then n+1 PE cables must be arranged together

with them on a cable rail as shown in principle by the fig. 2.1/10 with n=4.

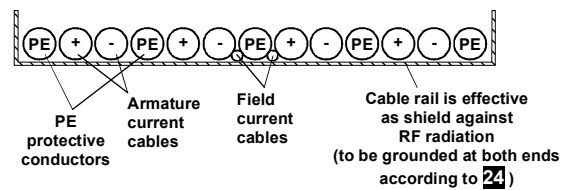


Fig. 2.1/10 Cross-sectional view of arrangement of field current cable **F** and armature cable **A** for higher currents

15 Placement of cables within the cabinet

All power cables which are directly connected with the converter (U1, V1, W1, C1, D1) must either be screened or be kept close together and close to the mounting plate and separate from all other cables (L1, L2, L3 included) and especially from unscreened signal cables. A recommended separation possibility is to place these power cables at the rear side of the mounting plate. If direct crossings of "polluted" cables and others, especially signal cables, are inevitable then they must be made rectangular.

16 Placement of cables outside the cabinet

The power cables must be arranged parallel and close together, see drawings in 14. The speed feedback must be screened and placed directly along the power cables to the motor if the housing of the tacho machine is electrically connected with the housing of the motor. If the housing of the tachometer or the encoder is insulated from the motor then a distance between the power and signal cables is advantageous.

17 Others

18 Earthed public low voltage lines

The rated voltages of a public European low voltage line are 400 V between the 3 phases and 230 V between a phase and the neutral conductor. These voltages are provided by a transformer with its 3-phase secondary winding in star connection. The star point is connected with the neutral conductor and it is earthed at the transformer station. The electrical power is distributed by 4-wire cables to the electricity consumers. At a cable stub to a consumer, the neutral

conductor must be earthed (local earth of the house or plant), and then it is split into a neutral and a PE conductor. Therefore a 3-phase load with neutral conductor must be supplied by a 5-wire cable. Converters, however, are 3-phase loads which do not need the neutral conductor in most cases. They can be supplied by 4-wire cables as shown in fig. 2.1/5. The change from the earthed neutral conductor outside the house, plant or factory to the internal PE conductor with the local earthing point between is not shown in this figure. Power limitation: see end of section 4!

19 Public low voltage lines in industrial regions

In an industrial region the noise level which is caused by converters is allowed to be 10 dB higher than in a residential region with included light industry. Therefore the protection targets concerning EMC can be met without screened motor cables if these cables are configured according to 14.

A public low voltage line of an industrial region may have an own supply transformer as shown in fig. 2.1/5, but often the lines of an industrial region and of a residential one are supplied by a common transformer. This depends on the power consumption of both regions and on their distance. Power limitation: see end of 4!

The dashed line between the lines of both regions indicates the version with only one transformer. This dashed line represents a power cable from the transformer at the right to the industrial region at the left. The power cable is important also for the EMC. Due to its length it reduces the noise level by at least 10 dB from the industrial to the residential region.

20 Industrial low voltage lines

Industrial low voltage lines are local lines in plants or factories. They have own supply transformers (see 6). In most cases they are insulated (IT network / no earthed star point) and their voltages are often higher than 400 V. The loads tolerate higher noise levels. Therefore and because industrial lines are decoupled from public lines by their transformers and distances, converters do not need EMC filters at industrial low-voltage lines (see 6). Problems for other loads

on the same line caused by commutation notches can be solved with the aid of line reactors (see 4).

Insulated lines must have also an earth conductor. The earth conductor is important for the feedback of parasitic RF noise currents from the DC motor via the converter to the earth point of the supply transformer of the line. Without such a conducted feedback the loop of the parasitic RF noise current is closed via the earth with the result that roving parts of this current can interfere with electronic equipment far away from the drive.

21 Fuses at the stubs from the low voltage line

At the stubs the cross-sections of the conductors become lower than in the main cable. Therefore fuses are prescribed which are adapted to the reduced cross section, and they must be located close to the stubs. This principle must be repeated at each reduction of the cross section from the stub at the main cable via the distribution net in a house or factory down to the connection point of a converter. The resulting fuse hierarchy is not shown in fig. 2.1/5. Only the fuses of the lowest rank are mentioned.

22 Fast Fuses

The converters are protected against overload by their control systems. Therefore dangerous overcurrents can be caused only by faults in the converters themselves or in the loads. In such cases the thyristors can be protected only with the aid of special fast fuses. Such fast fuses are shown directly at the AC connection points of the converters in fig. 2.1/5 as well as in the connection example, with more details, at the beginning of 24. But fast fuses outside the converters are necessary only for units of the lower power range. Larger converters comprise the fast semiconductor fuses.

23 Stub for auxiliary devices

Examples for auxiliary devices: field supply converters, transformers, fan motors.

24 Connection example in accordance with EMC

See fig. 2.1/11.

25 Armature and field cables with screens for "first environment"

See fig. 2.1/11.

26 Armature and field cables without screens for "second environment"

See fig. 2.1/11.

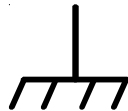
27 Encoder inputs and analogue I/O

See fig. 2.1/11.

Remarks

28 Internal ground connections

Additionally to the PE connections good HF connections to ground must be realised with the aid of a mounting plate which has a well conducting surface (sheet metal from zinc-plated steel for example). This means, the housings of all components like the line filter and the converter must be pressed directly to the mounting plate by at least four fixing bolts. The seating surfaces of the housings must be free from non conducting coating. These ground connections are indicated in the drawing at the top by the following symbol (symbol often used to indicate mass or chassis):



The PE bar must be connected with the mounting plate by many bolts, which are distributed along its whole length with equal distances. That's the reason the above symbol is used several times in the drawing.

29 Earth connections

All devices are connected with the PE bar by the mounting plate and also by PE conductors. The PE bar is earthed via the PE conductor of the 3-phase power cable.

Protective earth (PE) connections

The drive shall be earthed only by the earth conductor of the line cable. This serves for protection reasons and is indicated by the following symbol:



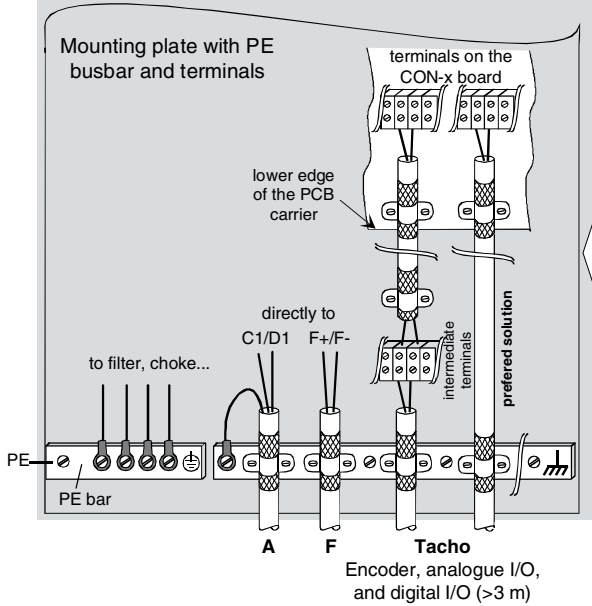
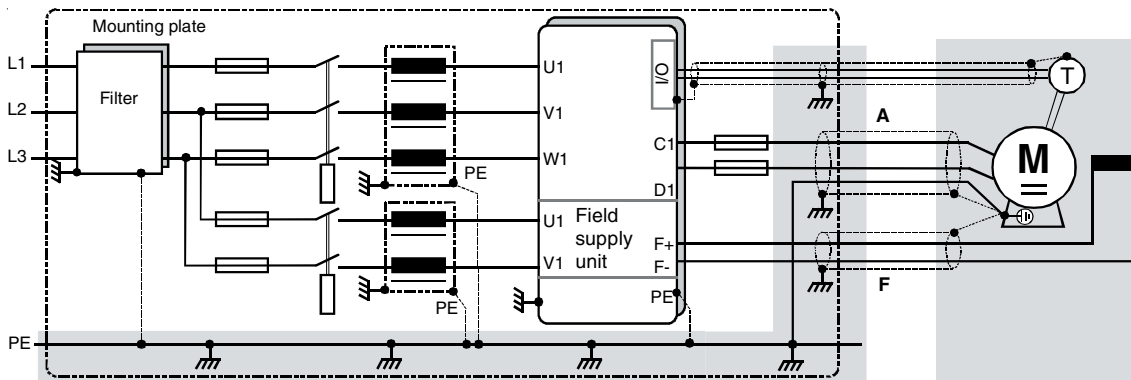
An additional local earthing, especially at the motor, raises the level of the RF noise on the line cable.

Earth connections between motor and driven machine

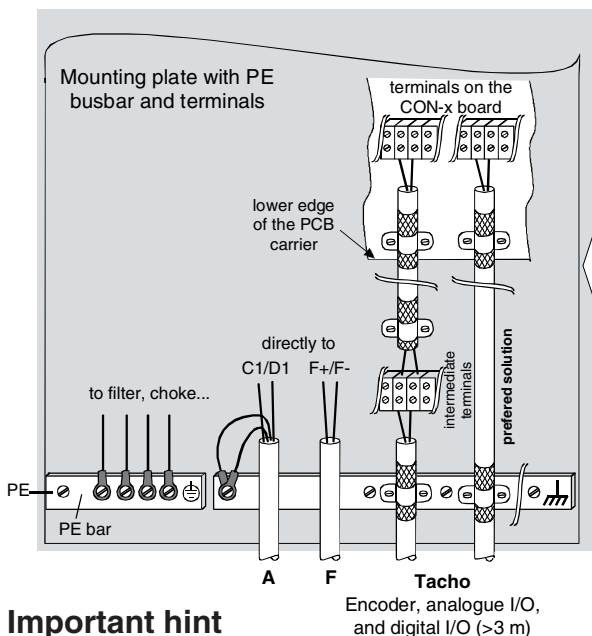
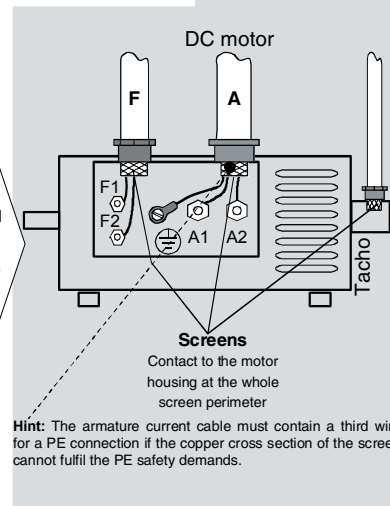
The earth of a grounded machine must be connected to the earth of the driving motor, in order to avoid floating potential.

Thermal motor protection

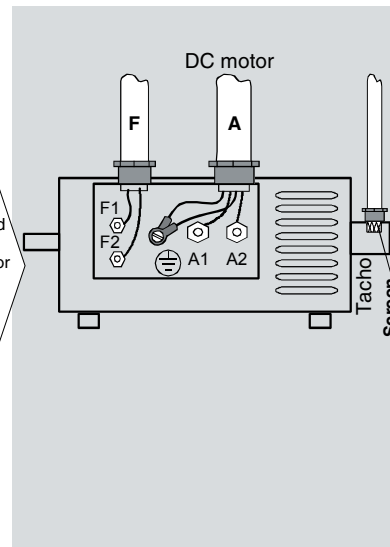
It is recommended that the cable of thermal motor protection device is fed through an appropriate filter at the point of entry into cubicle, in order to suppress EMC disturbances.



Armature and field cables with screens for "first environment"



Armature and field cables without screens suitable for "second environment"



Important hint

The example shows the principle structure of a DC drive and its connections. It is not a binding recommendation, and it cannot respect all conditions of a plant. Therefore each drive must be considered separately and with respect to the special application. Additionally the general installation and safety rules must be taken into account.

Fig. 2.1/11 Connection example in compliance with EMC

2.1.4 Summary

EC Declaration of Conformity for DCS Converters

An EMC declaration of conformity covering DCS converters verifies that they comply with the provisions of the European Low Voltage and EMC Directives (Directive 73/23/EEC, as amended by Directive 89/336/EEC and 93/68/EEC).

Compliance with the EMC Directive

The EMC Directive defines the requirements for immunity and emissions of electrical equipment used in the European Economic Area (EEA). The EMC product standard EN 61800-3 covers the requirements stated for thyristor power converters. DCS thyristor power converters comply with the EMC Directive in industrial low voltage network (up to 1000 V; also IT network), public low-voltage network in industrial regions and in earthed public low voltage network (restricted distribution) with the provisions summarised in the following three subsections.

Industrial Low-Voltage Network

1. Industrial low voltage lines are local lines in plants or factories with their own supply transformers (with earthed iron core), which decouple the industrial lines from the public lines. EMC filters are therefore not needed in industrial low voltage lines.
2. If static screening between primary and secondary windings of the supply transformer is present, it must be earthed in order to utilise the filtering effect.
3. Problems caused by commutation notches can be solved by insertion of appropriate line reactors.
4. The motor and control cables of the DCS converter must be installed in accordance with the specifications outlined in *section 2.1.3 - Installation hints* of this chapter.

Note: The DCS converter must not be equipped with EMC filter (refer to *section 2.1.3 - General* of this chapter) if installed in floating networks (IT-Network). The mains become connected to earth potential through the EMC Y filter capacitors. This may cause danger or cause damage to the unit. Furthermore a floating network is not public. Therefore higher noise levels are allowed.

Note: If screened motor cables are not available due to very high rated armature current, strict adherence to *section 2.1.3 - Power cables without screens* in this chapter is required.

Public Low-Voltage

Network in Industrial Regions


1. The DCS converters must be equipped with EMC filters (refer to publication *Technical data* for appropriate filter ratings) and line reactors.
2. The motor and control cables of the DCS converter must be installed in accordance with the specifications outlined in *section 2.1.3 - Installation hints* of this chapter.

Note: If screened motor cables are not available due to very high rated armature current, strict adherence is required to *section 2.1.3 - Power cables without screens* of this chapter.

Earthed Public Low-Voltage Network (Restricted Distribution)

1. The DCS converters must be equipped with EMC filters and line reactors.
2. The motor and control cables of the DCS converter are basically screened.
3. In case a separation transformer is applied, its screen and iron core must be grounded. If no static screen is present, an appropriate filter must be used.

C-Tick Marking for DCS Converters

A "C-Tick" mark  is attached to each variable speed drive in order to verify compliance with the relevant standard ("IEC 61800-3 (1996) - Adjustable speed electrical power drive systems - Part 3: EMC product standard including specific test methods"), mandated by the Trans-Tasman Electromagnetic Compatibility Scheme.

Definitions

EMC stands for Electromagnetic Compatibility. It is the ability of electrical/electronic equipment to operate without problems within an electromagnetic environment. Likewise, the equipment must not disturb or interfere with any other product or system within its locality.

The Trans-Tasman Electromagnetic Compatibility Scheme (EMCS) was introduced by the Australian Communication Authority (ACA) and the Radio Spectrum Management Group (RSM) of the New Zealand Ministry of Economic Development (NZMED) in November 2001. The aim of the scheme is to protect the radiofrequency spectrum by introducing technical limits for emission from electrical/electronic products.

First environment includes establishments connected to a low-voltage network, which supplies buildings used for domestic purposes.

Second environment includes establishments connected to a network not supplying domestic premises.

Restricted distribution: mode of sales distribution in which the manufacturer restricts the supply of equipment to suppliers, customers or users who separately or jointly have technical competence in the EMC requirements of the application of drives.

Unrestricted distribution: mode of sales distribution in which the supply of equipment is not dependent on the EMC competence of the customer or user for the application of drives.

Compliance with IEC 61800-3

First environment (restricted distribution)

The drive complies with the limits of IEC 61800-3 with the following provisions:

1. The drive is equipped with an EMC filter.
2. The drive is installed according to the instructions given in figure 2.1/5.
3. The motor and control cables used are selected as specified in figure 2.1/5.
4. Maximum cable length is 100 meters.

Notes:

The drive must not be equipped with the EMC when installed to IT (unearthed) networks. The mains become connected to earth potential through the EMC filter capacitors. In IT systems this may cause danger or damage the unit.

Second environment

The drive complies with the limits of IEC 61800-3 with the following provisions:

1. It is ensured that no excessive emission is propagated to a neighbouring low-voltage network (refer to figure 2.1/4 and 2.1/5). In some cases, the natural suppression in transformers and cables is sufficient. If in doubt the use of EMC filters and/or supply transformers with static screening between primary and secondary windings is strongly recommended.
2. The drive is installed according to the instructions given in figure 2.1/4 and 2.1/5.
3. The motor and control cables used are selected as specified in figure 2.1/4 and 2.1/5.

3 Engineering of DC drives

3.1 Fusing aspects of DC drives

3.1.1 General

Protection elements such as fuses or overcurrent relays are used whenever overcurrents cannot entirely be ruled out. In some configurations, this will entail the following questions: firstly, at what point should which protective element be well suited incorporated? And secondly, in the event of what faults will the element in question provide protection against damage?

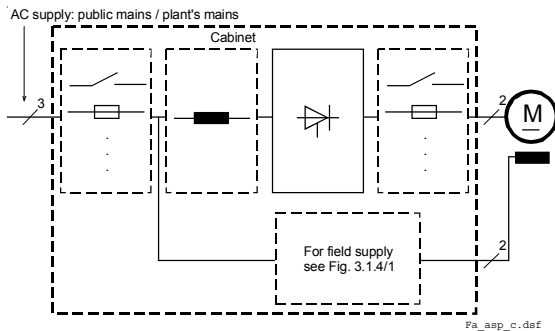


Fig. 3.1.1/1 Arrangement of the switch-off elements for the armature supply

A thyristor can be switched on in a controlled manner by a firing pulse, but it cannot be switched off by any command. It will switch off automatically when the current drops below the holding current and no firing pulse is generated; it can be switched off by forcing the current below the holding current. The earliest switch-off moment is prepared by the next zero crossing of the line voltage half-wave when firing pulses are moved to the safe position. Until then, full short-circuit current is flowing over the thyristor. The duration concerned will depend on the firing moment within the half-wave, and can already result in destruction, or at least preliminary damage.

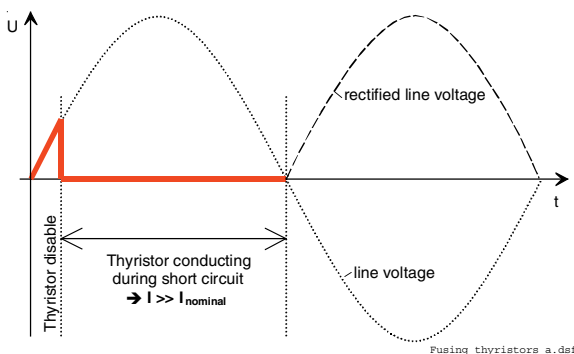


Fig. 3.1.1/2 Thyristor behavior with EMF = 0 V

Even ultra-fast monitoring programs in the drive software can no longer switch off fired thyristors, so that only a semiconductor fuse can

ensure adequate protection. It is, however, definitely possible that the fuse will **not yet trip** during **one** half-wave. Fuse and thyristor, however, are already suffering preliminary damage, which may not become apparent until later.

Basic principles

1. Only **semiconductor fuses** of matched size can in the event of a fault protect the power semiconductors. Unprotected power semiconductors may **explode** and cause the device to catch fire.
2. In earthed networks, only **semiconductor fuses** in the **supply** can protect the device in the event of an **earth fault**.
3. Well suited semiconductor fuses constitute an optimum protection for the semiconductors only in "hard" networks. In "soft" networks, and in the motor circuit, the protection is questionable. In "soft" networks, during regenerative operation, an increased risk of conduction-through must be anticipated. In the motor circuit, **high-speed DC circuit-breaker** constitute optimum protection.
4. Semiconductor fuses in the armature circuit must be dimensioned for DC voltages, so as to assure an adequate spark-quenching gap in the event of a fault. A compromise is provided by **two series-connected fuses**, as used in the AC power supply of small modules or the power section of big ones.
5. In 2-Q devices, no circulating current occurs. If a thyristor failure due to overload or a qualitative defect results in a phase-to-phase short-circuit, only **semiconductor fuses** can protect the device.
6. In the case of 2-Q devices, in **regenerative** mode, conduction-through is possible as in 4-Q operation, with the consequence of overcurrent.
7. Conventional fuses in the tapered feeder to the power converter can be replaced by semiconductor fuses, if the feeder's cross-sectional areas are matched at least to the device's rated line current (local regulations not taken into account). A thermal overload in the event of a fault will first destroy the semiconductor fuses before upstream components can suffer damage. The power converter device is, however, protected electronically or by the matched semiconductor fuses. The **series connection** of fuses can thus be **dispensed with**.

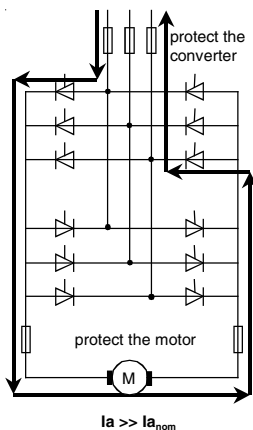
3.1.2 Armature supply

Possible sources of faults (SF) are explained based on the armature supply. They can be applied to the field supply as well.

Faults within the unit electronics

SF1

The power converter's working mode will usually be current-limiting. The maximum current corresponds to the current limitation set. If this limitation feature or one of the requisite components fails, then the current will frequently rise sharply.



SF2

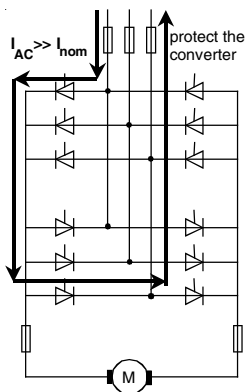
If one or more than one **false firing pulses** are produced, e.g. due to component faults or other influencing factors, then the current will likewise rise sharply.

→ Basic Principles 1 + 3 + 4

SF3

If -with four-quadrant units- thyristors of **both bridges become conductive**, circulating current is the consequence. The causes involved may be component defects or other influencing factors. The current on the three-phase side will rise substantially.

→ Basic Principles 1 + 5

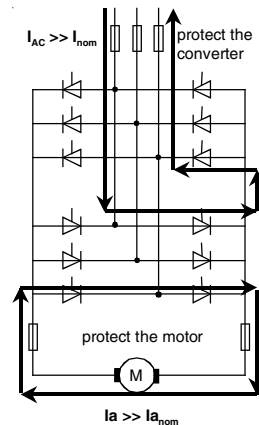


Faults caused by power components

SF5

Semiconductor faults can be manifested in that a thyristor no longer fires or in that it is permanently conductive.

→ Basic Principles 1 + 3 + 4 + 5 + 6



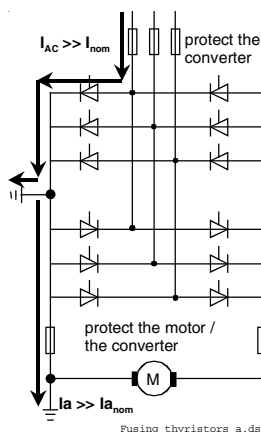
SF6

Insulation faults may occur within the cabling of the mains supply, the power converter and the motor. These can be subdivided into faults finally resulting in a short-circuit and those leading to an earth fault.

- In the event of a short-circuit, the following generally applies $I \gg I_{nom}$
- In the event of an earth fault, depending on where the fault has occurred, the current may range between $I = I_{nom}$ and

$I \gg I_{nom}$

→ Basic Principles 1 + 2 + 3 + 4



Defective system conditions leading to commutation failure

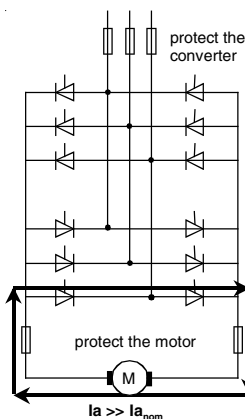
SF4

In the case of regeneration, the ratio of motor voltage and line voltage rises above 1.05, which is followed by a situation called "shoot-through". The current rises substantially.

Possible causes include:

- network malfunctions (line undervoltage)
- overspeed due to the load involved (load accelerates motor) or due to a control error
- field supply generates a field current larger than $I_{e, nom}$ or control error in the field weakening range

→ Basic Principles 1 + 3 + 4 + 6



Conclusion

Due to cost saving in some of customer applications standard fuses are used instead of "more expensive" semiconductor fuses. Under normal and stable operating conditions, this is even understandable and comprehensible, as long as **fault scenarios can be ruled out**.

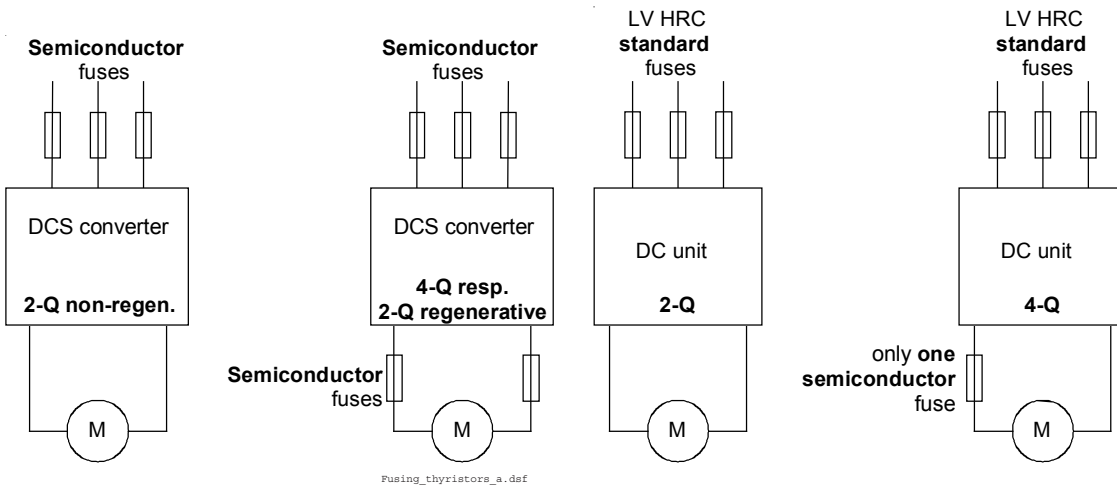
In the **event of a fault**, however, the saving may

cause very high consequential costs. Exploding power semiconductor may not only destroy the power converter, but also **cause fires**.

Adequate protection against **short-circuit** and **earth fault**, as laid down in the **EN50178** standard, is possible only with **appropriate semiconductor fuses**.

Recommendations

Protection level of other solutions



Complies with Basic Principles on:

- | | |
|-------------------------|------------|
| 1 – Explosion hazard | yes |
| 2 – Earth fault | yes |
| 3 – "Hard" networks | yes |
| 4 – Spark-quenching gap | yes |
| 5 – Short-circuit | yes |
| 6 – 2Q regenerative | yes |

Complies with Basic Principles on:

- | | |
|-------------------------|---|
| 1 - Explosion hazard | no |
| 2 - Earth fault | partly , only with 4-Q, between fuse and motor |
| 3 - "Hard" networks | no |
| 4 - Spark-quenching gap | no |
| 5 - Short-circuit | no |
| 6 - 2Q regenerative | no |

LV HRC = **L**ow **V**oltage **H**igh **R**upturing **C**apacity.

LV HRC refers to DIN 43 620, mechanical dimensions of the fuses. The different characteristics between semiconductor and standard fuses are only recognized by the type number.

Note: **NH** (in german) = **LV HRC** (in english)

3.1.3 Field supply

Basically, similar conditions apply for both field supply and armature-circuit supply. Depending on the power converter used (diode bridge, half-controlled bridge, fully controlled 4-quadrant bridge), some of the fault sources may not always be applicable. Due to special system conditions, such as supply via an autotransformer or an isolating transformer, new protection conditions may additionally apply.

The F3.2 and F3.3 fuse types serve as line protectors and **cannot protect the field supply** unit. Only pure HRC fuses or miniature circuit-breakers may be used. Semiconductor fuses would be destroyed, for example, by the transformer's starting current inrush.

Possible field supply units (**R**):

- SDCS-FEX-1: uncontrolled diode bridge; commutating reactor K not necessary
Fault Source: **SF5, 6**
- SDCS-FEX-2: half-controlled bridge, 1Q; due to EMC reasons commutating reactor K is highly recommended
Fault Source: **SF1, 5, 6**
- DCF 503: half-controlled bridge, 1Q; commutating reactor K is already built-in
Fault Source: **SF1, 5, 6**
- DCF 504: fully controlled bridge, 4Q; commutating reactor K is already built-in
Fault Source: **SF1, 3, 4, 6**
- DCF x01/2: fully controlled 3-phase bridge, 2Q/4Q;
Fault Source: **SF1, 3, 4, 6**

SF1 and **6**, the current is limited to relatively small overcurrents due to the ohmic content of the field winding, so that the fuses may perhaps not be tripped.

SF 4 can also occur in the case of field supply units, but will not cause such a rapid and substantial current rise as encountered with an armature-circuit supply; this is due to the significantly higher inductance of the field winding.

In contrast to the armature-circuit supply, fuses are **never** used on the DC side for the field supply, since a fuse trip might under certain

circumstances lead to greater damage than would the cause tripping the fuse in the first place (small, but long-lasting overcurrent; fuse ageing; contact problems; etc.).

Conclusion

If conditions similar to those for armature-circuit supply are to apply, like for example protection of the field supply unit and the field winding, then a semiconductor fuse (super-quick-acting F3.1) must be used.

Recommendation

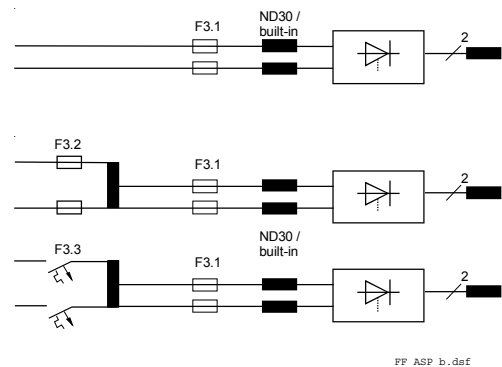


Fig 3.1.3/1 Configurations for field supplies

3.2 Commutation

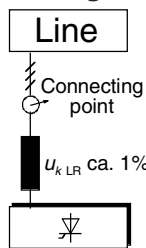
General

When power converters are operated with thyristors, the line voltage is short-circuited during commutation from one thyristor to the next. This operation causes voltage dips in the mains.

The information based on the different configurations can be applied for the armature supply (DCS converters) and for the field supply (3-phase DCF converters).

For the connection of a power converter system to the mains the following configurations can be made:

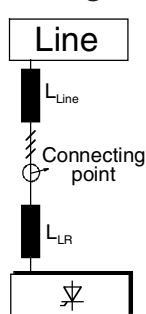
Configuration A



When using the power converter, a minimum of 1% impedance is required to ensure proper performance of the snubber circuit. A line reactor can be used to meet this minimum impedance requirement. The value must therefore not drop below 1% u_k (relative impedance voltage). It should not exceed 10%

u_k , due to considerable voltage drops which would then occur.

Configuration B



If special requirements have to be met at the connecting point, different criteria must be applied for selecting a line reactor. These requirements are most often defined as a voltage dip in percent of the nominal supply voltage.

The combined impedance of Z_{Line} and Z_{LR} constitute the total series impedance of the installation. The ratio between the line impedance

and the line reactor impedance determines the voltage dip at the connecting point.

$$\text{Voltage dip} = \frac{Z_{Line}}{Z_{Line} + Z_{LR}} * 100\%$$

Example:

Maximum allowable voltage dip is 20% at the power converter's connecting point. Above equation used and simplified to:

$$Z_{LR} = 4 * Z_{Line} \quad (1)$$

Since the line impedance is seldom known (it

can be determined by means of a measuring routine), and the short-circuit power at the same point is more frequently available, the line reactor can be calculated by means of this value.

Assumption: The system short-circuit power at the power converter's connecting point is 180 times the power converter's rated power.

- The system's relative impedance voltage u_k can thus be determined:

$$u_{k \text{ Line}} = \frac{1}{180} * 100\% = 0.55\%$$

- In accordance with equation (1), the following applies for the line reactor:

$$u_{k \text{ LR}} = 4 * u_{k \text{ Line}} = 2.2\%$$

- Since the line reactor has to be sized specific to a power converter, the relative variable u_k must be converted into an absolute value. For this purpose, the following equation applies:

$$u_k = \frac{I_{dN} * \sqrt{\frac{2}{3}} * \sqrt{3} * 2\pi * f_N * L_{LR}}{U_N}$$

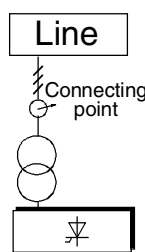
- I_{dN} : rated direct current
- f_N : rated frequency of the system
- U_N : rated line voltage
- L_{LR} : line reactor inductance

With reference to the power converter:

- The line reactors
 - have been allocated to the units nominal current
 - are independent of converter's voltage classification; at some converter types the same line choke is used up to 690 V line voltage
 - are based on a duty cycle
 - can be used for DCS as well as for DCF converters
- The duty cycle taken into account varies from line choke to line choke and is between 80% and 100%. If the converter is sized on a duty cycle or is used for a drive running with high load all time like extruders do next steps to check the overall selection:
 - Calculate the I_{DCrms} based on the duty cycle and the motor current
 - Multiply the I_{rms} of the line choke by 1.2
 - In case I_{rms} is higher than I_{DCrms} the combination is okay

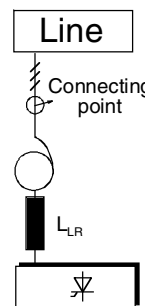
- In case I_{rms} is lower than I_{DCrms} take the line choke used for the next bigger converter with the same voltage classification
- If the line choke should be used for a DCF converter make sure the nominal field current doesn't exceed the thermal current of the choke. In case the field current is higher than I_{rms} of the line choke take the one used for the next bigger converter with the same voltage classification
- For units >2000 A or >690 V, we recommend using one isolation transformer per power converter as configuration C.

An examination of volume and costs results in the following configuration:



Configuration C

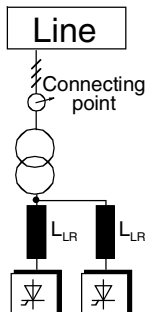
If an isolation transformer is used, it is often possible to comply with certain connecting conditions per Configuration B without using an additional line reactor. The condition described in Configuration A will then likewise be satisfied, since the u_k is >1 %.



Configuration D

In the case of high power converter outputs or high currents, a power converter transformer must frequently be used for voltage matching. If an autotransformer is used for this purpose, a commutating reactor must additionally be used if special conditions must be complied with as per Configuration B, the reason for this being that the u_k of commonly used autotransformers is generally too small. If you do not have to allow for special conditions of this kind, you must nevertheless check whether the u_k of the autotransformer concerned is sufficient for satisfying Configuration A.

Configuration C1



If 2 or more converters should be supplied by one transformer the final configuration depends on the number of drives in use and their power capability. Configuration A or B has to be used which are based on commutation chokes, if the drive system consists of C1, C2 or A5 converters. In case **only two** converters type A6 / A7 (A6 + A6, A6 + A7, A7 + A7) are involved **no** commutation chokes are necessary because the design of these converters is adapted to that wiring.



DC Drives Product Portfolio

DCS 400

The drive module for standard applications

- Integrated field supply (max. 20 A)
- Accurate speed and torque control
- Extremely small and compact design
- Very easy installation and commissioning
- Express delivery
- **Power range: 10...500 kW (13...670 HP)**



DCS 500B / DCS 600

The drive module for demanding applications

- Free programming of software
- 6- and 12-pulse configuration up to 10 MW/ 13,000 HP and more
- Plain text display
- **Power range: 10...5000 kW (13...6700 HP)**



DCE 400 plus

Highly integrated panel

- Extremely small and compact design
- Contains:
 - DCS 400 module
 - AC fuses
 - Auxiliary transformer
 - Motor fan starter with protection
 - Main contactor
- **Power range: 20...130 kW (26...174 HP)**



DCS 400 / DCS 500 Easy Drive

The complete standard cabinet solution

- Pre-engineered
- Easy installation and commissioning
- Protection class: IP 21
- Plain text display
- Short delivery time
- **Power range: 50...1350 kW (65...1800 HP)**



DCA 500 / DCA 600

For complex, completely engineered Drive System in common cabinet design

- Flexible and modular hardware structure
- 6- and 12-pulse configuration up to 18 MW/ 23,000 HP and more
- Pre-programmed applications:
Metals, Cranes, P&P application, Mining
- **Power range: 10...18000 kW (13...23000 HP)**



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3ADW 000 163 R0201 REV B
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