SIEMENS

EMC-Guideline

Control Panels

The EMC-Directive 2014/30/EU in Practice

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Control panels

The EMC Directive 2014/30/EU in Practice

Reference Manual

10/2024
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Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

DANGER
indicates that death or severe personal injury **will** result if proper precautions are not taken.

WARNING
indicates that death or severe personal injury **may** result if proper precautions are not taken.

CAUTION
indicates that minor personal injury can result if proper precautions are not taken.

NOTICE
indicates that property damage can result if proper precautions are not taken.

If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

Proper use of Siemens products

Note the following:

WARNING
Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

Trademarks

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Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

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Preface

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History

The term electromagnetic compatibility (EMC) came into common use not even 50 years ago. Before then, the physical phenomena existed, but there was not so much equipment around that items could interfere with each other. That changed with the invention of electrical telegraphy in the 1800s. Then came the telephone (victim of interference) and streetlighting (source of interference), and then pairing of radio receivers (victim) and motor vehicles (source), leading to more awareness of EMC – still called "radio interference (suppression)" at the time.

As the density of electronics grew further, laws and standards were introduced to ensure that electrical devices could work satisfactorily in their electromagnetic environment. But also without interfering unacceptably with that environment, to which other devices also belong. This rapid increase in electrical equipment, in particular in control panels has changed the way of looking at this topic entirely. EMC planning, which starts at the development phase of each equipment item and ensures in the control cabinet design that the EMC of the overall system is maintained, is more necessary than ever.

Objective of the EMC guideline

The intended objective of this EMC guideline is to help users to:

- Understand and ensure compliance with the requirements of the new European EMC Directive 2014/30/EU for control panels,
- Understand and put into practice the possibilities and the details of the verification procedure as defined by EN 61439-1,
- Acquire a good basic understanding of EMC measures,
- Understand and apply practical tips illustrated by an example.

Device-specific technical documentation

The binding document for EMC-compliant configuring and installation is always the device-specific technical documentation. Compliance with the measures described in this documentation is essential in order to ensure adherence to the statutory limit values and proper functioning of equipment.

Disclaimer of liability

The examples and interpretations of directives, standards and guidelines are not binding and do not claim to be complete with respect to configuration, equipment or any other eventuality. They are not customer-specific solutions and are only intended to provide assistance with typical tasks.

Each user of this document is responsible for correct operation of the products described. This document does not exempt you from your obligation to use directives and standards in a proper manner.

By using this document, you agree that Siemens cannot be made liable for possible damage beyond the above-mentioned liability clause.

We reserve the right to make changes and revisions to this document at any time without prior notice.

Some tables and texts included in this description were lifted straight from the relevant directives, standards and technical documentation. All users of this documentation must always check whether or not the quoted passages are still up to date.

The final decision about the appropriateness of applying the relevant directives and standards must be made by the user of this documentation.

Glossary

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This glossary contains an overview of all important abbreviations and terms that are used in connection with our products, services, and technical information.

Equipment

The purpose of the guideline is to ensure the proper functioning of **equipment**. The term "equipment" refers in this case to a single **apparatus** or to **fixed installations**.

Apparatus

An apparatus is defined as "any finished appliance or combination thereof made available on the market as a single functional unit, intended for the end-user and liable to generate electromagnetic disturbance, or the performance of which is liable to be affected by such disturbance". (DIRECTIVE 2014/30/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 February 2014 on electromagnetic compatibility, OJ L 96/84, CHAPTER 1, Article 3, par. (1), 2.)

Fixed installation

A "fixed installation" is defined as "a particular combination of several types of apparatus and, where applicable, other devices,which are assembled, installed, and intended to be used permanently at a predefined location". (DIRECTIVE 2014/30/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 February 2014 relating to electromagnetic compatibility, OJ L 96/84, CHAPTER 1, Article 3, par. (1), 3.)

Classification of equipment

To assist with the classification of an item of equipment as an "apparatus" or "fixed installation", the European Commission has issued a "Guide for the EMC Directive 2004/108/EC (8th February 2010)", cf. Chapter 1.1.5, page 15. In this guide you will find examples of items of equipment that belong to the category "Fixed installation", cf. Chapter 1.3.1, page 20.

Functional earth (FE)

Earthing of one or more points of a network, an installation, or an equipment item for purposes other than electrical safety. Functional earth is required to ensure perfect functioning and disturbance-free operation of electrical installations. Unlike protective earth, this connection must not only be low-resistance but also low-inductance because high-frequency disturbances also have to be dissipated. We refer to a low-impedance connection in this case.

Impedance

Impedance, or apparent impedance, refers to the resistance of resistive, inductive, and capacitive elements in AC systems. Impedance depends on the frequency. As the frequency of a signal increases, the capacitive reactance X_C decreases, while the inductive reactance X_L increases. This results in changes to the total impedance as a function of the frequency. Impedance is quantified in the unit Ohm, just like resistance.

Ground

In the context of EMC, ground is considered to be the totality of the electrically interconnected metal parts of electrical equipment that ensures equalization of the potentials and provides the reference potential. For EMC purposes, this document introduces the term ground or grounding to complement the term functional earth (FE) and provide a clearer distinction between EMC and personal protection (protective earth) throughout the document.

Low-impedance

Low-impedance means low-resistance and low-inductance. Low-impedance connection to functional earth ensures that high-frequency disturbances are also discharged into the grounding system.

Shielding

Electromagnetic shielding is a metal barrier (e.g. cable shield, cabinet, or enclosure) that is used to attenuate electrical, magnetic, and electromagnetic fields. This reduces firstly the influence of such fields on, for example, modules, devices, or cables, and secondly the emission of interference fields from electrical and electronic equipment.

Protective earth (PE)

Earthing of one or more points of a network, an installation, or an equipment item for the purpose of electrical safety. The task of the protective conductor in electrical systems is to protect persons in case of an earth fault.

Emitted interference

Emitted interference (also known as radiated interference) is defined as the property of an electrical or electronic device to act as an electromagnetic source of interference and therefore disturb other devices. A basic distinction is made between conducted and field-based emissions.

Immunity

Immunity is defined as the ability of equipment to perform as intended without degradation in the presence of a disturbance variable of a certain magnitude. A basic distinction is made between immunity to conducted and field-based interference.

Disturbance variable

Electromagnetic (also electrical or magnetic) variable that can cause unwanted influence in an item of electrical equipment.

Victim of interference

Electrical device whose function can be affected by disturbance variables.

Source of interference

Origin of disturbance variables

CENELEC (Comité Européen de Normalisation Électrotechnique)

European Committee for Electrotechnical Standardization

CISPR (Comité International Spécial des Perturbations Radioélectriques)

International Special Committee on Radio Interference

The primary concern of the committee is the protection of radio services in the frequency range from 9 kHz to 400 GHz based on international agreements.

EMFV (German Occupational Safety and Health Ordinance on Electromagnetic Fields)

The EMFV Ordinance for the protection of employees from hazards arising from electromagnetic fields came into force on November 15, 2016. With this regulation, Germany meets its European obligations to implement the European Directive 2013/35/EU on electromagnetic fields which lays down the minimum health and safety requirements regarding the exposure of workers to the risks arising from electric, magnetic, and electromagnetic fields.

EMC (electromagnetic compatibility)

EMC refers to the ability of a technical device not to disturb or be disturbed by other devices due to unwanted electrical or electromagnetic effects.

EU (European Union)

The EU is an economic and political partnership between 27 European states.

EN (European standard)

EN standards are those that have been ratified by the three European standardization committees, namely the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC), and the European Telecommunications Standards Institute (ETSI).

High frequency

The term high frequency is used differently depending on the EMC topic. In radio interference protection, the term high frequency refers to frequencies above 9 kHz (9 kHz and below is referred to as low frequency). When dealing with shielding problems, the boundary between low frequency and high frequency is often 100 kHz, and in other contexts it sometimes as high as 30 MHz.

IT system (information technology system)

This refers to any type of electronic data processing system

Equipotential busbar

Equipotential busbars (also known as equipotential bonding conductors) are recommended as an additional or parallel connection between installation devices where distances are large. This additional connection ensures a low-impedance return line for interference currents because they can also flow in this conductor and no longer only, for example, via a cable shield.

Important: The equipotential busbar should always be installed in the immediate vicinity of the cable because otherwise the interference currents will ind other paths and the reduction effect is much lower.

EMC Directive 2014/30/EU 3

3.1 Requirements and safety objectives

Validity and scope

The responsibilities of manufacturers, importers and distributors in connection with the sale of **electromagnetic equipment** have been defined in the EMC Directive 2014/30/EU. The directive fulfills the role of defining how devices have to function together in a particular environment

You can download EMC Directive 2014/30/EU in all EU languages here (https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1721917643015&uri=CELEX%3A32019D1326).

The EMC Directive 2014/30/EU **applies only to apparatus**, but not to electromagnetic fields and their effects on people. Radio equipment and telecommunications terminal equipment are not covered by the EMC Directive 2014/30/EU, but are dealt with in the Radio Equipment Directive (RED) 2014/53/EU. However, the basic requirements of Directive 2014/53/EU include compliance with the safety objectives of EMC Directive 2014/30/EU, even if only the RED Directive is stated in the EU Declaration of Conformity. This means that if radio equipment is installed in control cabinets, RED Directive 2014/53/EU must also be complied with.

You can download EU Radio Equipment Directive 2014/53/EU in all EU languages here (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014L0053).

Note

Control panels

In the vast majority of cases, industrial, machine-oriented control panels fall within the scope of the EMC Directive 2014/30/EU since equipment **with electronic circuitry** are required for and therefore generally installed in control panel applications of this kind.

Requirements of EMC Directive 2014/30/EU

Correct functioning of equipment is ensured by defining an acceptable level with regard to electromagnetic compatibility. Accordingly, electrical equipment must be designed and manufactured so as to ensure that it possesses the following characteristics:

- The electromagnetic disturbance generated does not exceed the level above which radio and telecommunications equipment or other equipment cannot operate as intended.
- It has a level of immunity to the electromagnetic disturbance to be expected in its intended use which allows it to operate without unacceptable degradation of its intended use

The equipment must fulfill the essential requirements of the EMC Directive 2014/30/EU, cf. DIRECTIVE 2014/30/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 February 2014 relating to electromagnetic compatibility, OJ L 96/97, ANNEX I:

1. **General requirements**:
   - Equipment shall be so designed and manufactured, having regard to the state of the art
   - Limitation of interference emission
   - Adequate degree of immunity
2. Specific requirements for **fixed installations**:
   - Installed applying good engineering practices
   - Responsible person keeps the documents for inspection
   - Information on the intended use of its components is respected

3.2 Documentation requirements of EMC Directive 2014/30/EU

Documentation requirements of EMC Directive 2014/30/EU

- EMC Directive 2014/30/EU clearly stipulates that **documents must be kept for at least 10 years after the apparatus has been placed on the market** and be made available for inspection upon request. In the case of fixed installations, the responsible persons shall keep the document at the disposal of the relevant authorities for inspection for the entire service life of the apparatus.
- The documentation must be written in a **language** that can be easily understood by local authorities and end users of the product.
- The **postal address of the manufacturer** must be stated on the equipment itself wherever possible.
- Manufacturers may also provide the documentation and verification of conformity of the apparatus **in electronic form**.
- All apparatus placed on the EU market must bear the **CE marking** and thus provide the assurance that the apparatus complies with all essential requirements of EU regulations.

Note

Exception: Fixed installations

Equipment does not need to undergo a conformity evaluation if it is placed on the market solely for integration in a specific fixed installation. It must nevertheless comply with the protection requirements of the EMC Directive 2014/30/EU. In other words, the equipment does not require an EU Declaration of Conformity or a CE marking. However, the market surveillance authorities may demand proof of conformity, in particular if there are signs of non-conformity or in the event of complaints.

- Before receiving the CE marking, the manufacturer must perform an **assessment of conformity** and prepare **technical documentation for the equipment**.
- Importers or **distributors** of the product **are responsible for checking** whether the manufacturer has properly carried out the relevant **assessment of conformity procedure**. They are obliged to notify the national market surveillance authorities if they are of the opinion that the equipment does not comply with essential requirements.
- **The technical documentation must be devised such that it allows the product to be assessed against the essential requirements of EU regulations.**
- The documentation must include a **suitable EMC risk analysis and assessment**.
- The EMC Directive 2014/30/EU further defines the responsibility of national authorities to prevent products that do not meet essential requirements from being placed on the market.

On December 19, 2018, a Guide for the EMCD (Directive 2014/30/EU) (https://ec.europa.eu/docsroom/documents/33601?locale=en) was published and can be regarded as a manual for implementing the directive.

3.3 Risk analysis and assessment

To perform the risk analysis within the scope of the European directives, the European Committee for Electrotechnical Standardization (CENELEC) offers the CENELEC Guide 32:2014 as assistance for operating equipment with low voltage.

You can download this CENELEC Guide 32 and other documents here (https://boss.cenelec.eu/reference-material/refdocs/pages/cenelec-guides/).

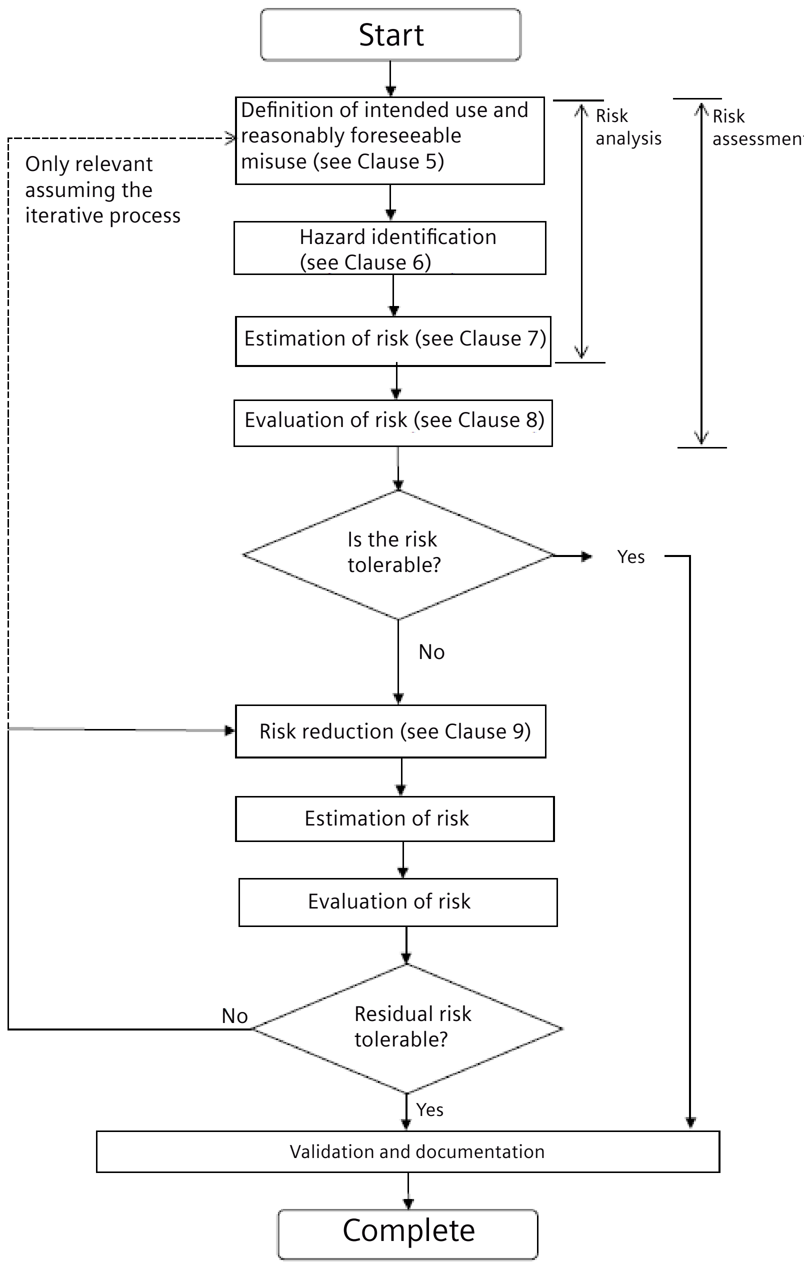


Figure 3-1 CENELEC Guide 32:2014: Risk evaluation and reduction

Harmonized EMC standards 4

4.1 Correlation between directives and standards

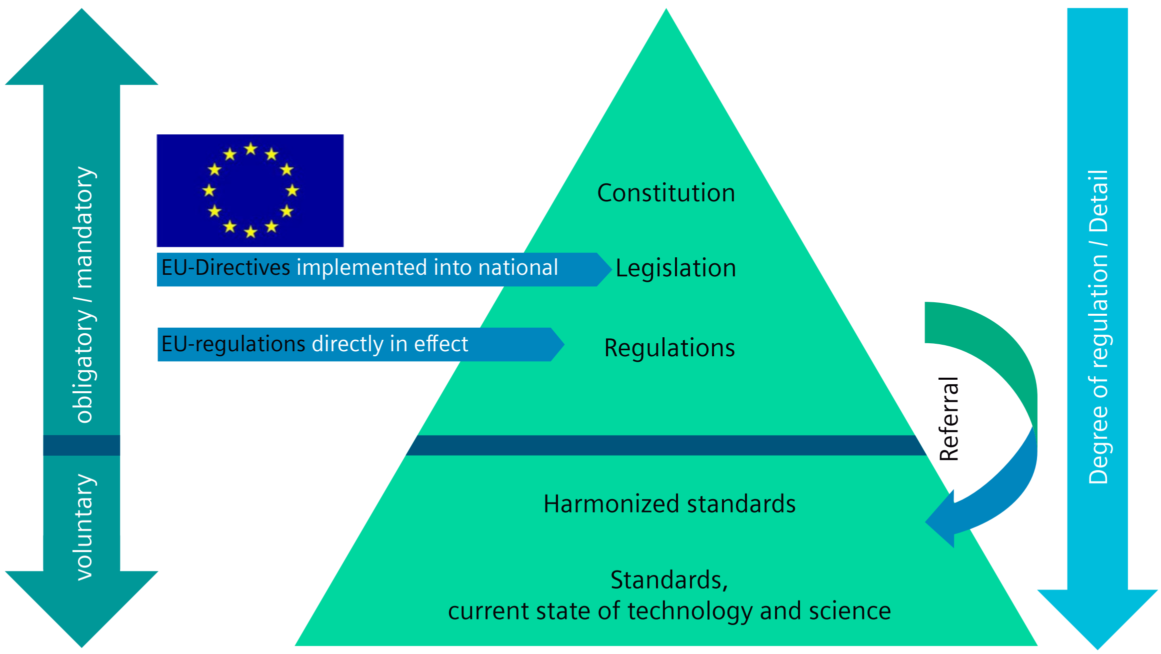


Figure 4-1 Correlation between directives, regulations, legislation, and standards

European legislation

European directives must be converted into national laws in the individual EU countries.

Example of a European regulation passed to implement European Health and Safety Directive 2013/35/EU:
German Occupational Safety and Health Ordinance on Electromagnetic Fields for the protection of workers from risks arising from electromagnetic fields (EMFV).

The technical specifications contained in the harmonized standards are regarded by jurisdiction (judiciary) as appropriate or sufficient in order to comply with the relevant EU legal regulations.

Note

Responsibility of the manufacturer

Individual manufacturers are responsible for deciding which directives, and accordingly, which standards they need to apply in order to achieve the safety objectives for their application.

We recommend using the harmonized standards listed in the EMC, Official Journal of the European Union (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018XC0713(02)).

The currently harmonized standards can be found in the Official Journals of the European Union, see Chapter EMC Official Journal of the EU (Page 17).

4.2 EMC Official Journal of the EU

The official journals that publish European directives list the various harmonized standards that make it possible to fulfill each respective directive's safety objectives (presumption of conformity). Every manufacturer is responsible for checking that the standards applied are still up to date.

In an excerpt from the Official Journal of the European Union2018/C 046/01 ff published on July 13, 2018, you will find a selection of EMC standards that apply to control panels:

C 293/46 EN Official Journal of the European Union 12.8.2016

(1)	(2)	(3)	(4)	(5)
Cenelec	EN 61439-1:2011 Low-voltage switchgear and controlgear assemblies — Part 1: General rules IEC 61439-1:2011	13.5.2016		
EN 61439-1:2011 does not give presumption of conformity without another part of the standard.				
Cenelec	EN 61439-2:2011 Low-voltage switchgear and control- gear assemblies — Part 2: Power switchgear and controlgear assemblies IEC 61439-2:2011	13.5.2016		
Cenelec	EN 61439-3:2012 Low-voltage switchgear and control- gear assemblies — Part 3: Distribution boards intended to be operated by ordinary persons (DBO) IEC 61439-3:2012	13.5.2016		
Cenelec	EN 61439-4:2013 Low-voltage switchgear and controlgear assemblies — Part 4: Particular requirements for assemblies for construction sites (ACS) IEC 61439-4:2012	13.5.2016		

Figure 4-2 Excerpt from the Official Journal of the European Union (2018/C 046/01 ff)

4.3 Equipment-specific EMC standards

Selection of standards applicable to control panel manufacture (not comprehensive)

Different standards can apply to different types of equipment. Listed below is a small selection of the EMC standards that may be applicable to control panels:

Standard	Title
EN 61439-...	**Low-voltage switchgear and controlgear assemblies** • Part 1: **General rules** Conformity according to EN 61439-1 can only be declared in conjunction with one of the relevant parts, e.g. Part 2. • Part 2: **Power switchgear and controlgear assemblies**
EN 61000-6-...	**Electromagnetic compatibility (EMC)** • Part 6-1: Generic standards – **Immunity** for **residential**, commercial and light-industrial environments • Part 6-2: Generic standards – **Immunity** for **industrial environments** • Part 6-3: Generic standards – **Emission** for **residential environments** • Part 6-4: Generic standards – **Emission** for **industrial environments** • Part 6-5: Generic standards – **Immunity for equipment used in power station and substation environments** • Part 6-8: Generic standards – **Emission standard** for **commercial and light-industrial locations**
EN 61800-3	**Adjustable speed electrical power drive systems** - Product standard • Part 3: EMC - requirements and specific test methods
EN 55011	Industrial, scientific and medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement

Assessment of conformity for switchgear and controlgear assemblies

5

5.1 Possible methods of assessing conformity

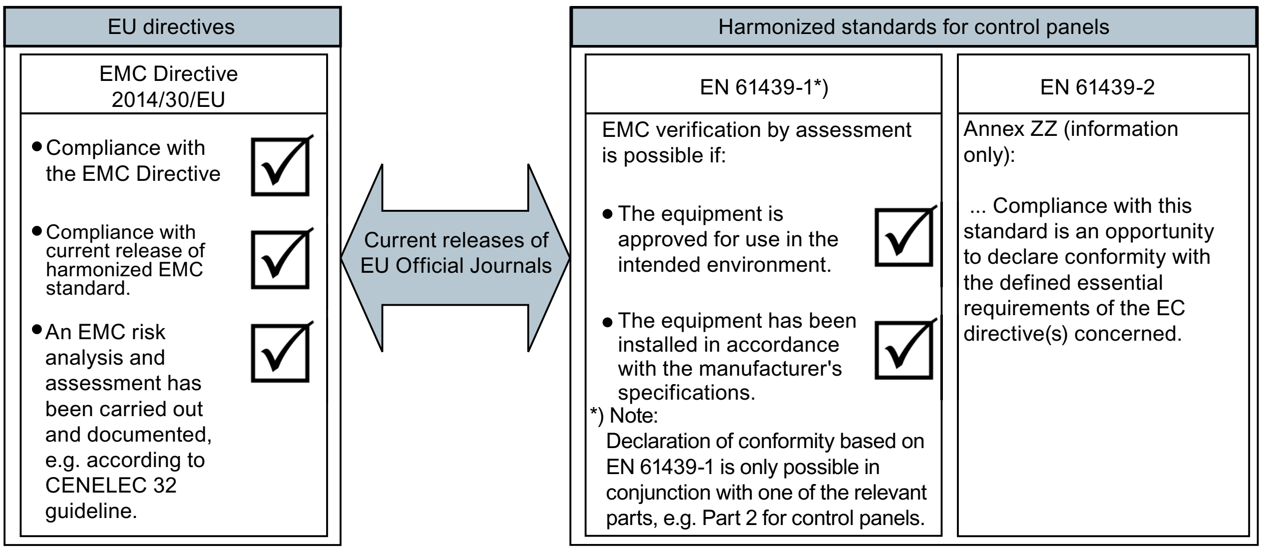


Figure 5-1 Possible methods of assessing conformity

Possible methods of assessing conformity

It is possible to declare the conformity of control panels to the EMC Directive 2014/30/EU in conjunction with the harmonized standards EN 61439-1 and EN 61439-2 by **verifying the following**.

1. The equipment is approved for use in the intended environment.
2. The equipment will be installed in accordance with the manufacturer's specifications.
3. The equipment conforms to the currently valid harmonized standards.
4. An analysis and assessment of the EMC risks have been carried out.
5. The manufacturer has complied with the formal requirements of the EMC Directive 2014/30/EU, e.g. obligations to supply documentation.

The individual steps are explained in more detail in the following chapters.

5.2 Design verification according to EN 61439-1

Requirement of the standard

Standard EN 61439-1 is the basic standard applicable to low-voltage switchgear and controlgear assemblies. According to the standard, a large number of design and routine verification processes must be carried out in order to verify design, assembly and functionality. For this purpose, standard EN 61439-1 provides a summary of the design verification processes (including the available verification methods) that can be selected in order to provide the required verification, cf. EN IEC 61439-1:2021, Annex J, page 158. Verification of electromagnetic compatibility (EMC) is also included in this summary as criterion no. 12.

Two equally valid, alternative verification options are available:

- Verification by testing
- Verification by assessment

Validity

Control panels with integral electronic circuitry must fulfill the requirement of the relevant applicable EMC product or generic standard. Electronic circuits include, for example, switch mode power supplies or circuits that contain high-frequency microprocessors. **Components with electronic circuits** must be suitable for the intended EMC environment. They must be installed and wired up in accordance with the equipment manufacturer's instructions.

Exceptions

Control panels are not susceptible to electromagnetic interference if they do not contain any equipment with electronic circuits. **Equipment without electronic circuits** include, for example, contactors (without electronics operating mechanisms). They do not therefore need to undergo interference immunity tests. Interference caused by supply conditions such as, for example, voltage fluctuations, dips or interruptions, is already taken into account in the equipment design, or can be eliminated by the inclusion of suitable circuit elements. The voltage strength of the equipment when it is loaded by transient surge voltages is assured by coordinated insulation measures.

Implementation in practice

In view of the fact that control panels are usually manufactured on behalf of a client and, when the individual choice of equipment and the variations in ambient conditions and fields of application are also taken into account, are almost always a unique design, it was eventually agreed that **verification by testing is practically impossible**. This is true not only for technical verification reasons, but for economic reasons as well.

As a result, the principle option remaining is to test individual items of equipment that are relevant in terms of EMC (e.g. circuit breakers with electronic tripping unit, electronic controllers, soft starters, frequency converters, etc.) for their electromagnetic compatibility and suitability for use for the intended application, and to take into consideration the usual wiring methods, clearances and manufacturer-specific information relating to individual items of equipment when it is installed in control panels.

Fundamental principles of EMC 6

6.1 Electromagnetic compatibility

EMC stands for electromagnetic compatibility and is defined as the ability of an electrical device to function satisfactorily in its electromagnetic environment without interfering unacceptably with this environment, to which other devices also belong. This is true when the emitted interference (emission) and the interference immunity are matched with each other.

Electromagnetic compatibility is the branch of electrical engineering concerned with the malfunctioning of electrical or electronic equipment caused by, for example, electrical, magnetic or electromagnetic fields or phenomena. A key factor in ensuring the electromagnetically compatible operation of electrical equipment is the proper construction and design of the equipment.

EMC interference emissions and interference immunity are regulated worldwide by standards, guidelines and legislation.

In the case of devices that are supplied ready to use, it normally suffices to install and operate them in accordance with the manufacturer's documentation in order to observe the EMC limit values and to achieve a satisfactory function. The binding document for configuring the respective device types is always the device-specific technical documentation. It is absolutely essential to follow the safety instructions given in the documentation.

6.2 EMC interference and its causes

EMC interference

EMC interference in devices, systems, or installations can have the following causes:

1. Low immunity, i.e. a device or system is not robust enough for the environment in which it is to work or
2. Excessive emission, i.e. a device or system emits strong interference into the environment in which it is to work.

The type of interference can be very different and have different effects in installations, e.g. erratic controls, sporadic disturbances, permanent faults in measurement and communication equipment, or even complete failure or destruction of equipment and sections of the installation.
Examples of causes of disturbances included transient phenomena such as bouncing of mechanical contacts, switching on/off of fluorescent lamps, connection of circuits, or disconnection of inductances, such as transformers or reactors. One example of a continuous emitter is a high-frequency switching frequency converter.
Spectacular examples of EMC interference include aircraft crashes due to strong electromagnetic fields, locked motor vehicle doors because of radio signals, or spontaneous industrial robot action caused by industrial radio equipment.

6.3 EMC interference model

The identification of sources and victims of interference is a crucial aspect of the risk analysis and risk assessment stipulated by EMC Directive 2014/30/EU.

The basic physical mechanism that results in the incompatibility of electrical and/or electronic components can be described by the so-called EMC interference model. There is always a source, a victim, and a coupling path, e.g. a coupling mechanism that describes how the EMC influence gets from the source to the victim.
Important to know: Without a source of interference, without a victim, or without a coupling path, there is **NO** interference and no EMC problem.

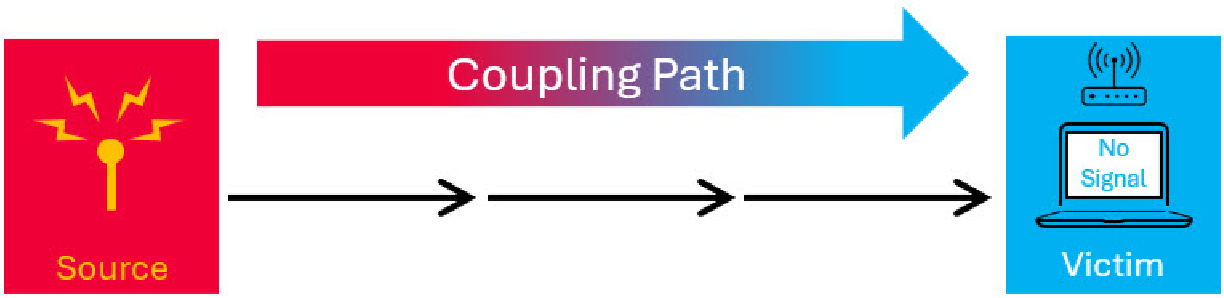


Figure 6-1 EMC interference model

This model provides a simple way of describing the interference. It applies to internal disturbance variables inside a single device or system, or external disturbance variables outside the system (e.g. interference from the environment affecting the system).

Typical interference sources

- Contactor, electronic valves
- Frequency converter
- Electric motor
- Power supply unit, switched-mode
- High-frequency appliances
- Transmitters (e.g. radio system)
- Differences in ground or reference potential
- Operators (static charge)
- Power cables

Typical interference victims

- Sensors
- Controllers
- Measuring equipment
- Signal interfaces
- Communication equipment

Coupling paths/coupling mechanisms

This is the basic physical phenomenon that takes the interference energy from the source to the victim. A distinction is made between four coupling mechanisms, which are explained in more detail below:

- Galvanic coupling
- Inductive coupling
- Capacitive coupling
- Electromagnetic coupling

6.4 Interference propagation and countermeasures

Coupling paths

Electromagnetic interference can be propagated along a variety of different coupling paths until it reaches the "victim".

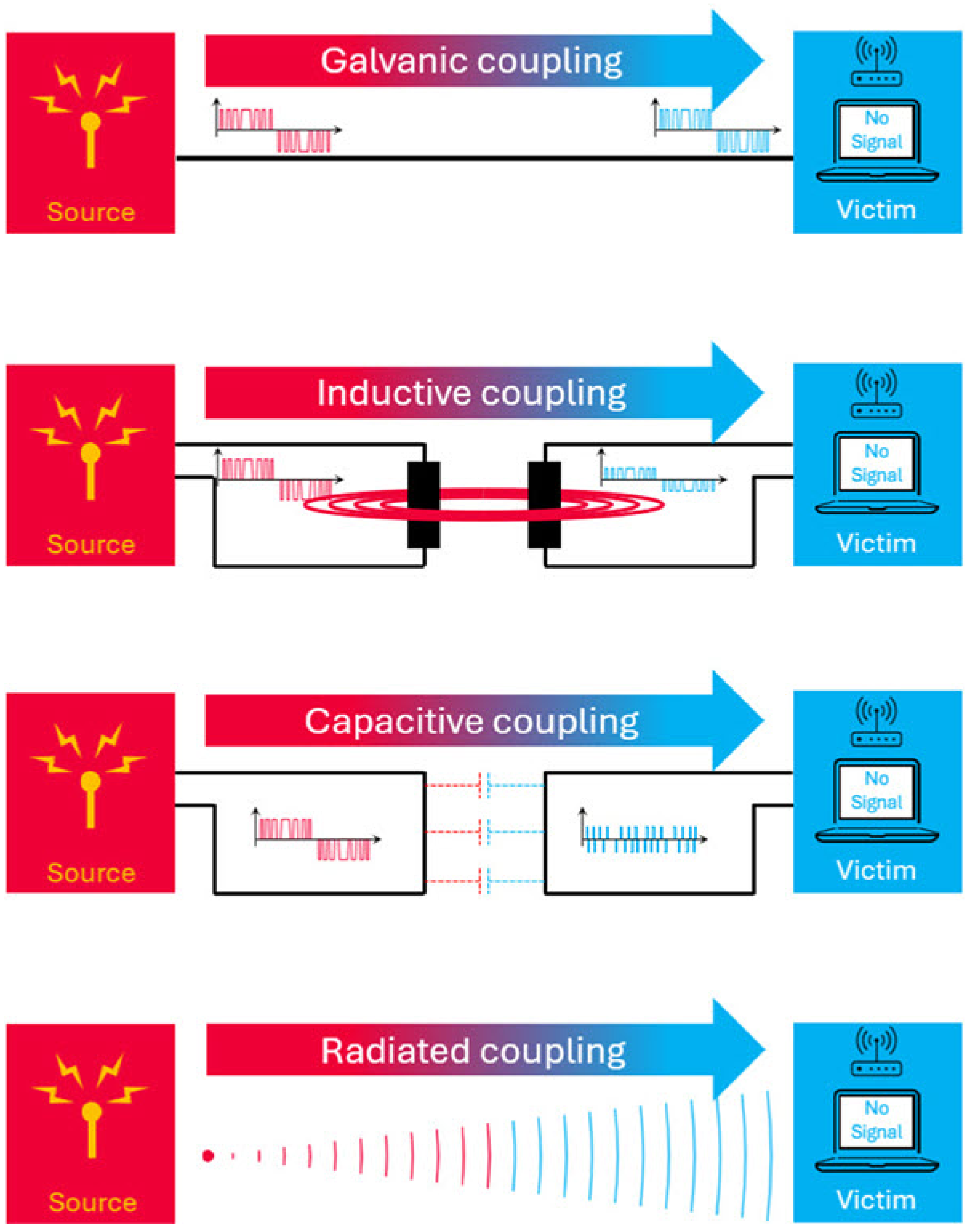


Figure 6-2 Coupling paths between sources and victims

6.4.1 Galvanic coupling

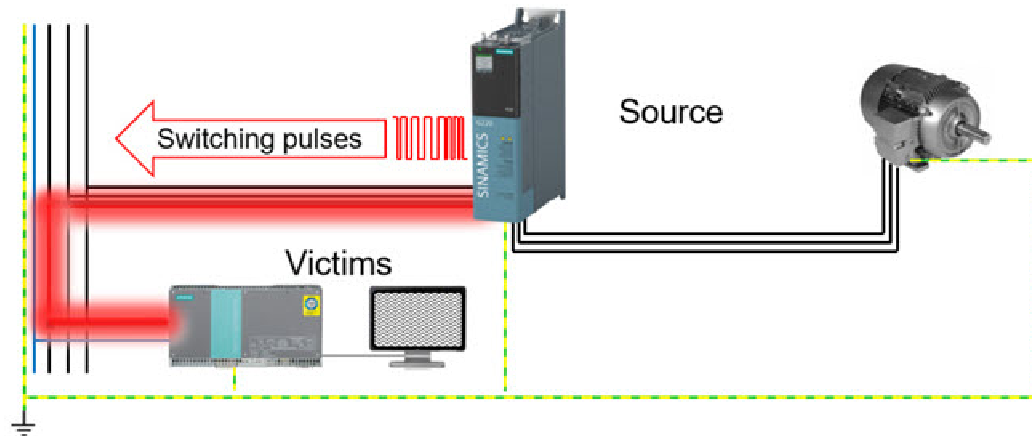


Figure 6-3 Galvanic coupling path

Galvanic coupling between two circuits occurs when their currents flow via a common conductor impedance. Such common impedances are, for example, internal resistances of power supplies that power multiple circuits, or ground and power supply conductors of assemblies.
To minimize galvanic coupling, the length of the shared conductors should be kept as short as possible. In lower-frequency applications, the cross-section of the conductors should be increased or, for high-frequency applications, more surface area (e.g. stranded wires) should be installed. The aim of all these measures is to keep the common impedance, i.e. the frequency-dependent resistance, as low as possible (large cable cross-sections and short cable lengths).

Countermeasures:

- Separation of the circuits
- Avoidance of coupling impedances between signal and power circuits
- Use a separate supply and return conductor for each circuit

6.4.2 Inductive coupling

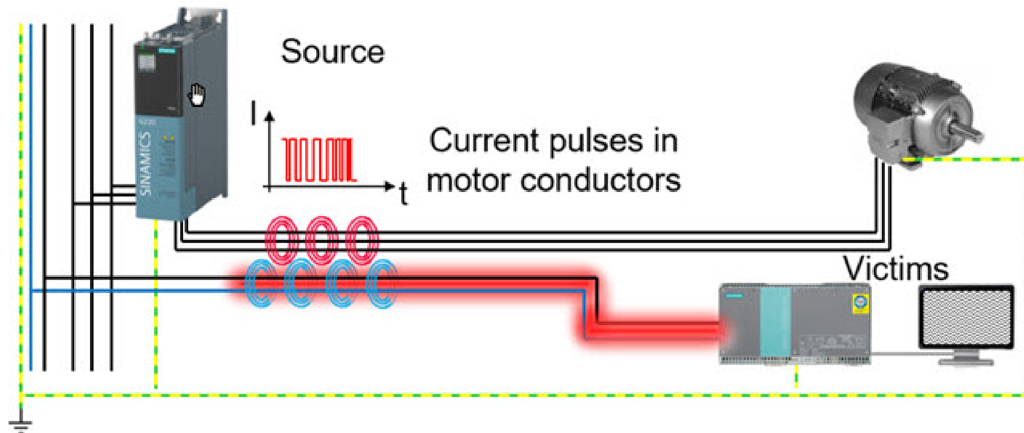


Figure 6-4 Inductive coupling path

Inductive coupling describes the signal transmission between two systems due to the magnetic field. Current pulses cause time-varying magnetic fields around motor cables. These magnetic fields, in turn, induce a pulsating disturbance voltage in adjacent conductors. The coupled disturbance voltage depends on the di/dt and on the coupling inductance.

Countermeasures:

- Route the emitting cable and the susceptible conductor loop at the greatest possible distance from one another
- Install cables closely over the grounded surface
- Use short cables
- Avoid parallel routing
- Keep the distance between the conductor loops as large as possible
- Keep the surface area of the conductor loops as small as possible, i.e. route the supply and return conductors in parallel and in the closest possible proximity to one another, or use twisted wires for signal cables
- Where applicable, use shielding measures: Use highly permeable (magnetically highly conductive) shields (e.g. Mu-metal or permalloy)

6.4.3 Capacitive coupling

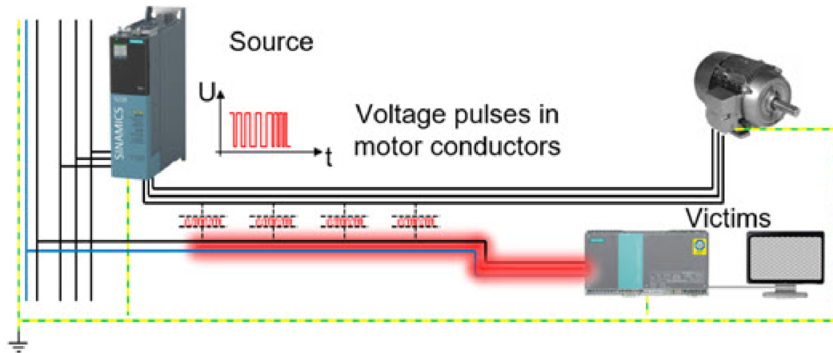


Figure 6-5 Capacitive coupling path

Capacitive coupling refers to the transmission of interference from one system to another due to the effect of alternating electrical fields. If a cable (system 1) with high-frequency voltage pulses, e.g. from a converter to the motor, is routed parallel to an insulated power supply cable (system 2), the two cables act like two capacitor plates. In this way, the current pulses be capacitively coupled from the motor cable to the power supply cable.
The point of origin is therefore the voltage pulses of a system to ground or to another system. Voltage variations cause changes to the electric field. These voltage variations drive interference currents that depend on the voltage variation (dv/dt) and the coupling capacitance.

Countermeasures:

- Route the emitting cable and the susceptible cable at the greatest possible distance from one another
- Install cables closely over the grounded surface
- Use short cables
- Avoid parallel routing
- Spatially separate structures that are sensitive or susceptible to interference
- Where applicable, use shielding measures: Use conductive shields (e.g. metal walls in cabinets or braided shields in cables)

6.4.4 Radiated coupling/electromagnetic coupling

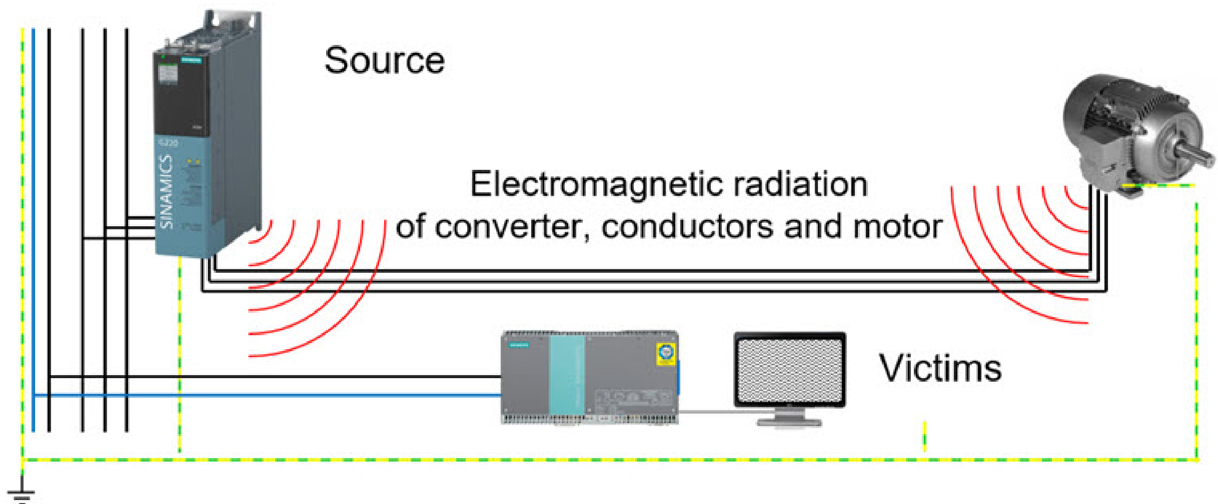


Figure 6-6 Coupling due to radiation

In the higher frequency range, the distinction between capacitive and inductive or high-impedance and low-impedance cannot be maintained. In this range, coupling occurs via the electromagnetic field with mutual influence and feedback between the source and victim of interference.

In the near field, either the magnetic or the electrical field is the prevailing coupling mechanism, depending on the type of interference. In the far field, the two fields are interconnected by the characteristic impedance of free space.

Countermeasures:

- Shielding
- Use metal control cabinets in which the connections between individual components (cabinet frame, walls, doors, etc.) are electrically conductive
- Use metal enclosures for devices and modules which have electrically conductive connections to one another and to the cabinet frame
- Use cables that are shielded with a finely stranded braid designed to provide immunity against high-frequency noise

6.5 Reference to device-specific documentation

Note the manufacturer's specifications

The generally known EMC measures do not always have the desired effect in every application. Whether the shield of analog signal cables should be bonded at one or both ends, for example, depends on the interference source and / or the coupling path.

The following therefore applies:

The technical documentation supplied with the devices or components used is always the binding document with respect to EMC measures. Follow the instructions contained in this documentation relating to EMC-compliant installation, operation and accessories (shielded cables, for example).

These requirements must be implemented to comply with the device Declaration of Conformity.

Take these manufacturer specifications as well as general EMC measures into account in the risk analysis and risk assessment.

6.6 Earthing in the context of EMC

The functions and tasks of earthing or grounding are numerous. On one hand, earthing is for personal safety and is therefore called protective earth (PE). It is intended to provide protection from dangerous voltages that can be generated by lightning or short-circuit currents, and generally protection from dangerous contact voltages.

Another purpose of earthing is to support correct functioning of electrical equipment, functional earth (FE). It is designed to ensure that electrical devices and systems function smoothly, and thus includes EMC as a functional task:

- Definition of a common reference potential for signals
- Discharge of interference currents, therefore limiting their voltage drops on ground cables that cause disturbance voltages
- Connection of shields to this potential in order to prevent interference coupling

Note

Where PE and FE conflict, measures for personal safety must always be given priority.

Earthing

For EMC purposes, the term ground, or grounding, is introduced to complement the term functional earth (FE) and provide a clearer distinction between EMC and personal protection throughout the document. This term is de ined as follows:

In the context of EMC, ground is considered to be the totality of the electrically interconnected metal parts of electrical equipment that ensures equalization of the potentials and provides the reference potential.

Electromagnetic interference can cause large deviations in potential between individual components and areas of the control cabinet. The resulting high compensation currents can have unwanted effects for the components in the control cabinet:

- Malfunctions
- Damage
- Destruction
- Burn damage to shields that are bonded at both ends

To ensure problem-free interaction between the components in a complex system, good equipotential bonding (grounding, functional earth) is required. This must be effective for (high) frequencies of up to 10 MHz and above.

DANGER

Hazardous touch voltage

Functional earth (FE) is not designed to provide electrical safety and is not identical to protective earth (PE).

When earthing an electrical installation, take appropriate measures to protect personnel in accordance with DIN VDE 0100.

EMC in the control panel (example) 7

7.1 Basic rules of EMC

EMC-compliant installation

If you follow the basic rules stated below, they will help you to achieve a control panel design that is EMC-compliant. If you adhere to these rules and observe the specifications in the device-specific technical documentation, you can feel confident that your design will comply with EMC limit values and also function satisfactorily.

Basic rules of EMC

1. Separation of sources and victims of interference
   - EMC zoning
   - Separate routing of cables
2. Functional earth and equipotential bonding
3. Use of shielded cables
4. Filters and suppressor circuits

Note

Note the manufacturer's specifications

The generally known EMC measures do not always have the desired effect in every application. Whether the shield of analog signal cables should be bonded at one or both ends, for example, depends on the interference source and / or the coupling path.

The following therefore applies:

The technical documentation supplied with the devices or components used is always the binding document with respect to EMC measures. Follow the instructions contained in this documentation relating to EMC-compliant installation, operation and accessories (shielded cables, for example).

Take these manufacturer specifications as well as general EMC measures into account in the risk analysis and assessment.

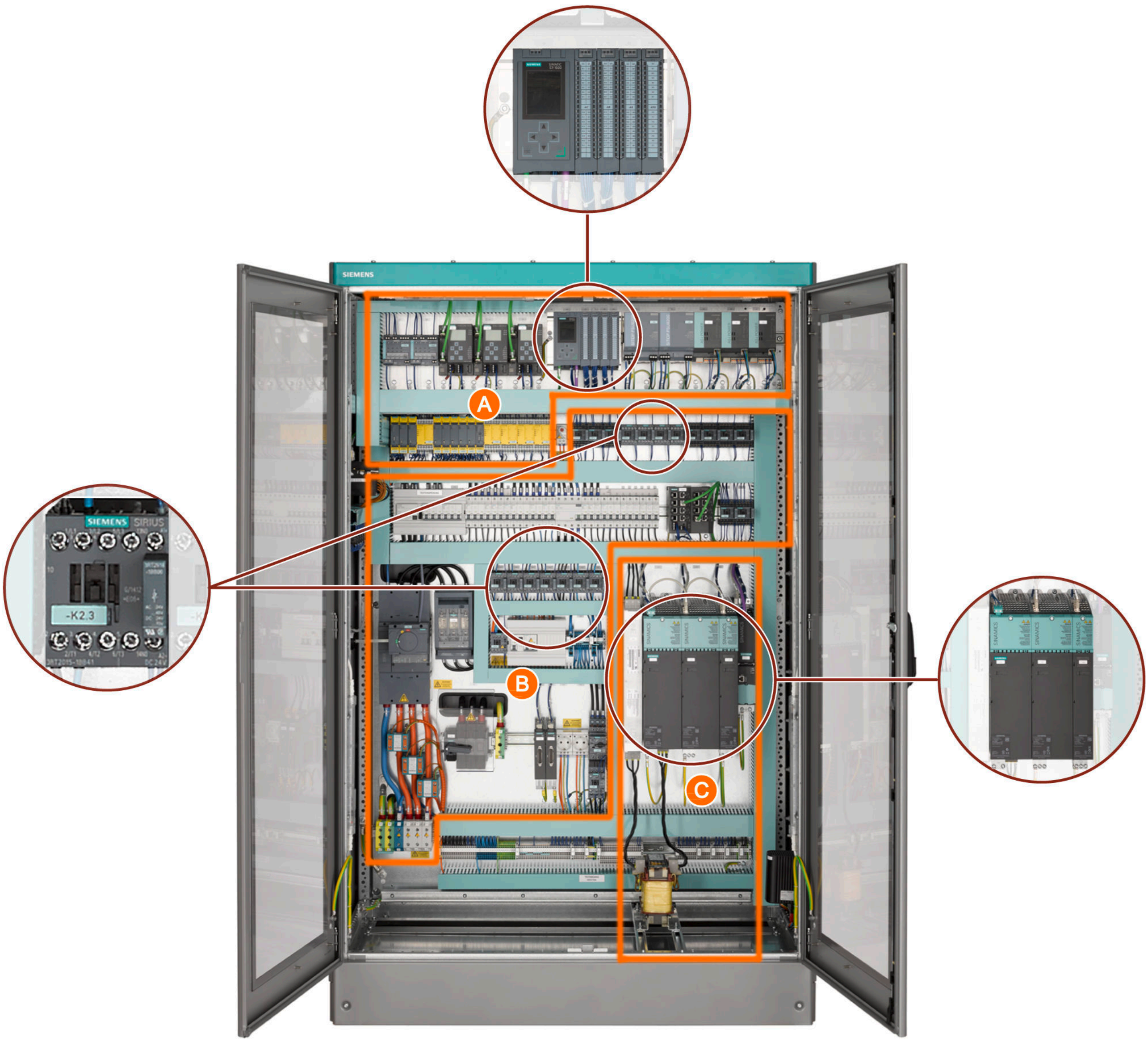
7.2 EMC zoning

Separation of sources and victims of interference

The easiest way to implement interference suppression measures within the control panel is to ensure that interference sources and interference victims are spatially separated.

1. Categorize each device as either an interference source or an interference victim.
2. Divide the entire control panel into EMC zones and assign the devices to these zones.
3. Prevent the interference sources from emitting interference:
   – Equipotential bonding
   – Shielding
   – Filters and suppressor circuits
4. Provide protection for interference victims:
   – Equipotential bonding
   – Shielding

EMC zoning of a control panel



Zone A **Control system and sensors (victims)**
e.g. SIMATIC, safety relays, sensor evaluation equipment

Zone B **Controls and mains connection (sources and victims)**
e.g. SIRIUS, fuses, switches, contactors, mains connection

Zone C **Power electronics (sources)**
e.g. SINAMICS converter comprising a rectifier, braking module, inverter and motor-end circuit breakers, reactors and filters

Figure 7-1 EMC zoning of a control panel

7.3 Zone A: "Control system and sensors (victims)"

7.3.1 SIMATIC S7-1500 automation system

We will assign devices that are susceptible to interference to zone A of our control cabinet. The S7-1500 automation system is an example of one of the devices assigned to zone A.

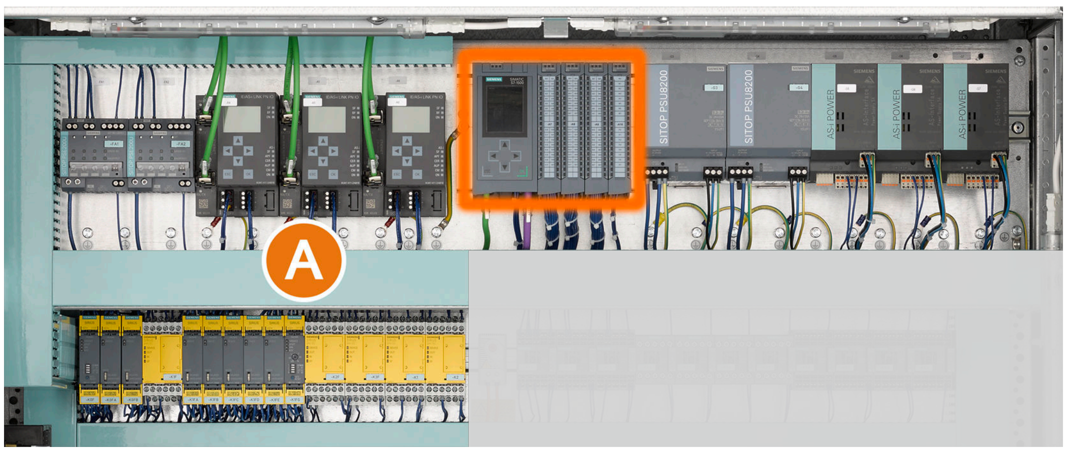


Figure 7-2 Section from the control cabinet (zone A)

Note

Power supply unit as an interference source

Zone A in our example also contains a SITOP power supply unit. Power supply units are sometimes a source of substantial interference owing to their pulsed DC voltage. It does not make sense to install them in a separate location, however, because it would then be necessary to route 24 V cables through the entire cabinet.

Note the information about EMC-compliant installation in the technical documentation supplied with the devices.

S7-1500 automation system

Figure 7-3 Example of an S7-1500 automation system

The SIMATIC S7-1500 automation system in our example consists of a CPU 1516-3 PN/DP and a number of digital modules.

The CPU 1516-3 PN/DP is a standard CPU with a large program and data memory for complex applications. It executes the user program and networks the controller with other automation components.

7.3.2 EMC environment for SIMATIC S7-1500

Permissible EMC environment for SIMATIC S7-1500

In order to provide verification of electromagnetic compatibility, you must first check whether the equipment is approved for use in the intended environment.

The permissible EMC environment (victim of interference) is defined as follows according to the specific EMC standards in the documentation of the SIMATIC S7-1500 Automation System (source of interference):

Use in industrial environments

The S7-1500 automation system/ET 200MP distributed I/O is designed for use in industrial environments. The following standards are complied with for this purpose:

- *Emission requirements for EN 61000-6-4: 2019*
- *Immunity requirements for EN 61000-6-2:2019*

Source: System Manual: SIMATIC S7-1500, ET 200MP Automation System, page 393

Use in mixed-use zones

Under certain conditions, you can use the S7-1500 Automation System/ET 200MP distributed I/O in a mixed-use environment. A mixed-use zone is used for housing and commercial operations that do not have a significant impact on residents.

If you use the S7-1500 automation system/ET 200MP distributed I/O in a mixed-use environment, you must ensure that emission of radio frequency interference is within the limits of generic standard EN 61000-6-3. Suitable measures for achieving these limits for use in a mixed-use environment include:

- *Installation of the S7-1500 Automation System/ET 200MP distributed I/O in grounded control cabinets*
- *Use of filters in electrical supply lines*

An individual acceptance test is also required.

Source: System Manual: SIMATIC S7-1500, ET 200MP Automation System, page 393

Application in residential environments

Note

S7-1500 Automation System/ET 200MP distributed I/O not intended for use in residential environments

The S7-1500 Automation System/ET 200MP distributed I/O is not intended for use in a residential environment. If you use the S7-1500 Automation System/ET 200MP distributed I/O in a residential environment, it may affect radio or television reception.

Source: System Manual: SIMATIC S7-1500, ET 200MP Automation System, page 393

Evaluation for EMC verification

EMC environment	Information in the S7-1500 Automation System documentation		Evaluation for EMC verification
	EN 61000-6-2/ EN 61000-6-3	EN 55011	
Industrial environments	Industrial environments	Class A	Equipment may be used in industrial environments.
Mixed-use zone[1)]	Commercial and light-industrial environments	Class B if the following conditions are fulfilled: • Installation in grounded control cabinets/control boxes • Use of filters in electrical supply lines	May be used in mixed-use zones under certain conditions.
Residential environment	-	-	S7-1500 Automation System/ET 200MP distributed I/O system not intended for use in residential environments.

1) Covered by generic standard EN 61000-6-8. To ensure operation beyond any doubt, EN 61000-6-3 is used by the manufacturer.

Source of verification and documentation

You can find documentation and detailed information about SIMATIC S7-1500 control systems for verification purposes on the Internet at:

- System Manual: SIMATIC S7-1500, ET 200MP Automation System
  Link (https://support.industry.siemens.com/cs/ww/de/view/59191792)
- Equipment Manual: SIMATIC S7-1500 CPU 1516-3 PN/DP
  Link (https://support.industry.siemens.com/cs/ww/en/view/59191914)

7.3.3 EMC phenomena associated with controllers

SIMATIC products and their components have been developed for use in industrial environments and fulfill all legal EMC requirements (EMC - Electromagnetic Compatibility). Before you install your controller, however, you still need to conduct an EMC assessment in order to identify any potential sources of interference on the automation system and include them in your considerations.

Electromagnetic interference is coupled into the automation system by various different paths. The major forms of interference and its causes are listed below:

- Electromagnetic fields that have a direct effect on the system
- Interference that is coupled into the system via bus signals (e.g. PROFINET)
- Interference that is coupled in via process wiring
- Interference that reaches the system via the power supply and/or the protective earth

The figure below shows the possible coupling paths for electromagnetic interference.

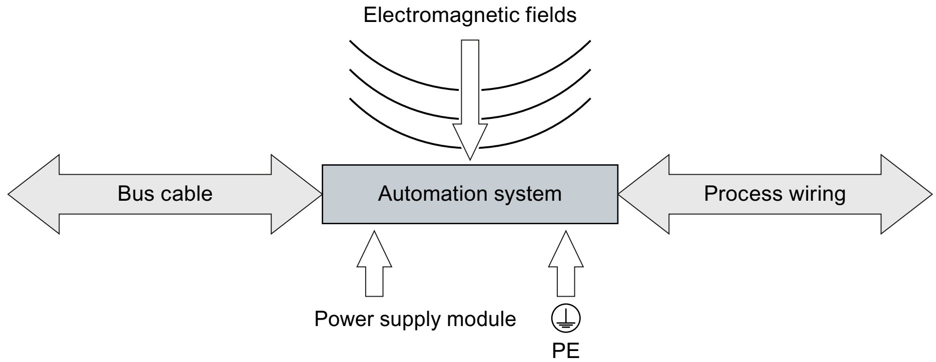


Figure 7-4 Sources of electromagnetic interference affecting a controller

7.3.4 EMC measures for controllers

Interference-proof cable routing

Interference can reach the automation system via various different coupling mechanisms depending on the propagation medium and the distance between the interference source and the victims.

- Assign cables to different categories depending on their sensitivity to coupled interference and emitted interference. The greater the distance you can maintain between the different categories of cable, the lower the level of mutual interference between cables due to capacitive and inductive coupling.
- When you bring cables into the control cabinet, do not route them in parallel past shield supports.
- If you install the cables in metal cable ducts, you can position the cable ducts directly adjacent to one another.
- If you intend to install cables from different categories in the same cable duct, then use metal cable ducts with a metal partition.
- Connect metallically conductive cable ducts to the equipotential bonding to ensure a low-impedance ground connection.
- If you cannot avoid crossing cables, then place them at an angle of 90° at crossing points wherever possible in order to minimize interference caused by electrical fields.

Shielding of cables

The purpose of shielding cables is to attenuate (dampen) magnetic, electrical or electromagnetic interference fields. Interference currents on cable shields are discharged to ground via the shield connection. To prevent these interference currents from becoming a source of interference themselves, a low-impedance connection to the grounding system is particularly important.

- Use cables with a braided shield wherever possible. The shield must make more than 80 % contact at the contact point.
- Always connect the cable shields at both cable ends to functional earth (FE) or ground. It is only by connecting the shield to ground at both ends that low-frequency and high-frequency interference can be reduced.
- If there is a potential difference between grounding points, a compensation current can flow across the shield grounded at both ends. In this case, install an additional equipotential bonding cable.
- If you do not have the option of installing an equipotential bonding cable (e.g. in an installation with large distances), connect one end of your shield via a capacitive coupling. This solution is only effective at reducing high-frequency interference.
- A special concept for connecting signal cable shields has been developed for the S7-1500 Automation System and the ET 200MP distributed I/O system. The following types of shield connection have proven successful for use on devices that are not equipped with special shield clamps:
  - Use metal cleats to secure the braided shields of the cables. The cleats must provide a good electrical contact and a large-surface connection to the shield.
  - Attach the shield to a shield bar directly after the cable entry point into the cabinet. The diagram below shows commonly used types of shield connection.

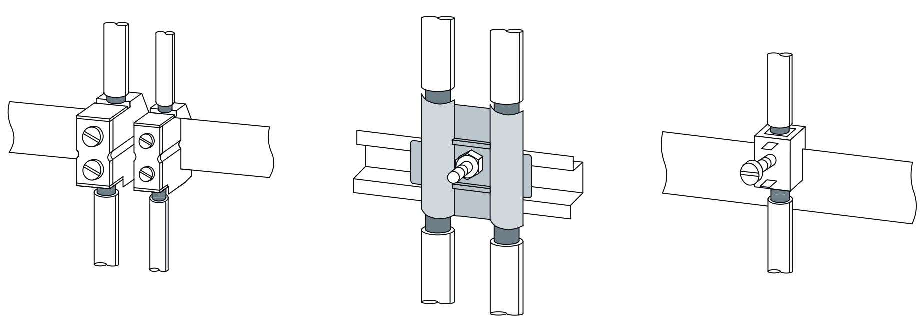


Figure 7-5 Cable shield connection

Equipotential bonding

Electromagnetic interference can cause large deviations in potential between individual components and areas of the control cabinet. The high compensating currents that develop as a result can have undesirable effects (e.g. malfunctions or damage) on the components inside the cabinet:

- Connect equipotential bonding cables over a large contact area to the grounding system.
- Protect the connection points against corrosion.
- Avoid creating large ground loops and route the cables on the grounded surface.

- Route the equipotential bonding cables as close as possible to the signal cables.
- The lower the impedance of the equipotential bonding cable, the greater the equipotential bonding effect. The impedance of the additionally installed equipotential bonding cable must not exceed 10 % of the shield impedance.
- In order to prevent the formation of grounding loops, equipotential bonding cables are routed in parallel and, whenever possible, close to the signal/bus cable. This will minimize the size of the area between the two cables.

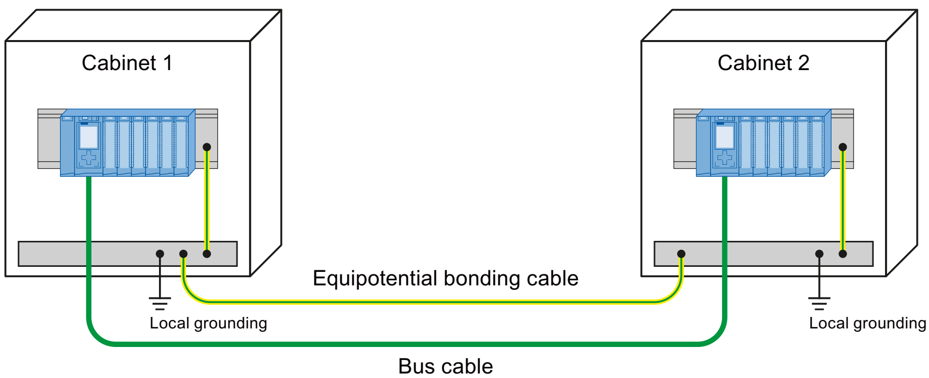


Figure 7-6 Installation of equipotential bonding cables

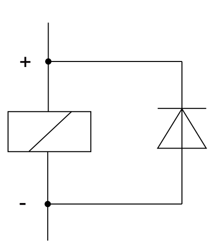
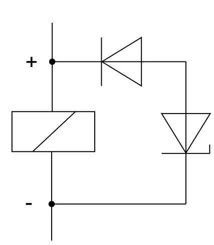
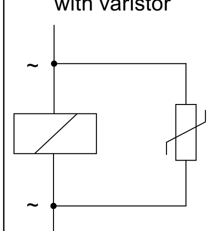
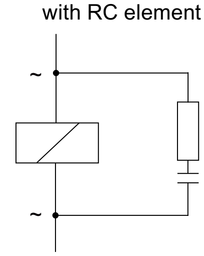
Connecting snubber elements to inductive loads

Under ideal conditions, it is not necessary to connect external snubber elements to inductive loads (e.g. contactor or relay coils) that are controlled by SIMATIC. The snubber elements required are already integrated in the modules.

However, if the SIMATIC output power circuit can also be interrupted by built-in contacts (e.g. relay contacts for EMERGENCY STOP), the snubber elements integrated in the modules will no longer work effectively. In this case, you must connect snubber elements to the inductive loads.

Equip the inductive loads with elements such as freewheeling diodes, varistors or RC suppressors.

Table 7-1 Protective circuit for inductive loads

Protective circuit for DC-operated inductive loads		**Protective circuit for AC-operated inductive loads**	
with diode	with Z diode	with varistor	with RC element
			

Detailed information

You can find detailed information about designing electromagnetically compatible SIMATIC S7-1500 controllers and the special shield concept on the Internet:

- Function Manual: SIMATIC S7-1500, ET 200MP, ET 200SP, ET 200AL Designing interference-free controllers
  Link (https://support.industry.siemens.com/cs/ww/en/view/59193566)

7.4 Zone B: "Controls and mains connection (interference sources and victims)"

7.4.1 3RT2 contactors and contactor assemblies

The mains connection components are assigned to zone B of our control cabinet. The 3RT2015 interference-proof contactors are an example of one component from zone B.

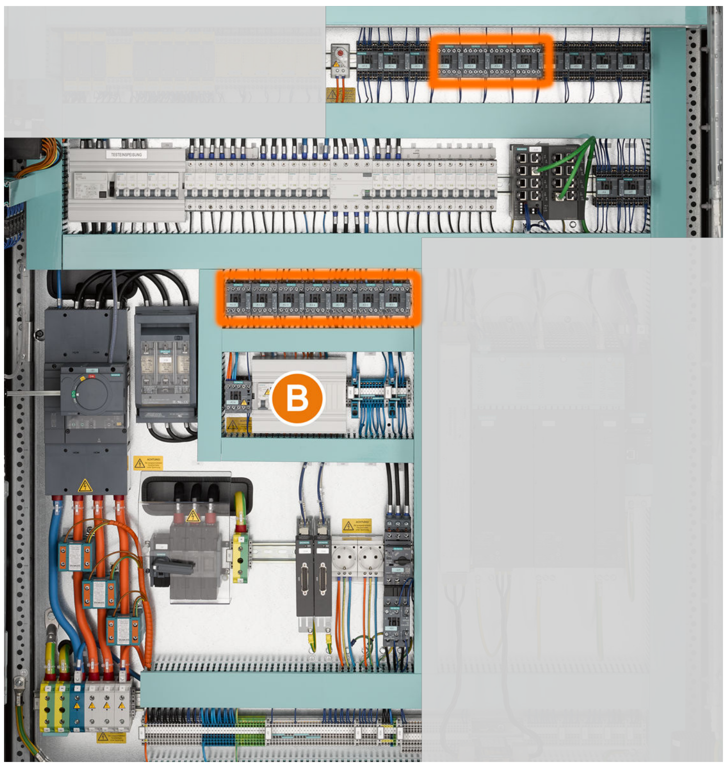
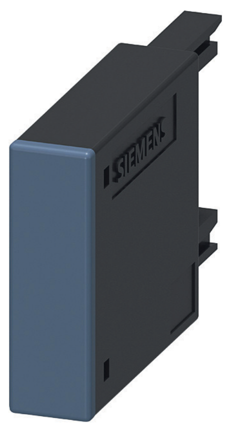


Figure 7-7 Section from the control cabinet (zone B)

3RT2015-1BB41 coupling relays

The SIRIUS coupling relays for switching motors as well as auxiliary and control circuits are specially designed for operation with electronic controllers. The key characteristics of these coupling relays are their low power consumption and extended solenoid coil operating range. The excellent contact reliability of the auxiliary contacts guarantees that no spurious signals are generated, even at low switching capacities. An integral system of overvoltage damping protects sensitive output stages against coil opening surges.

3RT2916-1BB00-Z surge suppressor (varistor)



All 3RT2 contactors and 3RH2 contactor relays can be retrofitted with RC elements or varistors for damping opening surges in the coil. Diodes or diode combinations (comprising noise suppression diodes and Zener diodes for short break times) can be used.

This also applies analogously to the main conducting paths. If, for example, you switch off low-power 400 V motors, the same behavior also occurs on the main conducting paths. For this, too, there are three-phase connection options ready-made from the manufacturer.

7.4.2 EMC environment for 3RT2 contactors

EMC verification

In order to provide verification of EMC compliance, you must first check whether the equipment is approved for use in the intended environment according to the specific product technical standard.

Since contactors do not contain any electronic circuitry, they are not susceptible to electromagnetic interference and are not therefore subject to any EMC product standard or generic standard. It is not therefore necessary to carry out interference immunity tests for these components and no specifications pertaining to testing are included in the documentation.

Note

Exception

Contactors with electronics operating mechanisms designed for Environment A according to IEC/EN 60947-1, IEC/EN 60947-4-1, or Class A according to CISPR 11, EN 55011 are an exception, cf. Equipment Manual: Industrial Controls, Switching devices–SIRIUS 3RT contactors/contactor assemblies (https://support.industry.siemens.com/cs/ww/en/view/60306557), page 27.

Owing to the opening surges associated with contactors that can affect electronic controllers, however, they must nevertheless be taken into consideration in the evaluation of EMC phenomena and measures and therefore included in the EMC risk analysis and assessment.

7.4.3 EMC phenomena associated with contactors

Surge voltages

Surge voltages occur when contactor coils are de-energized (inductive loads). Voltage peaks of up to 4 kV can occur at a rate of rise of voltage of 1 kV/microsecond (shower discharges). This leads to:

- Substantial erosion and, as a result, premature wear of the contacts which switch the coil.
- Injection of interference signals which lead to spurious signals in electronic controllers.

Therefore, all contactor coils should be equipped with damping elements to attenuate opening surge voltages, particularly when the coils are operating in conjunction with electronic controllers.

Furthermore, the high rate of rise of the voltage waveforms generated can lead to the capacitive coupling of significant interference signals with adjacent systems. They necessitate an RC circuit directly at the location where the source of interference originated, i.e. at the contactor coil. This prevents overvoltages from occurring directly at the place of origin and protects the electronic components which are sensitive to voltage too. It also prevents the capacitive coupling of interference signals with the control cables of electronic circuits.

Coil without RC circuit

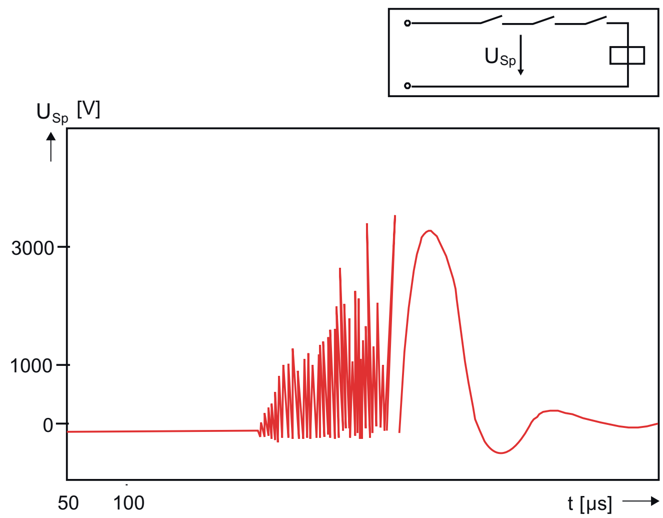


Figure 7-8 Disconnection of a contactor coil without RC circuit

Oscillogram of the disconnection of a contactor relay coil; the coil does not have an RC circuit: Shower discharges are clearly visible (voltage peaks up to around 4 kV). Once the disconnection process has started, the shower discharges occur for about 250 μs; after that, the vibration is simply damped.

7.4.4 EMC measures for contactors

Damping methods

The following RC circuit elements are commonly used to damp overvoltages; they are connected in parallel with the contactor coil:

- Freewheeling diode
- Diode combination
- Varistors
- Suppressor diode
- RC element

All 3RT2 contactors and 3RH21 contactor relays can be subsequently connected to RC elements or varistors for damping opening surges in the coil. Diodes or diode combinations can also be used.

Coupling relays, on the other hand, do not require any additional surge suppressor elements and can be used directly with electronic controls.

RC circuit with varistor

Varistors (voltage-dependent resistors) limit the maximum level of the overvoltage, as they become conductive above a certain threshold voltage. Shower discharges occur up to that level, in a similar way to those seen with the magnet coil without an RC circuit, but they do not last as long overall. Varistors can be used for DC- and AC-operated contactors.

Note

Varistors extend the contactor's OFF time by around 2 to 5 ms.

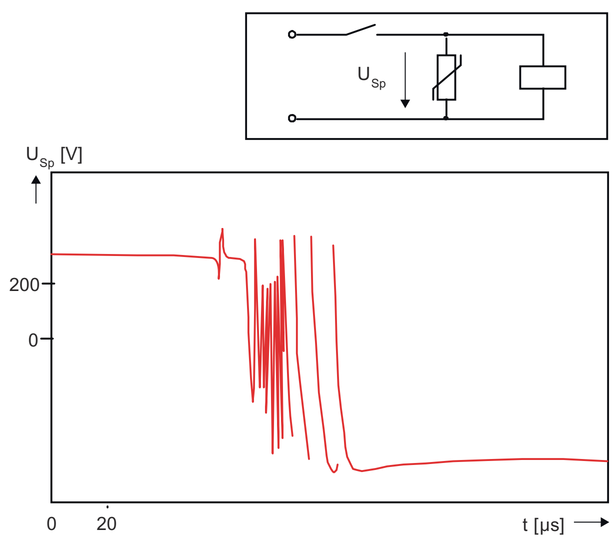


Figure 7-9 RC circuit with varistor (AC/DC operation)

Voltage peaks still occur. They are truncated at around 400 V and do not last as long overall (approximately 50 µs).

Note

Oscillogram is truncated; voltage drops to zero after around 3 ms.

Detailed information

You can find detailed information about electromagnetically-compatible operation of contactors on the Internet.

- Equipment Manual: Industrial Controls, Switching devices – SIRIUS 3RT contactors/contactor assemblies
  Link (https://support.industry.siemens.com/cs/ww/en/view/60306557)
- Reference manual: Basics of Low-Voltage Controls and Distribution
  Link (https://support.industry.siemens.com/cs/ww/de/view/34973099)

7.5 Zone C: "Power electronics (sources)"

7.5.1 SINAMICS S120 converter

Zone C of our control cabinet contains the power electronics equipment and in our example, this is the SINAMICS S120 drive system.

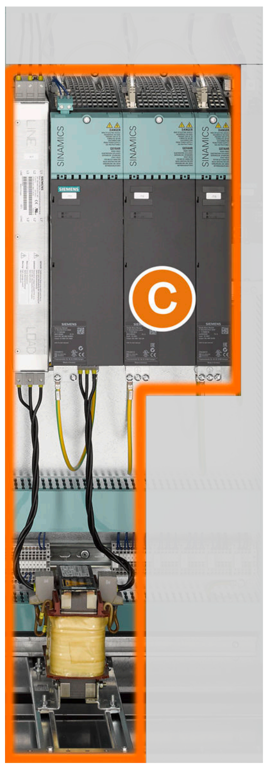


Figure 7-10 Section from the control cabinet (zone C)

SINAMICS S120 drive system

Figure 7-11 SINAMICS S120 drive system

The modular SINAMICS S120 drive is the modular system for high-performance motion control applications in industrial plant and machinery construction. Customized solutions can be implemented based on a wide range of components and functions that are optimally coordinated with one another. For instance, high-performance single-motor drives and coordinated drives (multi-axis applications) with vector or servo functionality. Users of the SINAMICS S120 drive will benefit from a system that offers higher performance, enhanced productivity and improved flexibility.

7.5.2 EMC environment for SINAMICS S120 converters

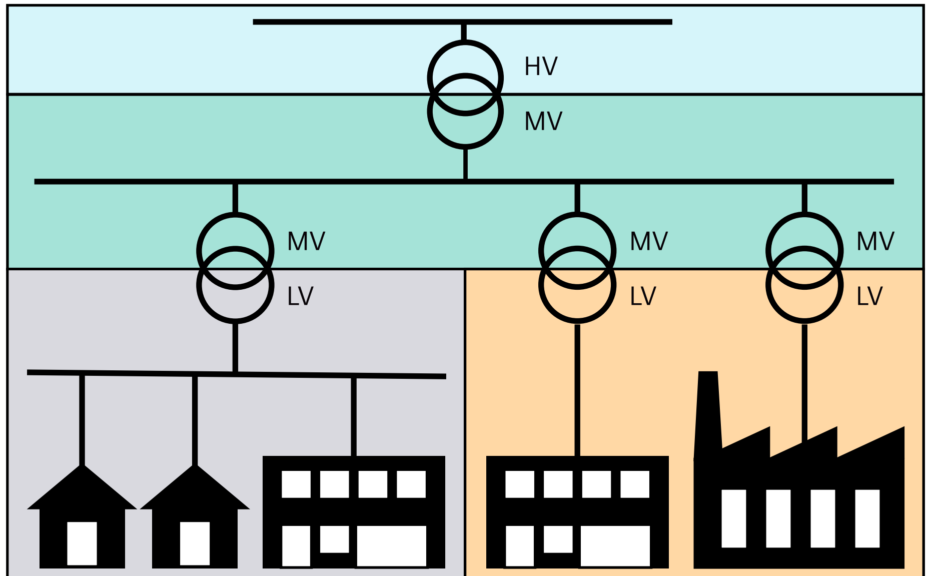
Evaluation for EMC verification

In order to provide verification of electromagnetic compatibility, you must first check whether the equipment is approved for use in the intended environment. The permissible EMC environment is defined as follows according to the specific standards in the SINAMICS S120 drive system documentation.

The various standards concerning EMC and power quality at device level and system level distinguish between the following environments:

- *Residential environments supplied by the public supply low-voltage network.*
- *Commercial and light-industry environments supplied by the public low-voltage network, e.g. supermarkets, auto repair workshops.*
- *Environments for industry and large-scale plants, supplied by a separate, non-public power network. The separate power network uses a high voltage transformer or medium voltage transformer designed specifically to supply the plant. The same separate power network is also used to supply non-industrial devices, such as office equipment.*
- *Environments for heavy industry, supplied by a separate power network. The separate power network uses a high voltage transformer or medium voltage transformer designed specifically to supply the plant. The separate power network is used exclusively to supply industrial devices, such as converters.*

The following figure provides an overview of the different operating environments:



Low-voltage network	Public supply network		Non-public and industrial supply networks	
Operating environment	Residential	Commercial/-light industry	Industry/large-scale plants	Heavy industry
High-frequency interference [1)]	IEC 61800-3 Category C1	IEC 61800-3 Cat. C1 or C2 [5)]	IEC 61800-3 Cat. C2 or C3	IEC 61800-3 Cat. C3 or C4 [6)]
Current harmonics [2)]	IEC 61000-3-2 (up to 16 A) IEC 61000-3-12 (16 A to 75 A)		-	
Voltage changes, fluctuations and flicker	IEC 61000-3-3 (up to 16 A) IEC 61000-3-11 (16 A to 75 A)		-	
Voltage harmonics [3)]	IEC 61000-2-2		IEC 61000-2-4 Class 2 or 3	IEC 61000-2-4 Class 3
Voltage distortions [4)]	IEC 61000-2-2		-	
Harmonics in electric power systems [7)]	IEEE519			

① Limit values for radio-frequency disturbance voltage 9 kHz to 30 MHz and radio-frequency emitted interference >30 MHz. IEEE 519: Standard for Harmonic Control in Electric Power Systems

② Limit values up to 2 kHz for devices

③ Compatibility level up to 2 kHz at system grid connection point

④ Compatibility level 2 kHz to 150 kHz at system grid connection point (IEC 61000-2-2:2018 Edition 2.2)

⑤ Category C2 PDSs must be set up and put into operation by trained staff.

⑥ Category C4 is applicable for PDSs with a rated current >400 A, for use in complex industrial systems or for operation in IT supply systems.

⑦ IEEE 519: Standard for Harmonic Control in Electric Power Systems

Figure 7-12 Voltage levels in public and non-public/industrial supply networks

Note

The compatibility levels listed in the IEC 61000-2-X series of standards are not limit values, but defined reference levels for coordination of interference emission limits in the specified environment. The compatibility levels do not relate to individual devices, but to the system grid connection point.

Source: Configuration Manual: EMC Installation Guidelines/Basic System Requirements, pages 33, 34, and 35

Table 7-2 Electrical data

Line connection voltage	380 ... 480 V 3 AC ±10% (-15% < 1 min)
Line frequency	47 ... 63 Hz
Electronics power supply	24 V DC -15/+20% 1), PELV or SELV extra low voltage
Radio interference suppression	Category C3 according to IEC 61800-3 (standard) Category C2 according to IEC 61800-3 (option) For implementing plants and systems corresponding to the EC Declaration of Conformity for EMC and the "EMC installation guidelines" Configuration Manual. Article number: 6FC5297-.AD30-0AP
Overvoltage category	III2) According to IEC 61800-5-1, EN 61800-5-1, UL 61800-5-1, and CSA C22.2 No 274
Pollution degree	23) According to IEC 61800-5-1, EN 61800-5-1, UL 61800-5-1, and CSA C22.2 No 274

1) The supply voltage may not fall below the minimum value of 20.4 V (24 V -15%) at the last device in the line-up, as otherwise malfunctions can occur. The input voltage must be set sufficiently high for this. In order to prevent the maximum 24 V power supply voltage from being exceeded (= 28.8 V), the voltage can be injected at various locations in the line-up.

2) The components are designed for connection to electric circuits of overvoltage category III. If this has not already been ensured by the installation, an upstream overvoltage protection device may have to be installed. Overvoltages must be limited to 6 kV against ground and 4 kV between phases. Overvoltage protection devices must be suitable for the line voltage and the prospective short-circuit current of the line.

3) The components must be protected against conductive pollution, e.g. by installing them in a control cabinet with degree of protection IP54 according to IEC 60529 or Type 12 according to NEMA 250. If conductive pollution can be excluded at the installation site, a lower degree of cabinet protection is permissible.

Source: Equipment Manual: S120 Control Units and Additional System Components, page 39

EMC verification

EMC environment	Comparison of relevant standards SINAMICS S120 drive system EN 61800-3	Evaluation for EMC verification
Industrial environments	Fulfilled with Category C3 (standard)	The equipment may be used in industrial environments if it is installed and commissioned by specialist personnel.
Residential environments	Conditionally fulfilled with Category C2 (option)	Use in residential environments is permissible subject to fulfillment of the following conditions: • Equipment is installed and commissioned by specialist personnel. • A line filter must be installed to ensure compliance with the limit values defined according to EN 61800-3, Class C2.

Source of verification and documentation

You can find further information about the EMC requirements of the SINAMICS S120 drive system in the relevant documentation:

- Configuration Manual: EMC Installation Guidelines / Basic System Requirements
  Link (https://support.industry.siemens.com/cs/ww/en/view/60612658)
- Equipment Manual: S120 Control Units and Additional System Components
  Link (https://support.industry.siemens.com/cs/ww/en/view/109782370)
- Equipment Manual: S120 Booksize Power Units
  Link (https://support.industry.siemens.com/cs/ww/en/view/109781351)

7.5.3 EMC phenomena associated with SINAMICS S120 converters

Frequency converters are powerful sources of electromagnetic interference. The following phenomena can occur as soon as the converter drive is running. The following list does not claim to be complete.

- Sudden malfunctions of machines and equipment, IT and telephone systems without a discernible cause
- Erroneous tripping of protective switches or circuit breakers
- Frequent failures of switched-mode power supplies, e.g. in IT systems
- Destruction of the capacitors, in reactive power compensation systems and filter systems, for example
- Overheating of cables, motors and equipment that are directly connected to the mains supply and equipment such as fuses, contactors, etc.

- Noise development (humming), for example in switches, motors and transformers that are connected directly to the mains supply
- Excessive load on the neutral conductor, e.g. in building technology when many single-phase converters/devices are operating on the mains supply with B2 rectifiers (3rd harmonic)

In addition to the direct effects, **long-term effects** can also present problems:

- Rapid device aging for capacitors and windings, e.g. in reactive power compensation systems and electronic devices (e.g. controllers, computers, cash register systems)
- Poor power factor with increased system losses

7.5.4 EMC measures for SINAMICS S120 converters

EMC zoning concept - planning guide

- Assign all of the devices that are to be installed in the control cabinet to the category "interference source" or "interference victim".
- When you have finished categorizing the individual devices, divide the entire area of the plant or control cabinet into EMC zones.
- Take measures to decouple the zones electromagnetically.
  Such decoupling measures include, for example, large spatial distances (approx. 20 cm). Better and more space-saving is decoupling using separate metal enclosures or large metal partitions.
- Install all of the components on a bare and highly conductive metallic mounting plate. Connect the mounting plate so that it is electrically conductive and flush with the side rails of the cabinet, the PE rail and EMC shielding rail, e.g. using braided copper bands
- The previous statement also applies if you are installing mounting plates or individual components to side plates, rear panels, top and bottom plates.
  Also connect the cabinet doors to the cabinet side rails with a braided copper band for improved discharge of high-frequency interference.
- Ground the entire control cabinet/box in an EMC-compliant manner. In case of doubt, also connect it to ground additional to the protective earth using a braided copper band, for example.

Note

Use of inductive loads (coils):

If connections are made using mechanical switching contacts, e.g. for the contactor, relay or output contacts of a PLC or converter, equip all of the connected actuators, contactor coils, solenoid valves, holding brakes, etc., with surge suppression elements, e.g. RC elements or varistors, directly at the interference source if possible. This prevents switching overvoltages.

EMC-compliant cabling

General information

- All of the communication and analog signal cables as well as the motor cables (lines, not individual conductors) from the converter must be shielded inside and outside the cabinet.
- The supply cable of the converter must be shielded downstream of the filter to the converter.

Notes on EMC-compliant cable routing in the control cabinet and the system

- Keep all cables in the control cabinet as short as possible.
- Route shielded and unshielded power and signal cables separately (except for short sections of cable) and with a minimum distance between them of 20 cm.
  It is permissible to cross cables.
- Do not route cables from different zones in shared cable harnesses or cable ducts.
- Route cables on the grounded surface, e.g. along the cabinet wall and not diagonally through the cabinet.
- Never install/implement the DC link in any other way than specified in the relevant manuals! The problem is: The DC link is often (incorrectly) set up with a large infeed and then routed across the hall/installation, which causes disturbances. The DC link carries the same interference as the braking resistor and motor cables.
- In the case of shielded combined cables to the motors (motor cable with brake control line, temperature cable, or signal cables), all the cables it contains must be treated as motor cables because they all carry the same HF emission.

Notes on shielding

Carefully comply with the following information about attaching cable shields.

- Always connect the shield at both ends using a 360° bonding shield support. If the potentials between the converter and the motor are unclear, lay an equipotential bonding cable parallel to the motor cable. This is usually not required for short cables.
- If possible, connect shielded cables to the device without intermediate terminals.
- Always attach the shield in the control cabinet and at the motor, for example, so that it has a 360° bond with the shield support or mounting plate.
- Clamp the shield down firmly using, for example, shield clamps, cable ties, or metallic hose clamps (motor cables).
- The shields of cables for analog signals must be connected at both ends. Good equipotential bonding between output and input is required.

Line reactors and line filters

The drive line filter that belongs to the converter system is tailored exclusively to the converter system and should only be used for this. For other loads, a commercially available line filter must be installed downstream of the main switch and fuses as close as possible to the cabinet entry point. Other loads are supplied via this line filter.

Detailed information

You can find detailed information about the SINAMICS S120 drive system on the Internet.

- Configuration Manual: EMC Installation Guidelines
  Link (https://support.industry.siemens.com/cs/ww/de/view/60612658/en)
- Configuration Manual: SINAMICS G130, G150, S120 Chassis, S120 Cabinet Modules, S150 (Supplement to Catalogs D 11 and D 21.3)
  Link (https://support.industry.siemens.com/cs/us/en/view/83180185)
- Equipment Manual: S120 Booksize Power Units
  Link (https://support.industry.siemens.com/cs/ww/en/view/109781351)
- Equipment Manual: S120 Control Units and Additional System Components
  Link (https://support.industry.siemens.com/cs/ww/en/view/109478725)
- Brochure: EMC - Electromagnetic Compatibility
  Link

Practical tips for dealing with EMC 8

8.1 Cabinet configuration

Shielding by enclosure

Metal enclosures can be used to guard equipment that is susceptible to interference ("victim") against the effects of magnetic and electrical fields, and electromagnetic waves. The easier it is for the induced interference current to flow, the greater the degree of self-weakening of the interference field. It is for this reason that the connections between all enclosure panels or plates in the cabinet must be highly conductive.

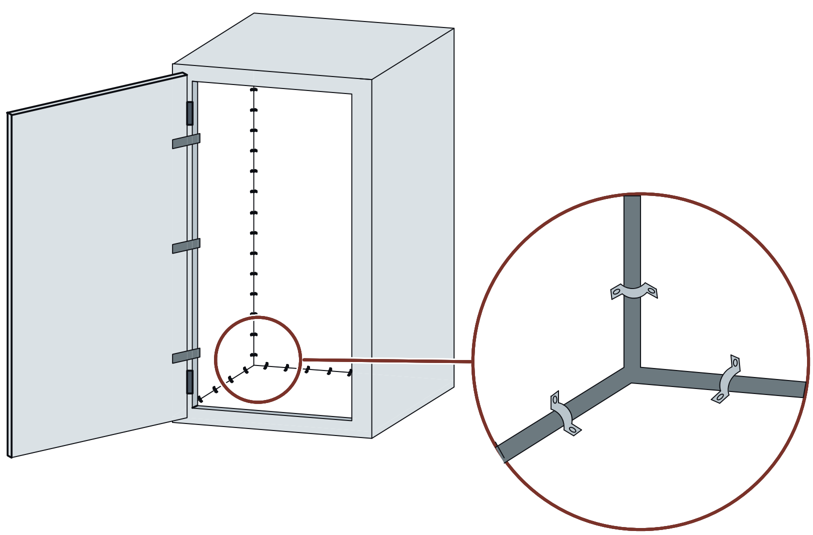


Figure 8-1 Shielding by enclosure

If the cabinet panels are mutually insulated, a connection that conducts high-frequency interference can be created using flat straps and high-frequency shield clamps, or HF conductive paste. The larger the surface area of the connection, the greater its ability to conduct high-frequency interference. This kind of connection cannot be achieved with simple wires.

Preventing interference by implementing an optimum equipment design (EMC zones)

Interference can be discharged effectively by installing equipment on conductive mounting plates (bare metal). It is easy to protect equipment against the effects of interference if the control cabinet is designed in accordance with the relevant guidelines. Power components (transformers, drive systems, load power supply units) should be spatially separated from control components (relay control unit, SIMATIC S7).

The following always applies:

- The effects of interference diminish as the distance between the interference source and the victim increases.
- Interference can be further reduced by the installation of shield plates.
- Load cables and power cables must be installed at a distance of at least 10 cm from signal cables.

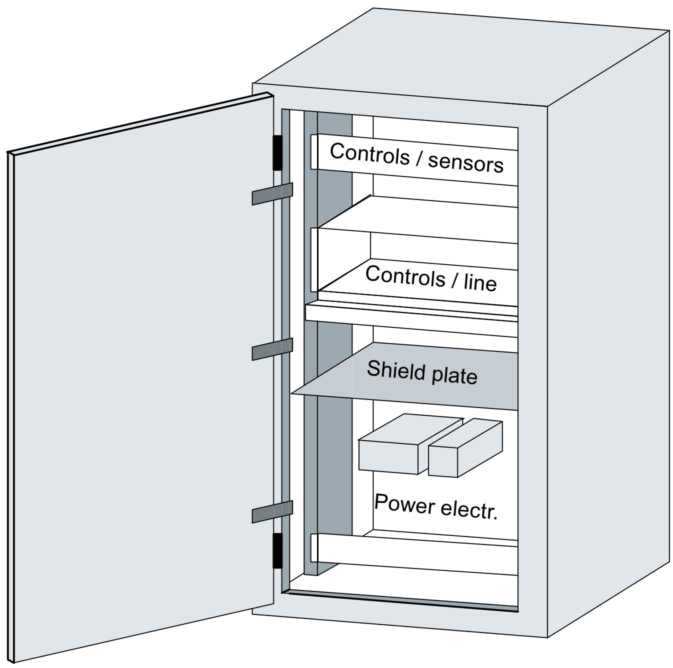


Figure 8-2 Preventing interference by implementing an optimum equipment design

Filtering the supply voltage

Installing line filters prevents external interference from the supply system from reaching the equipment. In addition to proper dimensioning of the filters, it is also essential to install them in the correct position. Line filters must always be mounted directly at the cabinet entry point. This ensures that an interference current is not allowed to pass through the cabinet, but is filtered out early at the cabinet entry point.

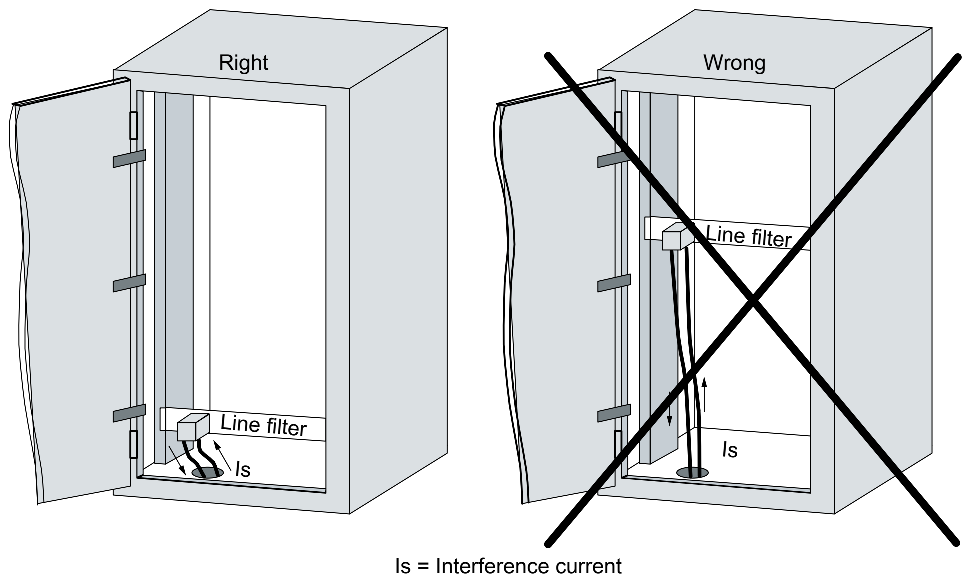


Figure 8-3 Filtering the supply voltage

8.2 Equipotential bonding

Differences in potential can develop between different sections of an installation owing to variations in system design and voltage levels. If the different sections are interconnected by signal cables, then compensating currents will flow along these cables. These compensating currents can falsify signals.

It is therefore essential to implement proper equipotential bonding.

- The cross section of the equipotential bonding cable must be sufficiently large (at least 10 mm^2).
- The distance between the signal cable and its equipotential bonding cable must be as small as possible (antenna effect).
- A finely stranded cable must be used (to conduct high-frequency interference more effectively).
- Equipotential bonding cables must be connected to the central equipotential busbar (EB) according to groupings of "power components" and "non-power components".
- Each of the equipotential bonding cables of the individual modules must be routed directly to the EB (equipotential busbar). When the cabinet includes sources of high-frequency interference, the mounting plate is also often used as a central EB.

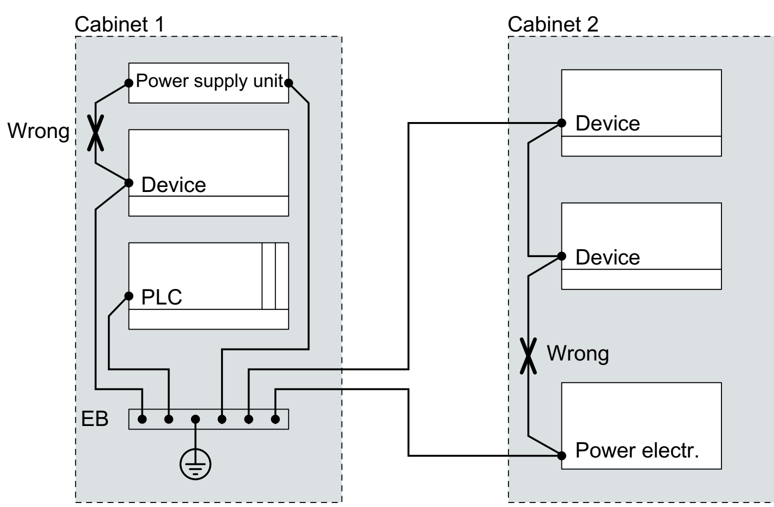


Figure 8-4 Equipotential bonding (EB = equipotential busbar)

The more effective the equipotential bonding system in an installation, the lower the risk of interference induced by fluctuations in potential.

The equipotential bonding system must not be confused with protective earth. The protective earth system is designed to prevent the occurrence of high touch voltages in the event of equipment faults, while equipotential bonding prevents differences in potential.

8.3 Cable shielding

Signal cables must be shielded to protect them against interference coupling.

Cables can be shielded most effectively by routing them through steel tubes, but this is only necessary if the signal cable is to be routed through an environment that is exposed to significant interference. It is normally sufficient to use cables with braided shields. Whichever of these two shielding methods is used, however, the shielding efficacy is largely dependent on correct bonding of the shield.

Note

A shield that is incorrectly bonded or not bonded at all has no shielding effect.

The following applies: (please refer to product-specific documentation for exceptions)

- In the case of analog signal cables, the shield must be bonded at one end at the receiver device.
  Low-frequency interference (ground loops) can develop on analog signal cables if the shield is bonded at both ends. In this case, only one end of the shield may be bonded at the converter. The other end of the shield should be connected via a capacitor of type MKT with approximately 10 nF/100 V.
- The shield of digital signal cables must be bonded at both ends to the enclosure.
- Since interference signals are often within the HF range (> 10 kHz), the shield must be bonded using an HF-immune shield connection with large contact area.

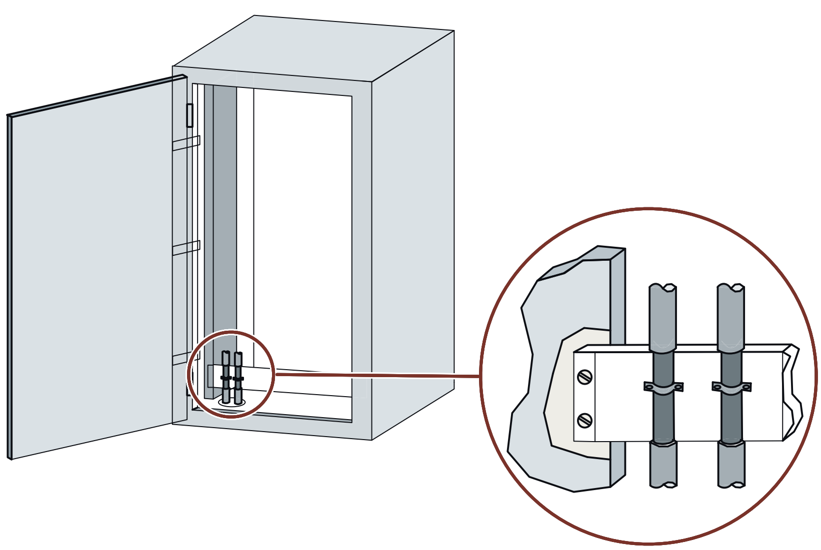


Figure 8-5 Shielding of cables

The shielding bus must be joined to the control cabinet enclosure in a highly conductive connection (over large contact area) and located as close as possible to the cable entry point. The insulation is stripped from the cables which are then clamped to the shielding bus (with high-frequency clamps) or fastened to it with cable ties. The connection between the shielding bus and cables must be highly conductive.

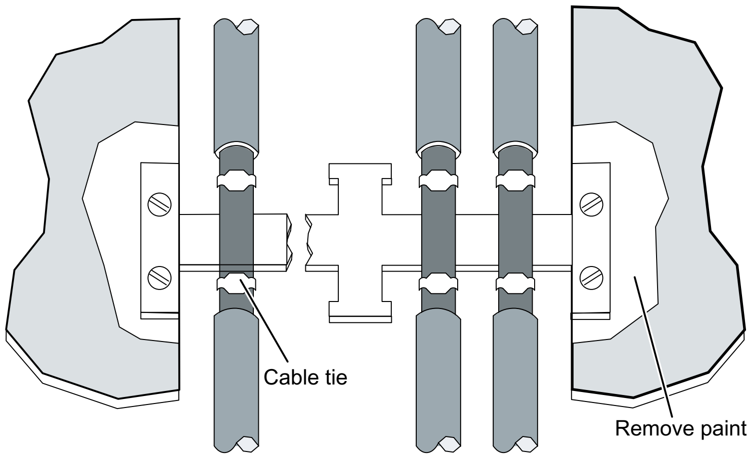


Figure 8-6 Connection of shielding bus

The shielding bus must be connected to the PE rail.

If it is necessary to interrupt shielded cables, the shield must be continued uninterrupted through the connector casing at the interruption point. The connectors used must be suitable for the purpose, e.g. they must not have a metallized connector casing, but a metal casing for high-frequency currents.

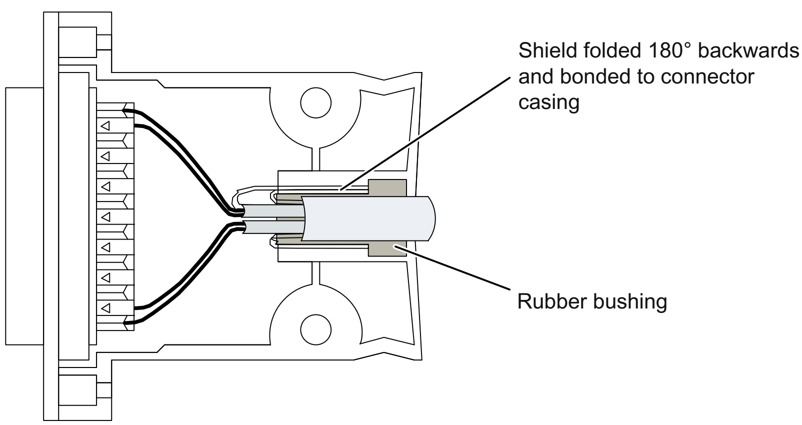


Figure 8-7 Interruption of shielded cables

If adapter plugs or terminals without a suitable shield connection are used, cable clamps must be used to continue the shield uninterrupted at the interruption point in order to provide an HF-conductive connection over a large contact area.

8.4 Prevention of interference sources

In the interests of boosting levels of interference immunity, inclusion of interference sources in an electrical installation must be avoided. Any kind of switched inductive load is a common source of interference.

Suppression of inductive load interference

Relays, contactors, etc. generate interference voltages and must therefore have one of the following interference suppression circuits.

When a 24 V coil is switched, it can generate an interference voltage of up to 800 V (even in a small relay), while the interference voltage produced by a 230 V coil can reach several kVs. Freewheeling diodes or RC circuits can be used to suppress the interference voltage and thus prevent inductive interference in cables that are routed in parallel to the coil cable.

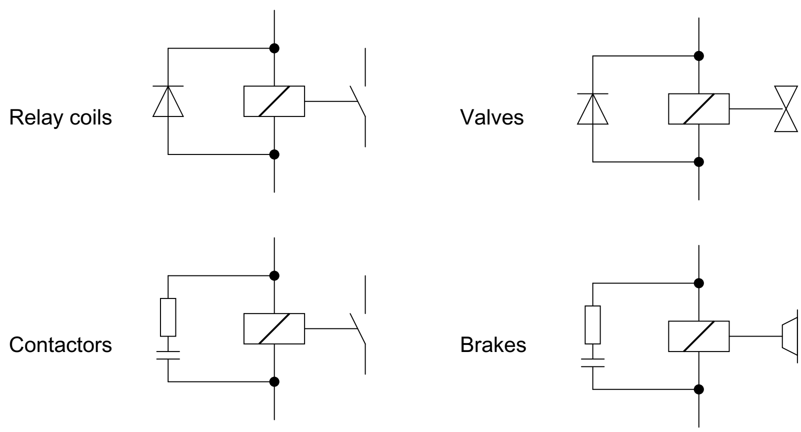


Figure 8-8 Suppression of inductive load interference

Note

All coils in the cabinet must be equipped with interference suppression elements or circuits. Valves and motor brakes are often forgotten. Fluorescent lamps in the control cabinet must undergo special tests.

8.5 Further assistance

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Link (https://www.sitrain-learning.siemens.com/DE/en/rw72322/EMC-for-the-practice-for-Engineering-and-Service-Staff)

Checklists

A

A.1 EMC verification

Verification of compliance with EMC Directive 2014/30/EU

The procedure outlined below is one possible option for verifying conformance with EMC Directive 2014/30/EU in conjunction with the harmonized standards EN 61439-1 and EN 61439-2. All conditions must be fulfilled and the relevant verifications / documentation must be available to ensure successful verification:

No.	Condition	Where can I find this information?	Assessment		Verification / Documentation	
			Condition met	Condition not met	Available	Not available
1	Is the equipment approved for use in the intended environment?	Documentation of the equipment				
2	Has the equipment been installed in accordance with the manufacturer's specifications?	Documentation of the equipment				
3	Have the most recent editions of harmonized standards been applied?	Standards for control panels: e.g. EN 61439-1 and EN 61439-2				
4	Have an analysis and assessment of the EMC risks been carried out?	e. g. in CENELEC 32				
5	Does the equipment comply with the formal requirements of the EMC Directive 2014/30/EU?	EMC Directive 2014/30/EU				

Note

Note the manufacturer's specifications

The generally known EMC measures do not always have the desired effect in every application. Whether the shield of analog signal cables should be bonded at one or both ends, for example, depends on the interference source and / or the coupling path.

The following therefore applies:

The technical documentation supplied with the devices or components used is always the binding document with respect to EMC measures. Follow the instructions contained in this documentation relating to EMC-compliant installation, operation and accessories (shielded cables, for example).

Take these manufacturer specifications as well as general EMC measures into account in the risk analysis and assessment.

A.2 EMC measures

Separation of sources and victims of interference

No.	Condition	Condition met	Condition not met	Not relevant
1	Does an EMC zone concept exist and has it been applied?			
2	Have appropriate measures (partitions, distances, etc.) been taken to separate sources and victims of interference?			
3	Have appropriate measures (metal cable ducts, distance, etc.) been taken to route power and signal cables separately?			
4	Have the cables been kept as short as possible?			
5	Are the signal cables installed as close as possible to grounded components?			
6	Do cables routed as single cables have twisted supply and return conductors?			

Functional earth and equipotential bonding

No.	Condition	Condition met	Condition not met	Not relevant
7	Does a grounding concept for equipotential bonding exist and has it been applied?			
8	Are all inactive metal parts including the shielding bus joined over a large area and in a highly conductive connection?			
9	Has the functional earth been implemented in accordance with the manufacturer's specifications?			

Shielded cables

No.	Condition	Condition met	Condition not met	Not relevant
10	Have appropriate measures (braided shield) been taken to shield signal cables?			
11	Is the shield connection a highly conductive bond with a large contact area? • Analog signal cables with shield bonded at one end unless otherwise specified by the manufacturer, e.g. to prevent ground loops • Digital signal cables with shield bonded at both ends			
12	Are the shields continuous?			

No.	Condition	Condition met	Condition not met	Not relevant
13	Have the cable shields been attached over a large area to the shielding bus at the cabinet entry point unless otherwise specified by the manufacturer, e.g. for motor cables at frequency converters?			
14	Has an equipotential bonding cable been routed in parallel to the shielded signal cable in installations with differences in potential?			

Filters and suppressor circuits

No.	Condition	Condition met	Condition not met	Not relevant
15	Have filters and reactors been installed according to the manufacturer's specifications?			
16	Have inductive loads, e.g. contactor coils, been equipped with snubber elements (overvoltage protection)?			

Plant-specific EMC topics (e.g. manufacturer's equipment specifications)

No.	Condition	Condition met	Condition not met	Not relevant
17				
18				
19				
20				
21				
22				
23				
24				
25				

List of references B

Siemens list of EMC references

SIRIUS controls

- Reference manual: Basics of Low-Voltage Controls and Distribution
  Link (https://support.industry.siemens.com/cs/ww/de/view/34973099)
- Equipment Manual: Equipment Manual: Industrial Controls, Switching devices– SIRIUS 3RT contactor assemblies
  Link (https://support.industry.siemens.com/cs/ww/en/view/60306557)

SIMATIC S7-1500 Automation System

- Function Manual: SIMATIC S7-1500, ET 200MP, ET 200SP, ET 200AL Designing interference-free controllers
  Link (https://support.industry.siemens.com/cs/ww/en/view/59193566)
- System Manual: SIMATIC S7-1500, ET 200MP Automation System
  Link (https://support.industry.siemens.com/cs/ww/de/view/59191792)
- Equipment Manual: SIMATIC S7-1500 CPU 1516-3 PN/DP
  Link (https://support.industry.siemens.com/cs/ww/en/view/59191914)

SINAMICS S120 drive system

- Configuration Manual: EMC Installation Guidelines / Basic System Requirements
  Link (https://support.industry.siemens.com/cs/ww/de/view/60612658/en)
- Brochure: EMC - Electromagnetic Compatibility
  Link
- Configuration Manual: SINAMICS G130, G150, S120 Chassis, S120 Cabinet Modules, S150 (Supplement to Catalogs D 11 and D 21.3)
  Link (https://support.industry.siemens.com/cs/us/en/view/83180185)
- Equipment Manual: S120 Control Units and Additional System Components
  Link (https://support.industry.siemens.com/cs/ww/en/view/109782370)
- Equipment Manual: S120 Booksize Power Units
  Link (https://support.industry.siemens.com/cs/ww/en/view/109781351)

Control panel engineering

- Panel building
  Link (www.siemens.com/panelbuilding)
- Electrical planning for the machine control cabinet with Control Panel Design
  Link (www.siemens.com/controlpanel/cpd)
- Mastering IEC control cabinet standards and EU directives
  Link (https://www.siemens.com/global/en/industries/machinebuilding/panel-building/eu-directives.html)

Directives and guidelines

- EU directives
  Link (http://eur-lex.europa.eu/homepage.html)
- CENELEC Guide 32:2014
  Link (https://www.cenelec.eu/membersandexperts/referencematerial/cenelecguides.html)
- "The "Blue Guide" on the implementation of EU product rules 2016"
  Link
- Guide for the EMC Directive 2004/108/EC (8th February 2010)
  Link (http://ec.europa.eu/growth/sectors/electrical-engineering/emc-directive/index_en.htm) (in section "Guidance" > "Guides")

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