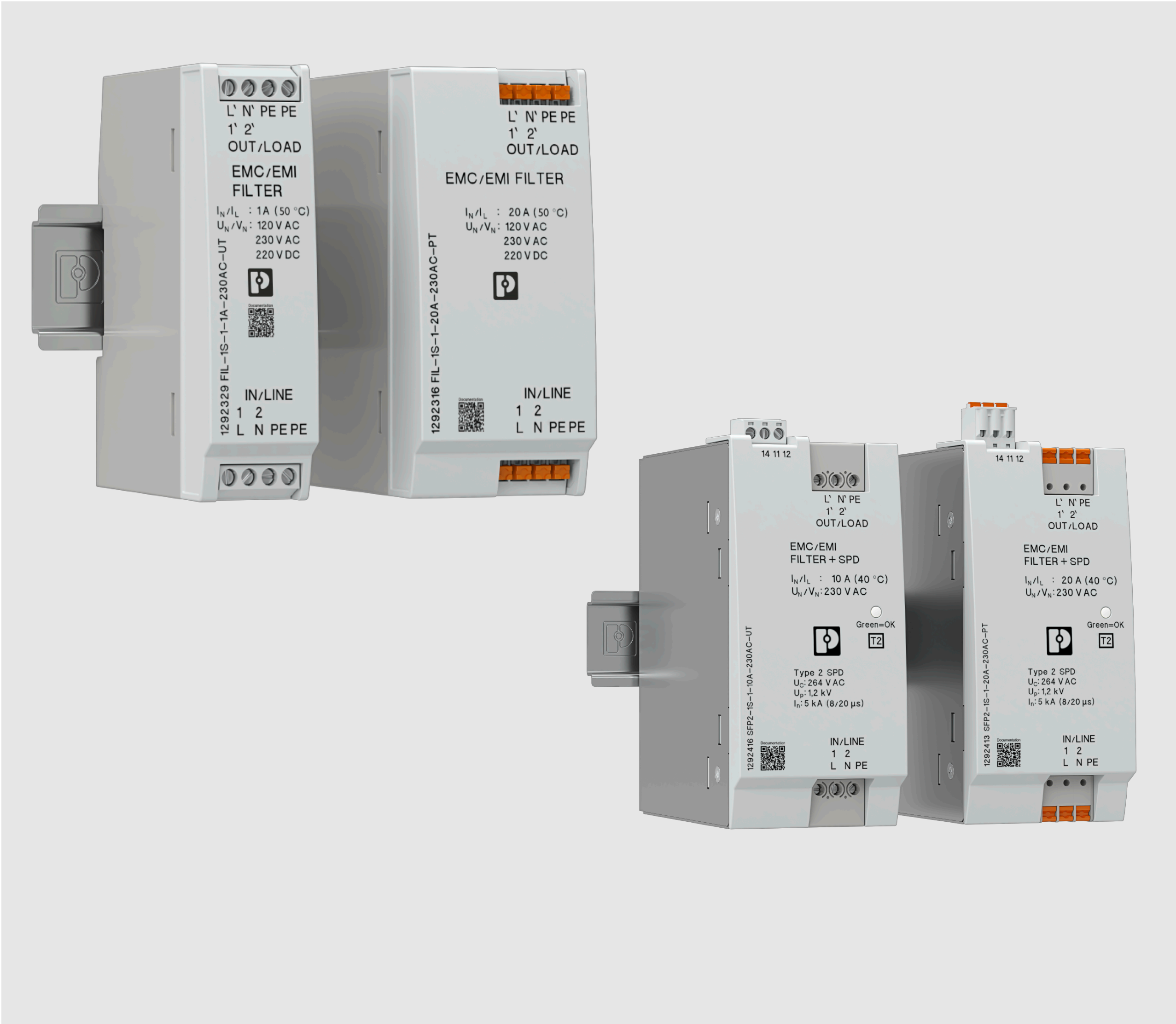


FIL-1S-1 and SFP2-1S-1 type EMC/EMI filters

Basic manual

Basic manual

FIL-1S-1 and SFP2-1S-1 type EMC/EMI filters

UM EN FIL-1S-1 SFP2-1S-1, Revision 01 2025-06-11

This manual is valid for:

Designation	Item No.	Designation	Item No.
FIL-1S-1-1A-230AC-PT	1292328	SFP2-1S-1-5A-120AC-PT	1292458
FIL-1S-1-1A-230AC-UT	1292329	SFP2-1S-1-5A-120AC-UT	1292315
FIL-1S-1-3A-230AC-PT	1292326	SFP2-1S-1-10A-120AC-PT	1292455
FIL-1S-1-3A-230AC-UT	1292327	SFP2-1S-1-10A-120AC-UT	1292457
FIL-1S-1-6A-230AC-PT	1292321	SFP2-1S-1-15A-120AC-PT	1292450
FIL-1S-1-6A-230AC-UT	1292323	SFP2-1S-1-15A-120AC-UT	1292453
FIL-1S-1-10A-230AC-PT	1292319	SFP2-1S-1-20A-120AC-PT	1292419
FIL-1S-1-10A-230AC-UT	1292320	SFP2-1S-1-20A-120AC-UT	1292421
FIL-1S-1-20A-230AC-PT	1292316	SFP2-1S-1-6A-230AC-PT	1292417
FIL-1S-1-20A-230AC-UT	1292318	SFP2-1S-1-6A-230AC-UT	1292418
		SFP2-1S-1-10A-230AC-PT	1292414
		SFP2-1S-1-10A-230AC-UT	1292416
		SFP2-1S-1-20A-230AC-PT	1292413
		SFP2-1S-1-20A-230AC-UT	1292605

110503_en_01

Table of contents

1 For your safety

This manual is valid for EMC/EMI filters that are designed to protect sensitive electrical equipment against high-frequency conducted interference. High-frequency conducted interference is expected from the mains supply side (IN/LINE).
This manual is not valid for applications where high-frequency conducted interference, which is generated by interference-emitting equipment in the immediate proximity of the EMC/EMI filter, is to be attenuated.

This manual contains similar information in several different sections. This is intended to provide greater clarity in the manual. You can utilize each section of the manual as a self-contained unit of information.

Read this user manual carefully and keep it for future reference.

1.1 Identification of warning notes

This symbol indicates hazards that could lead to personal injury.

There are three signal words indicating the severity of a potential injury.

DANGER
Indicates a hazard with a high risk level. If this hazardous situation is not avoided, it will result in death or serious injury.

WARNING
Indicates a hazard with a medium risk level. If this hazardous situation is not avoided, it could result in death or serious injury.

CAUTION
Indicates a hazard with a low risk level. If this hazardous situation is not avoided, it could result in minor or moderate injury.

This symbol indicates electrical hazards.

This symbol warns the reader about the risk of burns and fire.

This symbol together with the **NOTE** signal word warns the reader of actions that might cause property damage or a malfunction.

Here you will find additional information or detailed sources of information.

1.2 Qualification of users

The use of products described in this manual is oriented exclusively to electrically skilled persons or persons instructed by them. The users must be familiar with the relevant safety directives as well as applicable standards and other regulations.

This symbol informs you that the EMC/EMI filters may only be installed, tested, started up, decommissioned, and removed by electrically qualified personnel.

Five basic safety rules of electrical engineering

When working on electrical systems and EMC/EMI filters, always observe the five basic safety rules of electrical engineering (EN 50110-1, DIN VDE 0105-100):

– Disconnect from power source
– Secure against being switched on again
– Determine absence of voltage
– Earth and short-circuit
– Cover or fence off adjacent live parts

1.3 Intended use of EMC/EMI filters

FIL-1S-1 and SFP2-1S-1 type EMC/EMI filters are designed for universal use. They are primarily used to protect sensitive electrical equipment against high-frequency conducted interference. These EMC/EMI filters are what are known as low-pass filters. They are used in single-phase power supply systems with relatively low power.

High-frequency conducted interference

High-frequency conducted interference is usually caused by power electronics equipment or switching operations. Power electronics equipment includes all kinds of inverters and switched-mode power supply units, for example.

It is not just equipment that consumes electricity that may act as an emitter (source of interference). Due to the increased use of renewable energy in low-voltage supply networks, energy feeding equipment is being used more frequently. This means, for example, that grid-connected PV inverters or battery storage systems (with inverters) can also be a source of high-frequency conducted interference.

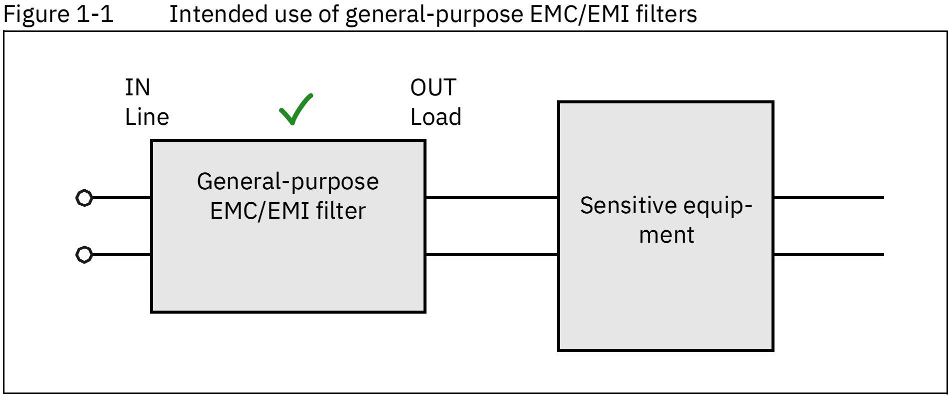
The number of switched-mode power supply units used in modern electrical equipment has continued to grow in recent years. The dominating trends here are increased power, increased electrical efficiency, and miniaturization.

To achieve these objectives, switched-mode power supply units with high switching frequencies are increasingly used. This reduces the volume of components for power factor correction (PFC), for magnetic materials, and for transformers.

Increasing the switching frequencies of power semiconductors provides many advantages, but there are also certain disadvantages. The higher the switching frequency of power semiconductors, the more likely it is that high-frequency conducted interference will be generated and emitted to nearby equipment. Conducted interference can disrupt sensitive electrical equipment.

Examples of applications with sensitive electrical equipment:
- Measurement technology
- Control technology
- Regulation technology
- Display units
- Operating devices
- Monitors
- Programmable logic controllers (PLCs)
- Distributed control systems
- Computers
- Information technology systems
- Equipment for computer networks
- Switched-mode power supply units
- Equipment with integrated switched-mode power supply units
- Test devices
- Medical devices

Figure 1-1 Intended use of general-purpose EMC/EMI filters



Filters for power supply systems are also referred to as mains filters (line filters, power line filters).

FIL-1S-1 and SFP2-1S-1 type EMC/EMI filters

FIL-1S-1 and SFP2-1S-1 type EMC/EMI filters are what are known as low-pass filters. They are used to convey mains frequency voltages and currents (fundamental frequencies up to 50/60 Hz). Mains frequency voltages and currents are conveyed through these EMC/EMI filters without significant attenuation.

Voltages and currents in AC power supply systems are referred to as harmonics if they occur with an integer multiple of the mains frequency. Harmonics are conveyed through FIL-1S-1 and SFP2-1S-1 type EMC/EMI filters for mains frequency voltages and currents without significant attenuation.

The EMC/EMI filters described in this basic manual are mains filters that filter (attenuate) high-frequency conducted interference. FIL-1S-1 and SFP2-1S-1 type mains filters are able to filter high-frequency interference voltages as well as high-frequency interference currents.

1.4 Possible misuse of EMC/EMI filters

General-purpose EMC/EMI filters are not usually designed to filter (attenuate) high-energy conducted interference that is generated by interference-emitting equipment.

Inverters such as frequency inverters, motor drive systems, or similar, and even other items of power electronics equipment, can be a source of high-energy conducted interference. In circuits that contain inverters, the possible emitted interference of this equipment must be taken into consideration when selecting EMC/EMI filters.

Inverters can generate interference voltages with a high rate of voltage change (du/dt, dv/dt), but also interference currents with a high rate of current change (di/dt).

General-purpose EMC/EMI filters can be damaged or destroyed by:
- Interference voltages with a high rate of voltage change (du/dt, dv/dt)
- Interference currents with a high rate of current change (di/dt)

On the input and output side of interference-emitting equipment, only use general-purpose EMC/EMI filters that are suitable for applications with interference-emitting equipment. Manufacturers of EMC/EMI filters will indicate in the relevant product documentation whether an EMC/EMI filter is suitable for use with interference-emitting equipment.

When selecting EMC/EMI filters, observe the recommendations and application information provided by manufacturers of interference-emitting equipment.

Figure 1-2 EMC/EMI filter for frequency inverters, motor drive systems, and other items of power electronics equipment

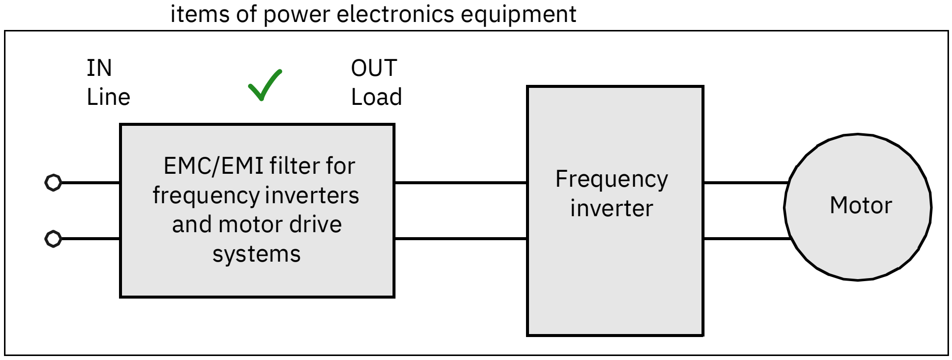
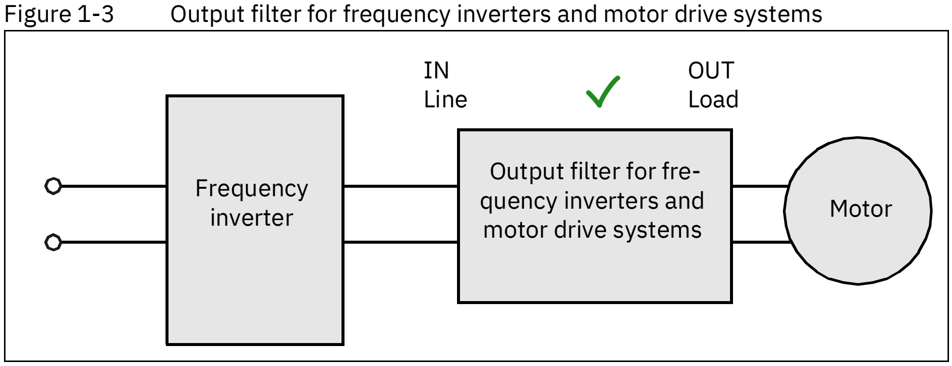


Figure 1-3 Output filter for frequency inverters and motor drive systems



1.5 General safety notes

DANGER: Risk of fatal electric shock
Hazardous voltages can occur in electrical systems. Coming in contact with live parts may result in electric shock. Improper handling of electrical systems and their equipment can result in death, injuries, or property damage.

DANGER: Risk of fatal electric shock
Even after the supply voltage has been switched off, the capacitors contained in EMC/EMI filters and other capacitors located in the same circuit may be charged with hazardous contact voltages. Completely discharge the capacitors contained in an EMC/EMI filter, and any other capacitors located in the same circuit, at all positions.

WARNING: Risk of electric shock and fire
Only ever operate an EMC/EMI filter within the respective technical specifications that apply for the corresponding EMC/EMI filter.

Observe the technical specifications for electrical, mechanical, thermal, and other environmental boundary conditions.

The operating voltage of the respective electrical system must not exceed the maximum permissible operating voltage or continuous operating voltage of the EMC/EMI filter (U_R, U_C, MCOV).

NOTE: Do not operate damaged or defective EMC/EMI filters
Check EMC/EMI filters for externally visible damage prior to installation and startup. Only use EMC/EMI filters if they are in perfect working order. Do not use an EMC/EMI filter if it is damaged or defective.

Defective or damaged EMC/EMI filters must be taken out of operation immediately. Remove defective or damaged filters from the electrical system immediately. Appropriately identify defective or damaged EMC/EMI filters so that they will not be used again by mistake.

Applicable product documentation

The safety-related product documentation for EMC/EMI filters consists of this basic manual and the product-specific installation instructions. Familiarize yourself with the product documentation before proceeding with the selection, installation, startup, maintenance, testing, decommissioning, or removal of EMC/EMI filters.

Observe all the safety-related notes in these documents:
- This basic manual
- Product-specific installation instructions
- Applicable technical guidelines
- Standards
- Regulations
- Other documents and sources of information that are relevant to the installation and safe operation of the respective electrical system

Special country-specific considerations

Observe the relevant country-specific or regionally applicable guidelines, standards, and regulations. When using EMC/EMI filters in the USA and Canada, observe the National Electrical Code (NEC) and Canadian Electrical Code (CEC) in particular.

2 Description of the EMC/EMI filters

2.1 EMC/EMI filters without surge protection (FIL-1S-1)

2.1.1 Features and use

Features

Key features of FIL-1S-1 type EMC/EMI filters:
- General-purpose EMC/EMI filters
- Used to protective sensitive equipment against high-frequency conducted interference
- Suitable for 1-phase AC and for DC
- Additional PE terminals for EMC-optimized installation
- Plastic housing
- Mounting on a 35 mm DIN rail
- Conductor connection: Screw terminal blocks (UT) or spring-cage terminal blocks (PT)

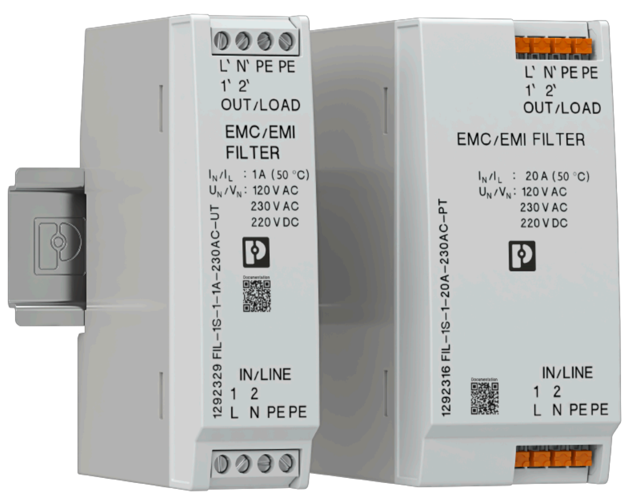
Intended use

FIL-1S-1 type EMC/EMI filters are used to protect sensitive electrical equipment against high-frequency conducted interference. Conducted interference is expected on the IN/LINE side.

Connect the equipment that is to be protected on the OUT/LOAD side.

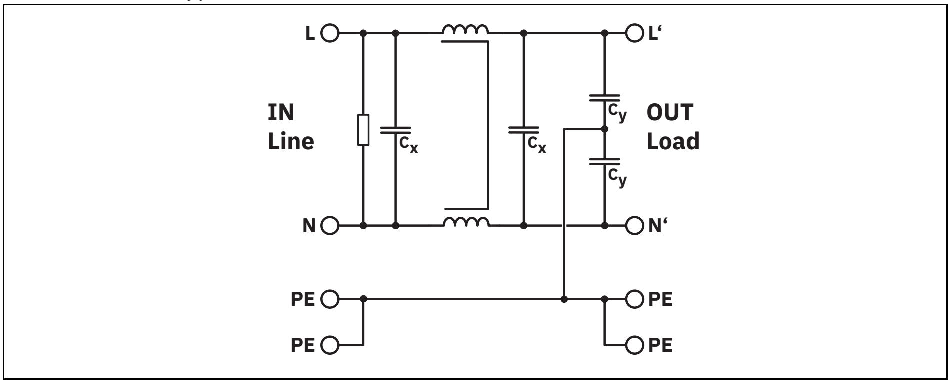
If transient voltage or current pulses are to be expected in a given environment, use EMC/EMI filters with integrated surge protection (e.g., type SFP2-1S-1).

Figure 2-1 EMC/EMI filters without surge protection (type FIL-1S-1)



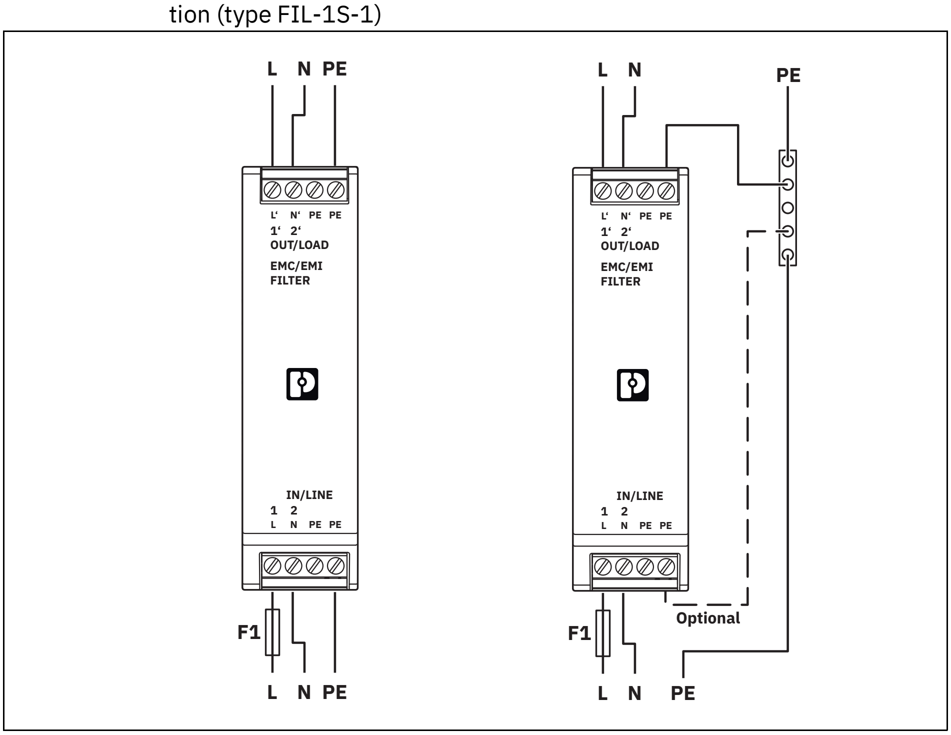
2.1.2 Circuit diagram and connection identification

Figure 2-2 Circuit diagram – EMC/EMI filters without surge protection (type FIL-1S-1)



C_X	X capacitor
C_Y	Y capacitor

Figure 2-3 Typical connection identification – EMC/EMI filters without surge protection (type FIL-1S-1)



2.2 EMC/EMI filters with surge protection (SFP2-1S-1)

2.2.1 Features and use

Features

Key features of SFP2-1S-1 type EMC/EMI filters:

- General-purpose EMC/EMI filters
- Used to protective sensitive equipment against high-frequency conducted interference
- With integrated surge protective device (SPD)
- For 1-phase AC
- Status indicator and remote indication contact
- Metal housing
- Mounting on a 35 mm DIN rail
- Conductor connection: Screw terminal blocks (UT) or spring-cage terminal blocks (PT)

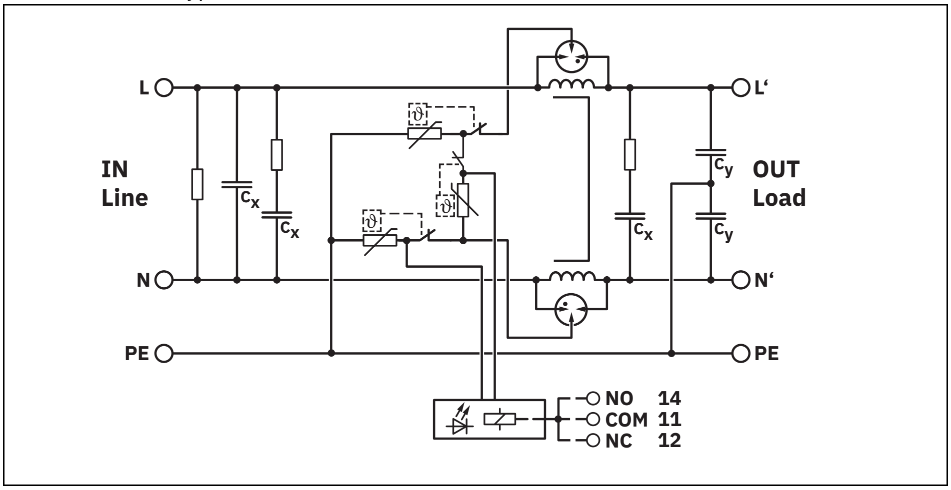
Intended use

- SFP2-1S-1 type EMC/EMI filters are used to protect sensitive electrical equipment against high-frequency conducted interference. Conducted interference is expected on the IN/LINE side.
- Connect the equipment that is to be protected on the OUT/LOAD side.
- SFP2-1S-1 type EMC/EMI filters are equipped with an integrated surge protective device (SPD). These EMC/EMI filters can be used in environments with transient voltage pulses or transient current pulses.

Figure 2-4 EMC/EMI filters with integrated surge protective device (type SFP2-1S-1)

2.2.2 Circuit diagram and connection identification

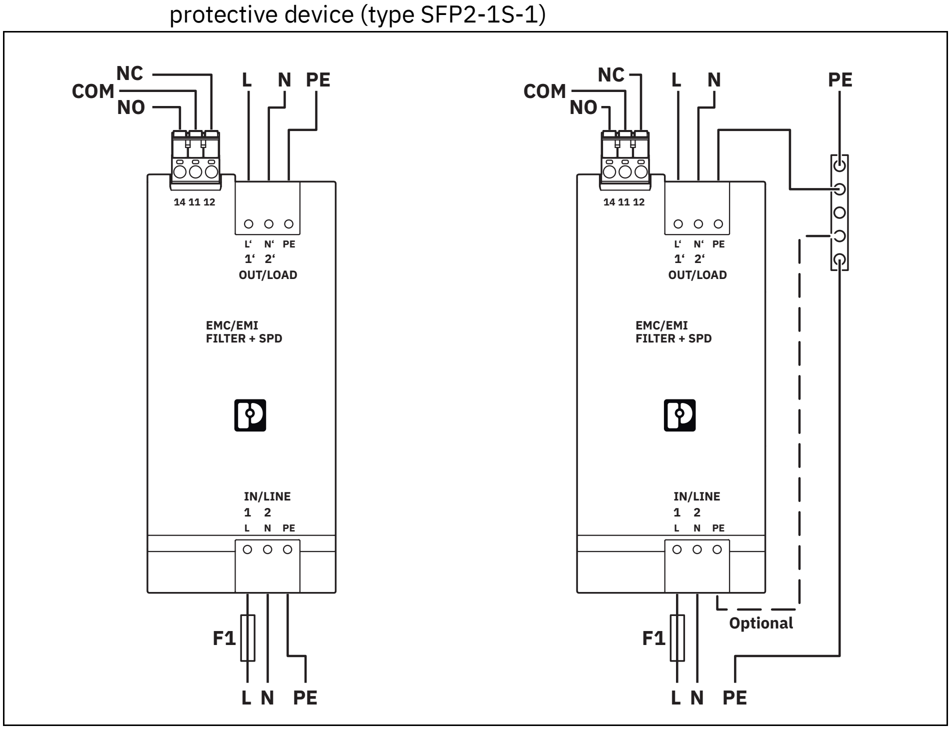
Figure 2-5 Circuit diagram – EMC/EMI filters with integrated surge protective device (type SFP2-1S-1)



C_X X capacitor

C_Y Y capacitor

Figure 2-6 Typical connection identification – EMC/EMI filters with integrated surge protective device (type SFP2-1S-1)



2.2.3 Status indicator and remote indication contact

SFP2-1S-1 type EMC/EMI filters are equipped with an integrated surge protective device (SPD).

SFP2-1S-1 type EMC/EMI filters have a status indicator on the front:

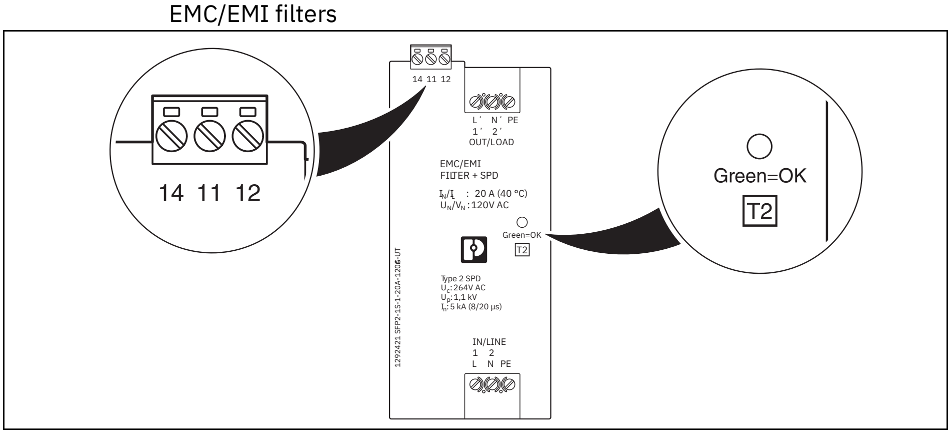
LED on	Surge protective device is OK and supply voltage is present
LED off	Surge protective device is defective or supply voltage is not present

The connection for the remote indication contact is located on the top of SFP2-1S-1 type EMC/EMI filters.

Remote signaling circuit with floating changeover contact (11 COM, 12 NC, 14 NO):

N/O contact 11-14 (NO) is closed:	Surge protection is OK and supply voltage is present
N/C contact 11-12 (NC) is closed:	Surge protective device is defective or supply voltage is not present

Figure 2-7 Status indicator and remote indication contact for SFP2-1S-1 type EMC/EMI filters



Important information regarding the functioning of the status indicator and the remote signaling circuit of SFP2-1S-1 type EMC/EMI filters:

SFP2...120AC	To ensure that the status indicator and the remote signaling circuit function properly, you must operate the SFP2...120AC EMC/EMI filter in circuits with a nominal voltage of 100 V AC ... 125 V AC.
SFP2...230AC	To ensure that the status indicator and the remote signaling circuit function properly, you must operate the SFP2...230AC EMC/EMI filter in circuits with a nominal voltage of 220 V AC... 240 V AC.

In the event of a defective EMC/EMI filter with defective surge protection, replace it with a fully functional EMC/EMI filter as soon as possible.

Do not route the connecting cables of the remote signaling circuit parallel to unprotected cables through which transient overvoltage pulses or transient current pulses can flow. The cables of these circuits must be crossed at a right angle.

2.3 Ordering data

EMC/EMI filters

Description	Type	Item No.	Pcs./Pkt.
EMC/EMI filter without surge protection (type FIL-1S-1), 230 AC	FIL-1S-1-1A-230AC-UT	1292329	1
	FIL-1S-1-1A-230AC-PT	1292328	1
	FIL-1S-1-3A-230AC-UT	1292327	1
	FIL-1S-1-3A-230AC-PT	1292326	1
	FIL-1S-1-6A-230AC-UT	1292323	1
	FIL-1S-1-6A-230AC-PT	1292321	1
	FIL-1S-1-10A-230AC-UT	1292320	1
	FIL-1S-1-10A-230AC-PT	1292319	1
	FIL-1S-1-20A-230AC-UT	1292318	1
	FIL-1S-1-20A-230AC-PT	1292316	1
EMC/EMI filter with surge protection (type SFP2-1S-1), 120 AC	SFP2-1S-1-5A-120AC-UT	1292315	1
	SFP2-1S-1-5A-120AC-PT	1292458	1
	SFP2-1S-1-10A-120AC-UT	1292457	1
	SFP2-1S-1-10A-120AC-PT	1292455	1
	SFP2-1S-1-15A-120AC-UT	1292453	1
	SFP2-1S-1-15A-120AC-PT	1292450	1
	SFP2-1S-1-20A-120AC-UT	1292421	1
	SFP2-1S-1-20A-120AC-PT	1292419	1
EMC/EMI filter with surge protection (type SFP2-1S-1), 230 AC	SFP2-1S-1-6A-230AC-UT	1292418	1
	SFP2-1S-1-6A-230AC-PT	1292417	1
	SFP2-1S-1-10A-230AC-UT	1292416	1
	SFP2-1S-1-10A-230AC-PT	1292414	1
	SFP2-1S-1-20A-230AC-UT	1292605	1
	SFP2-1S-1-20A-230AC-PT	1292413	1

Key for product designation

FIL	- 1S	- 1	- 1A	- 230AC	- UT
Product group	Power system	Number of filter stages	Nominal current	Nominal voltage	Connection
– FIL – SFP2	– 1S = 1-phase; with L, N, PE For DC voltage: L+, L- or L1, L2	1	– 1 A – 3 A – 5 A – 6 A – 10 A – 15 A – 20 A	– 230 AC – 120 AC	– UT = screw terminal blocks – PT = spring-cage terminal blocks

2.4 Selecting EMC/EMI filters

WARNING: Personal injuries and property damage due to incorrect selection and operation of EMC/EMI filters

EMC/EMI filters are what are known as design-in components. This means they must be carefully selected for the respective electrical system. Errors in the design-in process of EMC/EMI filters can result in personal injuries or property damage. Errors in the design-in process can also result in the unsatisfactory functioning of electrical systems. When it comes to the selection and operation of EMC/EMI filters, always keep in mind the applicable operational limitations for the relevant EMC/EMI filter.

For the design-in process of EMC/EMI filters, planners, installers, and operators must have adequate knowledge of the system and be sufficiently familiar with electromagnetic compatibility (EMC).

EMC/EMI filters are always selected based on the specific application. There are no EMC/EMI filters that are suitable for every conceivable type of application.

EMC/EMI filters can be used in many different electrical engineering applications. No manufacturer can produce an EMC/EMI filter that can be used for every conceivable type of application. In a customer installation, you must take the relevant technical boundary conditions and the environmental conditions into consideration. The user must therefore verify and assess whether an EMC/EMI filter is suitable for use in a specific customer installation.

It must be verified and determined on a case-by-case basis whether an EMC/EMI filter is suitable for an application. This is why, in practice, the suitability of EMC/EMI filters is often tested under realistic operating conditions.

You must take into account all electrical, mechanical, and thermal requirements and any other crucial boundary conditions that are relevant during the design-in process for the actual application in question.

3 Technical terms and abbreviations

3.1 Technical terms

Conducted disturbance
Electromagnetic disturbance that spreads via one or more conductors.

Electromagnetic compatibility (EMC)
Electrical equipment can generate electromagnetic interference. It can also be adversely affected by electromagnetic interference. Electromagnetic compatibility (EMC) describes the ability of electrical equipment to function satisfactorily in an electromagnetic environment without causing intolerable interference for other equipment.

Electromagnetic disturbance
Describes electromagnetic variables that occur at a given location and can occur in disruptive interaction with electrical equipment. They include, for example:
- Voltages
- Currents
- Electrical fields
- Magnetic fields
- Radiated variables

Electromagnetic disturbances are usually time-dependent and influenced by the respective operating state of an electrical system. The occurrence of electromagnetic variables can be so irregular that statistical methods are required to describe them.

Electromagnetic emission (EME)
Describes the emission of electromagnetic variables from an item of equipment. Electromagnetic variables are usually time-dependent and greatly influenced by the respective operating state of an electrical system. The occurrence of electromagnetic variables can be so irregular that statistical methods are required to describe them.

Electromagnetic environment (EME)
Describes the totality of the electromagnetic variables that occur at a given location and can occur in interaction with electrical equipment. They include, for example:
- Voltages
- Currents
- Electrical fields
- Magnetic fields
- Radiated variables

Electromagnetic interference
Electromagnetic interference can alter the operating behavior, reduce the performance, or degrade the technical properties of an item of equipment. The equipment can experience sporadic or permanent malfunctions. The malfunctions may or may not be reversible.

Electromagnetic radiation
Describes the emission of radiated electromagnetic variables from an item of equipment. In this case, electromagnetic waves are radiated from a source into the surrounding space.

Electromagnetic susceptibility
Due to electromagnetic disturbances, equipment, systems, or installations can deviate from their intended operating behavior. Depending on the level of susceptibility, disturbances can occur sporadically or permanently.

Electrostatic discharge

When two exposed conductive parts are charged with different electrostatic potential, electric charges may be transferred between the exposed conductive parts. The charge can be transferred by means of direct electrical contact or by flashover. High-frequency interference and transient voltages are to be expected when static electricity is discharged.

Emitter

Electromagnetic disturbances are caused by emitters. Emitters can be items of equipment, systems, or installations. These disturbances include, for example:

- Voltages
- Currents
- Electrical fields
- Magnetic fields
- Radiated variables

Functional impairment

Equipment, systems, or installations can deviate from their intended operating behavior. This can result in malfunctions and can also reduce the performance or adversely affect the technical properties of an item of equipment. These impairments can occur sporadically or permanently. Impairments may or may not be reversible.

High frequency

The term high frequency is often mentioned in the context of electromagnetic compatibility (EMC). This is where the frequencies in question are greater than 9 kHz.

Insulation monitoring device (IMD)

An insulation monitoring device monitors the insulation resistance in unearthed systems (IT systems). The insulation monitoring device indicates when a minimum insulation resistance is not reached.

Interfering signal

A signal that may be disruptive and impairs or prevents the reception or detection of a wanted signal.

IT system

Specific design of a low-voltage system within an electrical installation. In IT systems, the active conductors are isolated from earth or connected to earth via a high-resistance impedance.

Low frequency

The term low frequency is often mentioned in the context of electromagnetic compatibility (EMC). This is where the frequencies in question are less than or equal to 9 kHz.

Main earthing busbar (MEB)

The main earthing busbar is an equipotential bonding strip that is near the source of a consumer installation. To prevent or reduce dangerous potential differences between the exposed conductive parts of the electrical equipment of a consumer installation and extraneous electrically conductive parts, the following conductors are connected to the main earthing busbar:

– Protective bonding conductor
– Protective earthing conductor (PE conductor)
– Equipotential bonding conductor
– Main PE conductor (main equipotential bonding conductor)
– Functional earthing conductor
– Earthing conductor
– Earth electrode
– Connecting conductor to the lightning protection earthing system
– Extraneous conductive parts

To protect against electric shock, all items of equipment with PE connection are connected to the main earthing busbar via protective bonding conductors (PE conductors). Along with the main earthing busbar, additional earthing busbars (PE busbars) may be available in the power distribution boards of an electrical system. These earthing busbars have a low-resistance connection to the corresponding main earthing busbar.

Mains-borne disturbance

Electromagnetic disturbance that spreads via one or more conductors connected to a power supply system.

Miniature circuit breaker (MCB)

A miniature circuit breaker is an overcurrent protective device. It is used in low-voltage networks to protect cables from damage caused by overcurrents and short-circuit currents.

When a miniature circuit breaker is tripped, the corresponding circuit is automatically shut down and disconnected from the power source.

Overcurrent protective device

Overcurrent protective devices protect cables or other items of equipment against damage caused by operating, overload, and short-circuit currents. These currents can result in excessive heating. When selecting overcurrent protective devices, it should be ensured that they will prevent excessive heating caused by operating, overload, and short-circuit currents.

Potentially susceptible equipment

When an electromagnetic disturbance occurs, energy is transferred from at least one emitter to at least one item of potentially susceptible equipment. Potentially susceptible equipment can be items of equipment, systems, or installations that are disrupted by or whose function is adversely affected by electromagnetic interference.

Power factor correction

In AC circuits, reactive power can occur in addition to active power. The reactive power can occur due to capacitive or inductive characteristics of energy sources and energy consumers. In addition, distortion reactive power can occur due to non-linear loads. Reactive power also occurs as a result of leakage inductance or stray capacitance. Possible consequences of reactive power include:

- Premature response of overcurrent protective devices
- Excessive heating of cables
- Overload of the neutral conductor in three-phase systems
- Excessive heating of equipment
- Premature aging of equipment
- Excessive heating of transformers
- Resonance phenomena

Protection class I

Protection class I equipment always has a PE conductor connection. Exposed conductive metal parts of protection class I equipment are connected to the PE conductor. Automatic safety equipment that provides protection by means of automatic shutdown shuts down regardless of the type of overcurrent, short-circuit current, and earth fault current. The corresponding circuit is automatically shut down and disconnected from the power source.

If an earth fault occurs in a TN system, the earth fault current in the TN system can flow directly back to the current source via the PE conductor. In TT systems, ensure that the main earthing busbar (MEB) of the consumer installation and the earthing system of the current source are not connected together.

Protection class II

Protection class II equipment usually has plastic housing with an insulating function that provides double or reinforced insulation from dangerous live parts. Many protection class II items of equipment do not have a connection for a PE conductor. However, protection class II equipment can also be equipped with a connection for a PE conductor or a functional earthing conductor.

Protective earthing conductor (PE conductor)

Earthed conductor of a circuit that is primarily used to automatically shut down the voltage in the event of a fault and to reduce the contact voltage.

A low-resistance PE conductor is vitally important for providing protection against electric shock. The lower the resistance of a PE conductor, the lower the contact voltages that occur in the event of an earth fault. PE conductors are used in TN, TT, and IT systems.

A PE conductor is also an important prerequisite for detecting insulation faults, residual currents, and discharge currents.

Radio environment

Describes the electromagnetic environment at a given location in the frequency range for radio waves.

Residual current device (RCD)

Residual current devices monitor earthed networks (TN and TT systems) for undesirable and potentially hazardous residual and discharge currents. They are installed in power distribution boards or final circuits of consumer installations.

Using measuring current transformers, residual current devices measure the sum of the currents of all active conductors except for the PE conductor. When residual and discharge currents occur that may be dangerously high, the corresponding circuit is automatically shut down and disconnected from the power source. Using residual current devices reduces the risk of electrical accidents and fire.

Residual current monitor (RCM)

Residual current monitors monitor residual currents in earthed networks (TN and TT systems). Using measuring current transformers, they measure the sum of the currents of all active conductors except for the PE conductor. This allows residual and discharge currents to be detected at an early stage.

Short-circuit current rating (I_{SCCR}, SCCR)

Parameter that specifies the maximum short-circuit current a component or item of equipment can withstand.

Surge protective device (SPD)

Surge protective devices protect the electrical system and equipment against transient overvoltages and transient overcurrents. These transient events can occur as a result of switching operations or the effects of lightning, for example.

TN system

Specific design of a low-voltage power supply system within an electrical installation. In the case of a TN system, one point of the current source has a low-resistance connection to the earthing system of the current source.

In TN systems, the exposed conductive parts of equipment in the electrical system are connected to the main earthing busbar (MEB) of the consumer installation by means of a low-resistance protective earthing conductor connection (PE conductor connection). The main earthing busbar of the consumer installation and the earthing system of the current source are connected with a low-resistance protective earthing conductor (PE or PEN conductor). In addition, the main earthing busbar of the consumer installation and the earthing system of the current source can be connected together via additional equipotential bonding conductors.

If a medium-voltage transformer is located in the immediate proximity of the consumer installation, the medium-voltage transformer and consumer installation can share a common earthing system.

True RMS value	In electrical engineering, the RMS value refers to the root mean square value of an electrical variable (e.g., voltage or current). The aim is to obtain comparable information regarding the output or input of electrical power. The RMS value depends on the peak value (amplitude) and the waveform. When determining the RMS value, it is not just the fundamental component of the current or voltage that is measured. Multiples of the fundamental component (harmonics) are also taken into consideration.
TT system	Specific design of a low-voltage power supply system within an electrical installation. In the case of a TT system, one point of the current source has a low-resistance connection to the earthing system of the current source. In TT systems, the exposed conductive parts of equipment in the electrical system are connected to the main earthing busbar (MEB) of the consumer installation by means of a low-resistance PE conductor connection. The main earthing busbar of the consumer installation and the earthing system of the current source are not connected together. In TT systems, the main earthing busbar of the consumer installation is earthed independently of the earthing system of the current source with a separate earth electrode.
Unwanted signal	A signal that impairs or prevents the reception or detection of a wanted signal.

3.2 Abbreviations

Table 3-1 Abbreviations and technical terms

Abbreviation	Technical Term
EMC, EMI	Electromagnetic compatibility Electromagnetic interference
GDT	Gas discharge tube
IMD	Insulation monitoring device
IT system	IT network, IT system Isolated power supply system
MCB	Miniature circuit breaker
MEB	Main earthing busbar Main grounding busbar Main equipotential bonding strip
OCPD	Overcurrent protective device
PFC	Power factor correction
RCD	Residual current device
RCM	Residual current monitor
RMS	Root mean square
	true RMS value
SCCR	Short circuit current rating
SPD	Surge protective device
TN system	TN network, TN system Earthed power supply system The earthing conductors of the current source and the earthing conductors of the consumer installation are connected together by means of a low-resistance connection.
TT system	TT network, TT system Earthed power supply system The earthing conductors of the current source and the earthing conductors of the consumer installation are not connected together.

4 Using EMC/EMI filters

4.1 Selecting overcurrent protective devices

4.1.1 General information

WARNING: Risk of electric shock and fire
Only ever operate an EMC/EMI filter within the respective technical specifications for overcurrent protective devices that apply for the corresponding EMC/EMI filter.

You will find the technical specifications for overcurrent protective devices that apply for the relevant EMC/EMI filter in the corresponding installation instructions for the EMC/EMI filter and in the data sheet.

FIL-1S-1 and SFP2-1S-1 type EMC/EMI filters can be used together with the following overcurrent protective devices:

– Fuses (gG) suitable for protecting cables
– Miniature circuit breakers (MCBs)

Different types of overcurrent protective devices with the same nominal currents can have different response characteristics. Only use the overcurrent protective devices that are specified in the product documentation for the EMC/EMI filter.

Different technical specifications for overcurrent protective devices and maximum permissible short-circuit currents (I_{SCCR}, SCCR) may be specified for an EMC/EMI filter. The different specifications depend on the following, for example:

– Type of voltage: AC or DC
– Type of overcurrent protective device: Fuse or miniature circuit breaker
– Short-circuit current extinguishing capacity of the overcurrent protective device
– Maximum permissible prospective short-circuit current at the installation location

4.1.2 Overcurrent protection in TN and TT systems

In solidly earthed power supply systems (TN, TT), all active conductors are usually equipped with overcurrent protective devices. Under normal conditions these carry operating currents and operating voltage is applied to them.

Country-specific or regionally applicable regulations may require overcurrent protective devices to be used for all active conductors of solidly earthed power supply systems. Observe the country-specific or regionally applicable regulations.

4.1.3 Overcurrent protection in IT systems

Please note the following when using EMC/EMI filters in IT systems:

– In IT systems, all conductors that carry operating currents must be equipped with overcurrent protective devices.
– In IT systems, insulation monitoring devices (IMDs) or residual current devices (RCDs) can be arranged upstream of an EMC/EMI filter. Please note that leakage currents to earth can occur during normal use of EMC/EMI filters. Take these leakage currents into consideration when selecting and configuring insulation monitoring devices or when selecting residual current devices.

Please also refer to section “IT systems” on page 45.

4.1.4 Overcurrent protection in DC systems (for FIL-1S-1 only)

NOTE: Select the correct overcurrent protective device
- In DC systems, only ever use overcurrent protective devices that have been approved by the manufacturer for use in DC systems.
- Observe the manufacturer's information in the data sheets of DC-compatible overcurrent protective devices.

The DC short-circuit current extinguishing capacity of miniature circuit breakers usually greatly depends on the following criteria:
- Internal structure of miniature circuit breakers
- DC operating voltage
- Installation direction
- Inductance and resistance in DC circuits (L/R ratio)

If DC-compatible miniature circuit breakers are used at higher DC operating voltages (e.g., 110 V DC and above), the series connection of DC-compatible miniature circuit breakers may be necessary. You must observe the manufacturer's information for the installation of DC-compatible miniature circuit breakers.

4.2 Discharging capacitors

DANGER: Risk of fatal electric shock
Even after the supply voltage has been switched off, the capacitors contained in EMC/EMI filters may be charged with hazardous contact voltages. Completely discharge the capacitors contained in an EMC/EMI filter at all positions.

To discharge the capacitors of an EMC/EMI filter, use a suitable discharging circuit, e.g., a two-position voltage tester with discharge function for capacitors. Observe the information regarding the discharge function that is provided in the operating instructions for two-position voltage testers with discharge function.

Please note that there may be other equipment with capacitors, especially in DC systems. Even after the supply voltage has been switched off, the capacitors in other equipment may be charged with hazardous contact voltages. If necessary, completely discharge the capacitors contained in other equipment at all positions.

In some cases, the capacitors of other AC or DC equipment may have a much higher capacitance than the capacitors in the EMC/EMI filter.

Removing EMC/EMI filters

- Disconnect the relevant system part and/or the relevant circuit from the power source (safety rule 1)
- Secure the relevant system part and/or the relevant circuit against being switched on again (safety rule 2)
- Verify the absence of voltage at all positions before removing an EMC/EMI filter or its connecting cables (safety rule 3)
- Before proceeding to remove an EMC/EMI filter, wait until the voltage in the capacitors installed in the EMC/EMI filter and those installed in other equipment has reached a sufficiently low level.
- If necessary, use a suitable discharging circuit to discharge the capacitors installed in the EMC/EMI filter and those installed in other equipment.

4.3 PE conductor and protective bonding

DANGER: Risk of fatal electric shock
The PE conductor that is connected to an EMC/EMI filter is used as part of important protective measures. Connect the EMC/EMI filter to a PE conductor. If the PE conductor is interrupted, there may be hazardous contact voltages present at equipment. This can also occur in the absence of a sufficiently low-resistance connection from the PE conductor connection to the protective bonding.

In the event that a PE conductor is interrupted, hazardous contact voltages may be present at:
– The PE conductor leading to the filter
– The PE conductor leading away from the filter
– Exposed conductive metal parts of protection class I EMC/EMI filters
– Exposed conductive metal parts of other protection class I equipment
– Exposed conductive parts that are connected to the interrupted PE conductor

An EMC/EMI filter may only be operated if it is connected to a correctly rated and properly functioning PE conductor. If a suitable PE conductor is not connected, the operation of EMC/EMI filters is not permitted.

Possible causes of hazardous contact voltages on the PE conductor:
– Earth fault currents, short-circuit currents, insulation faults
– Filter discharge currents, in conjunction with the partial or complete interruption of the PE conductor or protective bonding conductor

Dimensioning of the PE conductor

Select the PE conductor so that the expected filter discharge currents can be safely conveyed through the corresponding PE conductor. This also applies to the expected earth fault currents and short-circuit currents in the event of a fault. There must be no impermissible heating, damage, or destruction of the PE conductor.

Use a PE conductor with a sufficiently high cross-section, sufficiently high conductivity, and sufficiently high mechanical strength. The PE conductor must be installed in such a way that it is adequately protected against accidental interruption.

Continuous and low-impedance equipotential bonding and protective bonding must be installed for the following points:
– Overcurrents and short-circuit currents are shut down by overcurrent protective devices (OCPD)
– Earth faults, earth fault currents, and leakage currents to earth are detected and shut down by residual current devices (RCDs)
– Leakage currents to earth are detected and indicated by residual current monitors (RCMs)
– Insulation faults are detected and indicated by insulation monitoring devices (IMDs)
– In the event of a fault (e.g., an earth fault), contact voltages are limited to a voltage value that is low enough for humans

The equipotential bonding and protective bonding must be installed using state-of-the-art technology. In addition to the relevant standards, other regional or locally applicable standards, directives, and specifications may apply.

Connection between the EMC/EMI filter and the protective bonding

Preferably use more than one conductive, sufficiently low-impedance connection between the PE connection of an EMC/EMI filter and the protective bonding.

Advantages of using more than one connection between the EMC/EMI filter and the protective bonding:

– Reduced contact voltages in the event of a fault (e.g., an earth fault)
– Optimized attenuation characteristics between the active conductors and protective earthing conductor (PE conductor)

Installing EMC/EMI filters

• Connect the protective earthing conductor (PE conductor) to the EMC/EMI filter first before connecting other active conductors (L, N).

Removing EMC/EMI filters

• Disconnect the active conductors (L, N) from the EMC/EMI filter first before disconnecting the protective earthing conductor (PE conductor).

Protection class I equipment

In the case of protection class I equipment, the exposed conductive part of the equipment (e.g., the conductive metal housing) must be connected to the PE conductor.

EMC/EMI filters in metal housing are usually protection class I items of equipment.

Additional standards

Further important information is provided in the following standards:

– Protection against electric shock (IEC 60364-4-41, DIN VDE 0100-410)
– Protection against overcurrent (IEC 60364-4-43, DIN VDE 0100-430)
– Earthing systems and PE conductors (IEC 60364-5-54, DIN VDE 0100-540)

4.4 Dimensioning of PE conductors

During the normal operation of circuits – when a short circuit, earth fault, or insulation fault is not present – the PE conductor belonging to a circuit can carry the following currents:

- Earth leakage currents
- Filter discharge currents
- Stray currents
- Direct currents
- Alternating currents

An EMC/EMI filter usually discharges discharge currents to the PE conductor. Equipment on the OUT/LOAD side of a filter can also convey additional currents through the PE conductor of the respective circuit.

The filters differ with respect to the discharge currents:

Standard EMC/EMI filters

With typically occurring discharge currents for standard EMC/EMI filters to the protective earthing conductor (PE conductor)

Typical applications: Standard applications, no special requirements for low discharge currents to the protective earthing conductor (PE conductor)

Low discharge current filters (low leakage current filters)

With reduced discharge currents to the PE conductor

Typical applications:

- Together with RCDs (prevention of erroneous tripping)
- Together with RCMs (prevention of erroneous measurements)
- Medical applications

The PE conductor currents that actually occur during the operation of a circuit must also be taken into consideration for the correct dimensioning of a PE conductor or protective bonding conductor. Electrical engineering standards require specific minimum cross-sections for PE conductors based on the PE conductor currents that actually occur during operation.

If the PE conductor current is greater than 10 mA under normal operating conditions, a reinforced PE conductor must be used (IEC 60364-5-54, DIN VDE 0100-540).

The following applies for **reinforced PE conductors**:

- The PE conductor must have a cross-section of at least 10 mm^2 (Cu) or 16 mm^2 (Al) over its entire length.
- If the PE conductor has a cross-section of less than 10 mm^2 (Cu) or 16 mm^2 (Al), a second PE conductor with at least the same cross-section must be installed. This applies up to the point where the additional PE conductor has a cross-section of at least 10 mm^2 (Cu) or 16 mm^2 (Al).

If the PE conductor current could exceed 10 mA during the operation of the electrical system or equipment, it must be protected against mechanical damage along its entire length.

To ensure the correct dimensioning of PE conductors and protective bonding conductors, it is necessary to determine the operational PE conductor currents of the respective circuit. The information provided by equipment manufacturers regarding PE conductor currents usually offers guidance here. For a proper evaluation of PE conductor currents, it is necessary to take measurements of the PE conductor current for the respective circuit. These measurements must be performed in typical operating states.

PE conductor currents usually comprise a mixture of different frequencies. You therefore need to use a suitable measuring device to measure PE conductor currents. The measuring device must measure the true RMS value (RMS = root mean square) of the PE conductor current with sufficient accuracy.

You can find further information on the dimensioning of PE conductors for increased PE conductor currents in the following, for example:

- IEC 60204-1, DIN EN 60204-1
- IEC 60364-4-41, DIN VDE 0100-410
- IEC 60364-5-54, DIN VDE 0100-540

Please note that other regional or locally applicable specifications for PE conductors may apply.

Observe the maximum possible cross-section for connecting PE conductors to the respective EMC/EMI filter.

Please note that a second independent PE conductor may be required for EMC/EMI filters if PE conductors are connected on both the IN/LINE side and the OUT/LOAD side of an EMC/EMI filter.

A second independent PE conductor is required if the PE conductor current through the EMC/EMI filter exceeds 10 mA.

The second independent PE conductor must be routed via the local PE busbar to which the respective EMC/EMI filter is connected.

Notes

- When specifying cross-sections of PE conductors and protective bonding conductors, the focus is often on achieving the protection objective of electrical safety. Unfortunately, aspects associated with the electromagnetic compatibility of systems are sometimes not given enough consideration in real systems.
- To enable the EMC-optimized operation of electrical systems while simultaneously achieving a good level of effectiveness from EMC/EMI filters, an EMC-optimized, low-impedance installation is required for PE conductors, protective bonding conductors, and equipotential bonding conductors.
- Always plan electrical systems so that the requirements for electrical safety as well as the requirements for EMC-optimized operation are appropriately considered. You will find further information on this topic in the relevant EMC application standards and in the specialist literature regarding the electromagnetic compatibility of systems.

4.5 System resonance

DANGER: Risk of fatal electric shock
EMC/EMI filters contain energy-storing components, such as capacitors, chokes, and coils.

Together with other energy-storing elements of a circuit, the energy-storing components of an EMC/EMI filter can form a resonant circuit.

Each resonant circuit has one or more resonant frequencies. System resonance can occur as series or parallel resonance. In the event of system resonance, resonance-related voltage or current increases can occur.

Voltage increases

Voltage increases can result in the following:
- Excessive heating of capacitors
- Loss of the insulation capability of components
- Short circuits and earth faults

Current increases

Current increases can cause excessive heating. Heating due to increased current flow can occur in:
- Electrical conductors
- Resistors
- Chokes
- Coils
- Capacitors
- Other electronic or electromechanical components

NOTE: Damage to components
Resonance-related voltage or current increases can result in the premature aging of components. They may even reduce the service life of equipment.

Resonance-related voltage or current increases

Resonance-related voltage or current increases can result in the loss of function or failure of components. This can then result in the loss of insulation. Hazardous contact voltages can occur on conductive parts of equipment. Hazardous contact voltages can also occur on other parts of a switchgear and controlgear assembly or electrical system.

Plan electrical systems in such a way that system resonance cannot occur. During operation, prevent system states in which system resonance could occur.

Even with the careful planning of electrical systems, system resonance can still occur during normal operation. Planners, installers, and operators of systems must therefore take appropriate measures to identify and prevent system resonance. This applies in particular to the commissioning, operation, and expansion of electrical systems.

When an electrical system is extended, converted, or modified, its resonance conditions can change. As a result of this change, system resonance may now be present in the electrical system that did not exist prior to the change.

It is not just changes to the hardware of an electrical system that can cause changes in the resonance conditions. A change in the switching frequency of power electronics equipment or a change to the operating mode used can also alter the resonance conditions of an electrical system. Unexpected system resonance may even occur.

Even if no resonance-related voltage or current increases have previously been identified in the normal operation of an electrical system, it is possible that resonance-related voltage increases or current increases may occur in future in unfavorable conditions.

Always keep in mind that seemingly spontaneous resonance-related voltage and current increases may occur.

Switching frequency and system resonance

The switching frequency of power electronics equipment, the modulation type, and the operating mode of switched components can significantly influence the operating behavior of circuits. System resonance can occur under the following boundary conditions, for example:

– The switching frequency of a power electronics circuit roughly corresponds to the natural resonant frequency of a circuit.
– The switching frequency of a power electronics circuit roughly corresponds to the integer multiple of the natural resonant frequency of a circuit.

Setting values of frequency inverters

Unexpected resonance-related voltage or current increases can occur on the input and output side of frequency inverters and other power electronics inverters or transformers.

The following setting values may even be changed for frequency inverters and power electronics inverters:

– Switching frequency
– Modulation type
– Operating mode

System resonance can be prevented by choosing suitable setting values. Always keep in mind that system resonance may occur if unsuitable setting values are chosen. Changing setting values can result in unexpected system resonance.

Equipment with automatic mode

Power electronics equipment sometimes features an automatic mode. In automatic mode, the respective equipment attempts to determine the optimized setting values automatically. Automatic mode is usually an operating mode that focuses on achieving acceptable operating behavior in terms of energy efficiency. It is rarely possible to predict reliably whether the use of automatic mode will result in good EMC behavior.

If system resonance occurs when power electronics equipment is operated in automatic mode, automatic mode should be disabled. Select setting values with which no system resonance occurs.

4.6 Attenuation characteristics

The voltage attenuation and current attenuation effect of EMC/EMI filters greatly depends on the electrical characteristics of the circuits in which an EMC/EMI filter is installed.

For example, the following factors are important for the attenuation characteristics in an electrical system:
- Output impedance of current sources
- Input impedance of loads
- Operating state of an electrical system
- Switching state of an electrical system
- Other factors

The earthing, shielding, and equipotential bonding measures implemented in an electrical system also have a significant influence on the attenuation characteristics of EMC/EMI filters.

The lower the impedance of the EMC/EMI filter connection to earth potential, the better the expected attenuation characteristics between active conductors and earth potential.

The attenuation curves published together with EMC/EMI filters only ever offer guidance. The effectiveness of EMC/EMI filters in electrical systems can only be assessed on a case-by-case basis. For the qualified assessment of the effectiveness of an EMC/EMI filter, it is always necessary to perform electrical measurements in an electrical system under typical operating conditions.

In electrical systems, elements of the system can interact with the components contained in EMC/EMI filters. These can include energy-storing elements of the system or power electronics equipment. This can significantly influence the attenuation characteristics of EMC/EMI filters.

Always keep in mind that system resonance may occur in certain frequency ranges if EMC/EMI filters are used. It is often the case that the frequency ranges with system resonance that occur in systems cannot be reliably derived from the attenuation curves that are published together with an EMC/EMI filter.

The attenuation curves published together with EMC/EMI filters are determined based on standardized measurement methods and measurement setups (e.g., in accordance with CISPR 17). The electrotechnical environment present in electrical systems can differ greatly from the measurement setups used for standardized measurement methods. In certain cases, the attenuation of high-frequency conducted interference that is actually achieved can deviate considerably from the standardized attenuation curves that are published for an EMC/EMI filter.

The standardized measurement procedures and measurement setups for EMC/EMI filters (e.g., in accordance with CISPR 17) are selected to ensure that comparable measurement results can be obtained for different types of EMC/EMI filters. This is why standardized measurement setups usually do not contain other energy-storing components. The measured values and attenuation curves obtained by standardized means are generally intended to offer guidance.

In contrast to standardized measurement setups with EMC/EMI filters, electrical systems often contain other energy-storing components. These energy-storing components can include capacitors, chokes, and coils, for example. Other parasitic capacitances and parasitic inductances in the circuit can also have a considerable influence on the operating behavior of a circuit and on its resonance characteristics.

It is often difficult to predict the actual attenuation behavior of EMC/EMI filters in electrical systems. Two real-world examples:

Example A	An EMC/EMI filter with an above-average attenuation curve actually exhibits better attenuation behavior in a real electrical system than an EMC/EMI filter with an average attenuation curve.
Example B	An EMC/EMI filter with an average attenuation curve actually exhibits better attenuation behavior in a real electrical system than an EMC/EMI filter with an above-average attenuation curve.

Many aspects of the operating behavior of electrical systems can be replicated with a high degree of reliability by computer simulations. In many cases, however, when assessing the operating behavior of EMC/EMI filters in electrical systems, computer simulations do not yield satisfactory results. This is why EMC/EMI filters are often tested in real electrical systems and under typical operating conditions. During testing, the measured conducted interference is assessed with and without the EMC/EMI filter.

4.7 Electrical measurements

WARNING: Risk of electric shock and electric arcs when performing electrical measurements

The voltage increases and current increases that occur in the event of system resonance can exceed the electric strength and current carrying capacity of electrical measuring devices.

Only use measuring devices with sufficiently high electric strength, current carrying capacity, and short-circuit current rating for the measurement task in question. Observe the operating instructions and safety notes for the corresponding measuring devices. If required, use suitable personal protective equipment. If unsuitable measuring devices are used, they may be damaged or destroyed. The use of such devices may also result in personal injury or property damage.

Dangerous electric arcs can occur, especially in electrical systems with high prospective short-circuit currents. Work on electrical systems should be planned so that there is no risk of electric shock or electric arcs. Take appropriate measures to protect against electric arcs. If required, use suitable personal protective equipment.

Oscilloscope input circuits and oscilloscope probes are usually unsuitable for direct measurement on low-voltage power supply systems. Please note that resonance-related voltage increases can occur.

For measurements on low-voltage power supply systems, do not use oscilloscope probes that use the chassis of the oscilloscope as reference potential.

Always use probes with electrical isolation between the input and output side for oscilloscope measurements on low-voltage power supply systems. For example, differential probes with electrical isolation are suitable for this.

When selecting measuring devices and the corresponding accessories, always ensure that their electric strength is high enough in terms of:

- Impulse withstand voltage
- Continuous electric strength
- Short-circuit current rating

Make sure that measuring circuits are equipped with suitable overcurrent protection. If required, use suitable personal protective equipment.

Observe the short-circuit current extinguishing capacity of fuses that are integrated in measuring devices.

Notes:

- Use an oscilloscope and probes with sufficient bandwidth to ensure you can measure high-frequency interference with sufficient accuracy.
- Use an oscilloscope with spectrum analyzer to ensure the meaningful analysis of high-frequency interference.

5 Installation instructions

5.1 Ambient conditions

Install EMC/EMI filters in clean and dry conditions, e.g., in control cabinets, housings, or closed electrical operating areas. Please note that the housing of EMC/EMI filters is not usually hermetically sealed.

Protect EMC/EMI filters against the following ambient conditions:

- Electrically conductive dust particles
- Non-electrically conductive dust particles
- Other deposits
- Liquids
- Corrosive or aggressive vapors
- Corrosive or aggressive gases
- The ingress of foreign objects and other matter that may impair the operation and safety of EMC/EMI filters

Condensation is not permitted. Avoid operating electrical equipment in environments where the relative humidity of the ambient air is in the range of the maximum permissible relative humidity for longer periods.

If necessary, take appropriate measures to prevent sustained high relative humidity.

5.2 PE conductor connection

DANGER: Risk of fatal electric shock
The PE conductor that is connected to an EMC/EMI filter is used as part of important protective measures. Connect the EMC/EMI filter to a PE conductor. If the PE conductor is interrupted, there may be hazardous contact voltages present at these points:

- Free ends of PE conductors
- Exposed conductive parts of protection class I equipment
- Electrically conductive parts connected to the PE conductor

This can also occur in the absence of a sufficiently low-resistance connection from the PE conductor to the protective bonding.

Installing EMC/EMI filters

- Step 1: Connect the protective earthing conductor (PE conductor) to the EMC/EMI filter.
- Step 2: Connect other active conductors (L, N) to the EMC/EMI filter.

Removing EMC/EMI filters

- Step 1: Disconnect the active conductors (L, N) from the EMC/EMI filter.
- Step 2: Disconnect the protective earthing conductor (PE conductor) from the EMC/EMI filter.

For further information, please refer to "PE conductor and protective bonding" on page 30.

5.3 Earthing busbar (protection class I/protection class II)

NOTE: Connection to the earthing busbar
If an earthing busbar (PE busbar) is present in a switchgear and controlgear assembly, you must connect at least one of the PE terminals of the EMC/EMI filter to the earthing busbar.

The **PE terminals** for FIL-1S-1 and SFP2-1S-1 type EMC/EMI filters are on the IN/LINE and OUT/LOAD side.

FIL-1S-1

FIL-1S-1 type EMC/EMI filters have **plastic housing** (protection class II).

These EMC/EMI filters are suitable for PE through-wiring in protection class II switchgear and controlgear assemblies without earthing busbar.

Please note the following for the PE through-wiring: You may only connect the PE conductors that belong to the supply circuit in question to the PE terminals on the IN/LINE and OUT/LOAD side of the EMC/EMI filter.

SFP2-1S-1

SFP2-1S-1 type EMC/EMI filters have **metal housing** (protection class I).

In industrially manufactured protection class I switchgear and controlgear assemblies, EMC/EMI filters from the SFP2-1S-1 series are installed on an earthed, conductive metal 35 mm DIN rail.

Install SFP2-1S-1 type filters in a switchgear and controlgear assembly with earthing busbar (PE busbar).

The following applies when installing SFP2-1S-1 type EMC/EMI filters (protection class I) in protection class II switchgear and controlgear assemblies:

- Equip the switchgear and controlgear assembly with an earthing busbar (PE busbar).
- Connect the incoming and outgoing PE conductors to the earthing busbar.
- Connect the PE conductor connections of all items of equipment in the switchgear and controlgear assembly to the earthing busbar.
- Install the EMC/EMI filter (protection class I) on an earthed, conductive metal 35 mm DIN rail.
- Connect this DIN rail to the earthing busbar (PE busbar) via a low-impedance connection.
- Use the symbol for “protective earthing” to identify the earthed DIN rail.

The following applies to EMC/EMI filters:

- Connect the PE terminal on the OUT/LOAD side of the EMC/EMI filter to the local earthing busbar via the shortest route and ensure that the impedance of this connection is as low as possible.
- Connect at least one of the PE terminals of an EMC/EMI filter to the local earthing busbar and ensure that the impedance of this connection is as low as possible.
- Install the EMC/EMI filter near to the local earthing busbar.

– FIL-1S-1 type EMC/EMI filters have four PE terminals each in total.
  – Two PE terminals on the IN/LINE side of the EMC/EMI filter
  – Two PE terminals on the OUT/LOAD side of the EMC/EMI filter

EMC-optimized installation

Recommended for EMC-optimized installation: Connect as yet unused PE terminals of EMC/EMI filters to the local earthing busbar or to an earthed 35 mm DIN rail and ensure that the impedance of this connection is as low as possible.

Recommended for protection class I control cabinets: Use the electrically conductive components of a control cabinet as additional connections to the local earthing busbar.

Install an earthed, conductive metal 35 mm DIN rail on a surface with excellent electrical conductivity. The surface must be free of lacquer and paint. Suitable surfaces include those made from unlacquered sheet iron, for example. Use sheet iron where the surface has been electroplated to protect against corrosion.

Surfaces made from aluminum usually have an insulating effect due to transparent, non-conductive aluminum oxide present on the surface. Do not install conductive metal DIN rails on surfaces made from aluminum.

5.4 Cable routing

In electrical systems, undesired couplings can occur between conductors. Undesired couplings may be caused by the following, for example:

- Magnetic fields
- Electrical fields
- Operating currents
- Overload currents
- Short-circuit currents
- Earth fault currents
- High-frequency conducted interference
- Transient voltage pulses
- Transient current pulses

Undesirable couplings should always be expected if conductors from different circuits are installed in parallel with little space between them.

- To prevent undesirable couplings, do not route the conductors connected on the IN/LINE and OUT/LOAD side of the EMC/EMI filter in parallel.
- If the crossing of these conductors is unavoidable, these cables must be crossed at a right angle.

5.5 Climatic category

WARNING: Risk of burns and fire
The surface temperature of an EMC/EMI filter can be much higher than the ambient temperature. Always keep in mind that the surface temperature of an EMC/EMI filter may be elevated.

A climatic category will be specified for an EMC/EMI filter. The climatic category comprises three groups of numbers separated by a slash:

First number:	Temperature for the tests with cold (in °C; temperature below zero)
Second number:	Temperature for the tests with dry heat (in °C; temperature above zero)
Third number:	Duration of the tests with constant humid heat (in days)

The maximum expected surface temperature (in °C) corresponds to the second number (middle number) in the specification for the climatic category.

Example for the specification of the climatic category for an EMC/EMI filter:

Climatic category: 40/100/21

– Temperature for the tests with cold: -40°C
– Temperature for the tests with dry heat: +100°C
– Duration of the test with constant humid heat: 21 days

5.6 Surface temperatures

WARNING: Risk of burns and fire
Danger due to high temperatures on the surface of an EMC/EMI filter. The components inside EMC/EMI filters can become very hot during normal use. If an operating current in the region of the permissible rated current (nominal current) flows through an EMC/EMI filter, the surface of the EMC/EMI filter can become very hot.

- Always keep in mind that the housing surface temperature of EMC/EMI filters may be elevated. The temperature can become so hot that the surface should not be touched.
- If necessary, take appropriate measures to prevent any hazards arising from excessive heating.
- Arrange the EMC/EMI filters so as to prevent a build-up of heat.

5.7 Heat dissipation

WARNING: Excessive heating and hot surfaces
Protect EMC/EMI filters against excessive heating resulting from insufficient heat dissipation. When installing an EMC/EMI filter, always ensure that there is sufficient heat dissipation by means of natural convection.

Heating can occur inside EMC/EMI filters and on the surface of EMC/EMI filters due to:

– Operating currents flowing through the EMC/EMI filter
– Residual currents flowing through the EMC/EMI filter
– High-frequency (discharge) currents flowing through the components of EMC/EMI filters

Heat dissipation when installing EMC/EMI filters

- When installing other equipment near an EMC/EMI filter, make sure that the equipment is not directly adjacent to the side panels of an EMC/EMI filter.
- Provide enough free space at the side of an EMC/EMI filter for ventilation. Ensure that sufficient heat dissipation by means of natural convection is possible via the side panels of an EMC/EMI filter.

EMC/EMI filters with vents

EMC/EMI filters can be equipped with the necessary vents required for heat dissipation.

- Preferably install EMC/EMI filters with vents so that the vents are in the top and bottom mounting position.
- Install EMC/EMI filters so that the vents in the bottom mounting position are supplied with cool ambient air.
- Make sure that the warm air generated inside the EMC/EMI filter can be dissipated via the vents at the top. The heat from EMC/EMI filters can warm up other nearby equipment.
- Do not place any equipment that emits heat below EMC/EMI filters.

WARNING: Excessive heating and hot surfaces
The installation of EMC/EMI filters in an overhead position is not permitted.

5.8 Temperature-dependent current derating

Observe the derating information for the operation of EMC/EMI filters at increased ambient temperatures (e.g., greater than 50°C). Protect EMC/EMI filters against excessive heating due to impermissibly high operating currents.

Use suitable overcurrent protective devices (OCPDs).

The rated current (nominal current) of an EMC/EMI filter is usually specified on the front of the EMC/EMI filter. This rated current is always based on a defined ambient temperature (e.g., 50°C). An EMC/EMI filter may be operated with the full rated current up to this ambient temperature.

Notes

- EMC/EMI filters can heat up due to load currents or filter discharge currents. In addition, you must observe the ambient temperature.
- At higher ambient temperatures, the maximum permissible temperatures inside an EMC/EMI filter can be reached before the maximum permissible operating current is reached.
- Prevent excessive heating inside an EMC/EMI filter by limiting the maximum possible operating current.

6 IT systems

6.1 General information

DANGER: Risk of fatal electric shock
In an IT system, only use EMC/EMI filters that are approved for use in IT systems. The electric strength of the EMC/EMI filters must be high enough to continuously withstand potentially longer voltage increases in IT systems in the event of a phase conductor earth fault.

FIL-1S-1 and SFP2-1S-1 type EMC/EMI filters are suitable for the following IT systems without neutral conductor:

- **Single-phase IT systems without neutral conductor**, where the nominal voltage between the phase conductors (L–L) does not exceed the nominal voltage of the EMC/EMI filter;
  conductors: L1, L2, PE
- **Three-phase IT systems without neutral conductor**, where the nominal voltage between the phase conductors (L–L) does not exceed the nominal voltage of the EMC/EMI filter;
  conductors: L1, L2, L3, PE

Please note the following when installing EMC/EMI filters in IT systems:

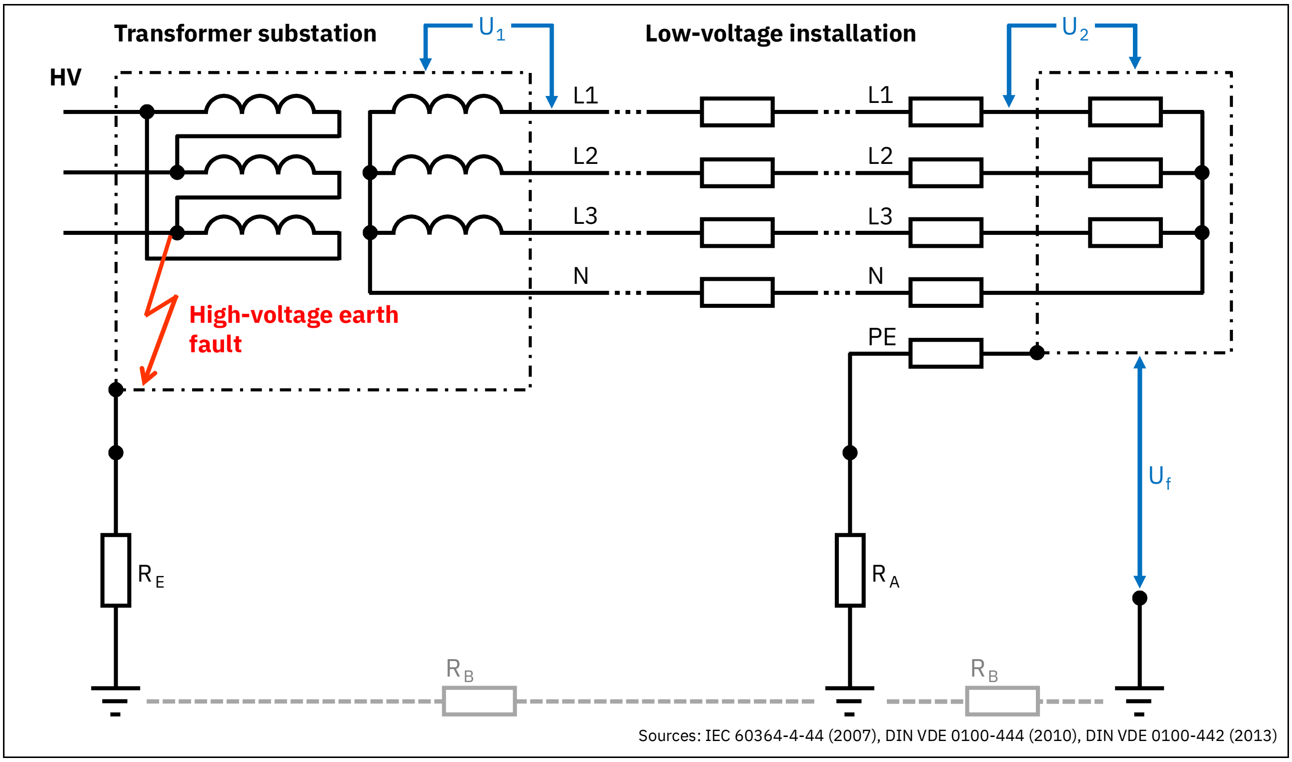
- **Case A**: The protective bonding system of the high-voltage transformer substation is separate from the protective bonding system of the low-voltage installation (consumer installation); without connection between R_E and R_A (see Figure 6-1 and Figure 6-3). There is no continuous protective earthing conductor (PE) present.
  → An additional RCD is required upstream of the EMC/EMI filter. The additional RCD must be arranged upstream of the EMC/EMI filter in the energy flow direction.
- **Case B**: The protective bonding system of the high-voltage transformer substation is connected to the protective bonding system of the low-voltage installation (consumer installation) via a low-impedance connection; with connection between R_E and R_A (IEC 60364-4-44:2007, DIN VDE 0100-444:2010, DIN VDE 0100-442:2013); see Figure 6-2 and Figure 6-3
  → No additional measures required

Please note the following when using EMC/EMI filters in IT systems:

- In IT systems, all conductors that carry operating currents must be equipped with overcurrent protective devices
- In IT systems, insulation monitoring devices (IMDs) can be arranged upstream of an EMC/EMI filter. Please note that leakage currents to earth can occur during normal use of EMC/EMI filters. Take these leakage currents into consideration when selecting and configuring insulation monitoring devices.

6.2 Earthing of the transformer substation and low-voltage installation

Figure 6-1 IT systems – case A

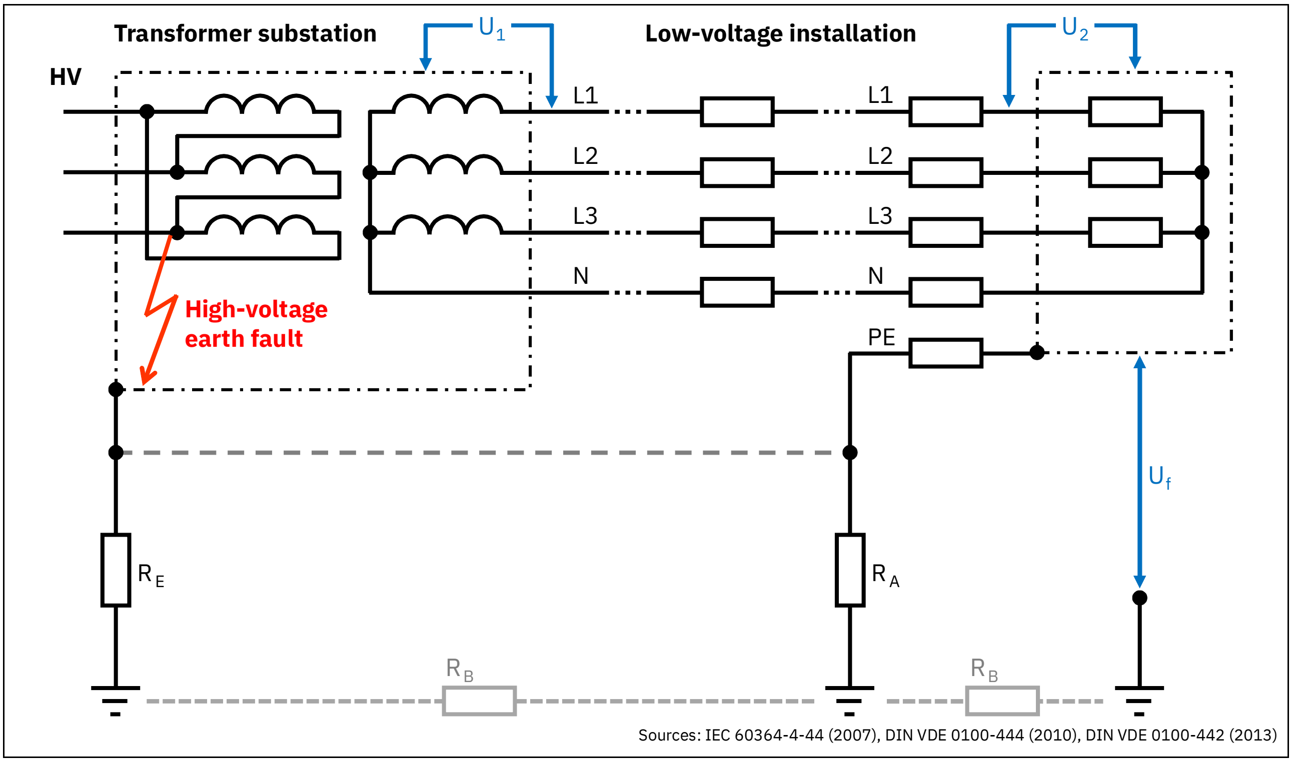


Schematic view in accordance with IEC 60364-4-44 (2007), DIN VDE 0100-444 (2010), DIN VDE 0100-442 (2013)
Connections to earth in the transformer substation and low-voltage installation and surge voltages in the event of a fault
Without connection between R_E and R_A

Key (IEC 60364-4-44 [2007, 2018])

R_E	Resistance of the earthing system of the transformer substation
R_A	Resistance of the earthing system of the exposed conductive parts of the equipment of the low-voltage installation
R_B	Resistance of the earthing system of the low-voltage system neutral, for low-voltage systems in which the earthing systems of the transformer substation and of the low-voltage system neutral are electrically independent
U_f	Power-frequency fault voltage that appears in the low-voltage system between exposed conductive parts and earth for the duration of the fault
U_1	Power-frequency stress voltage between the line conductor and the exposed conductive parts of the low-voltage equipment of the transformer substation during the fault
U_2	Power-frequency stress voltage between the line conductor and the exposed conductive parts of the low-voltage equipment of the low-voltage installation during the fault

Figure 6-2 IT systems – case B



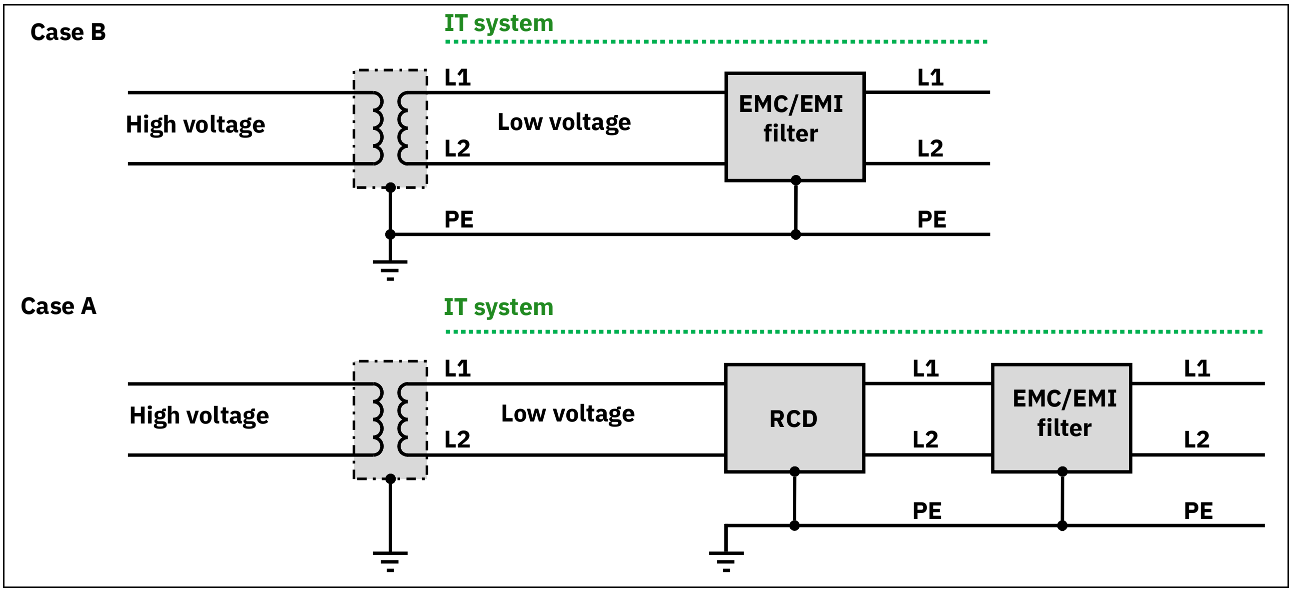
Schematic view in accordance with IEC 60364-4-44 (2007), DIN VDE 0100-444 (2010), DIN VDE 0100-442 (2013)
Connections to earth in the transformer substation and low-voltage installation and surge voltages in the event of a fault
With connection between R_E and R_A

Key (IEC 60364-4-44 [2007, 2018])

- **R_E** Resistance of the earthing system of the transformer substation
- **R_A** Resistance of the earthing system of the exposed conductive parts of the equipment of the low-voltage installation
- **R_B** Resistance of the earthing system of the low-voltage system neutral, for low-voltage systems in which the earthing systems of the transformer substation and of the low-voltage system neutral are electrically independent
- **U_f** Power-frequency fault voltage that appears in the low-voltage system between exposed conductive parts and earth for the duration of the fault
- **U_1** Power-frequency stress voltage between the line conductor and the exposed conductive parts of the low-voltage equipment of the transformer substation during the fault
- **U_2** Power-frequency stress voltage between the line conductor and the exposed conductive parts of the low-voltage equipment of the low-voltage installation during the fault

6.3 Low-voltage installation

Figure 6-3 IT systems – case A and B



Installing EMC/EMI filters in IT systems

Case B In low-voltage installations where the protective bonding system of the high-voltage transformer substation is connected to the protective bonding system of the consumer installation via a low-impedance connection

Continuous protective earthing conductor (PE conductor)

↪ No additional measures required

Case A In low-voltage installations where the protective bonding system of the high-voltage transformer substation is separate from the protective bonding system of the consumer installation

No continuous protective earthing conductor (PE)

↪ An additional RCD is required upstream of the EMC/EMI filter.
The additional RCD must be arranged upstream of the EMC/EMI filter in the energy flow direction.

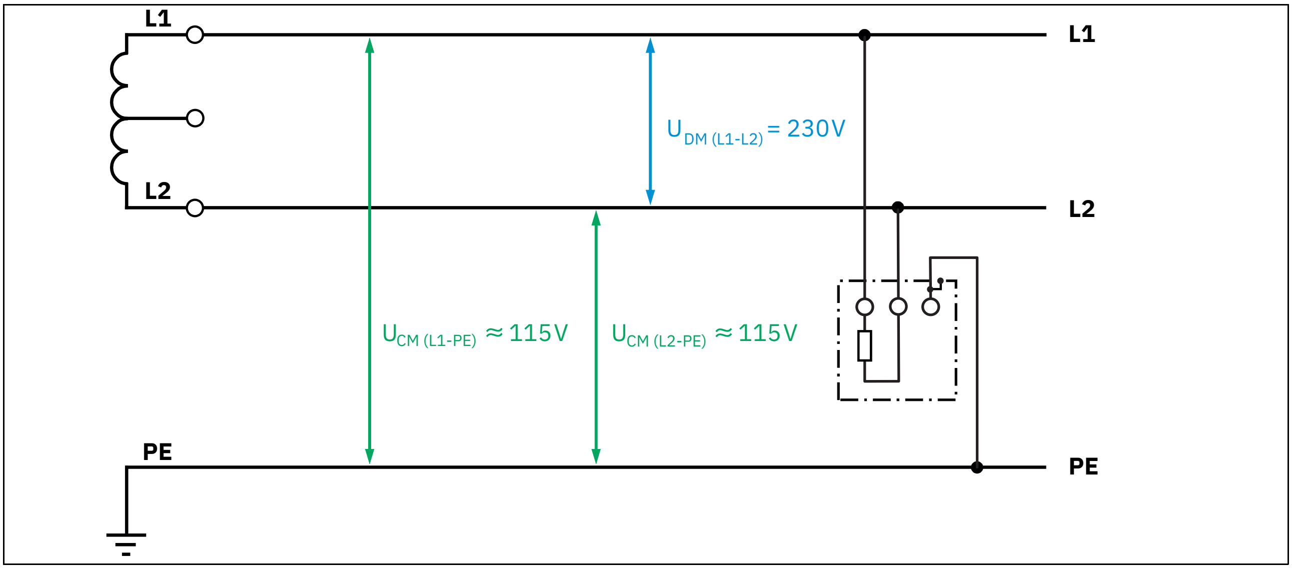
In IT systems, the live conductors are isolated from earth during error-free operation. However, one point in the IT system can be connected to earth via a sufficiently high impedance (resistance).

A neutral conductor may be present in an IT system, but it may only be present near the current source. If a neutral conductor is present at the current source, it does not necessarily have to be routed to the consumer installation.

In IT systems, the voltage differences between the individual phase conductors and earth (L–PE) are not defined exactly during error-free operation. The voltage differences that occur in IT systems are caused by stray capacitances between phase conductors and earth. In IT systems that are connected to earth with the help of a high impedance (resistance), this impedance can also have an influence on the voltage differences between phase conductors and earth.

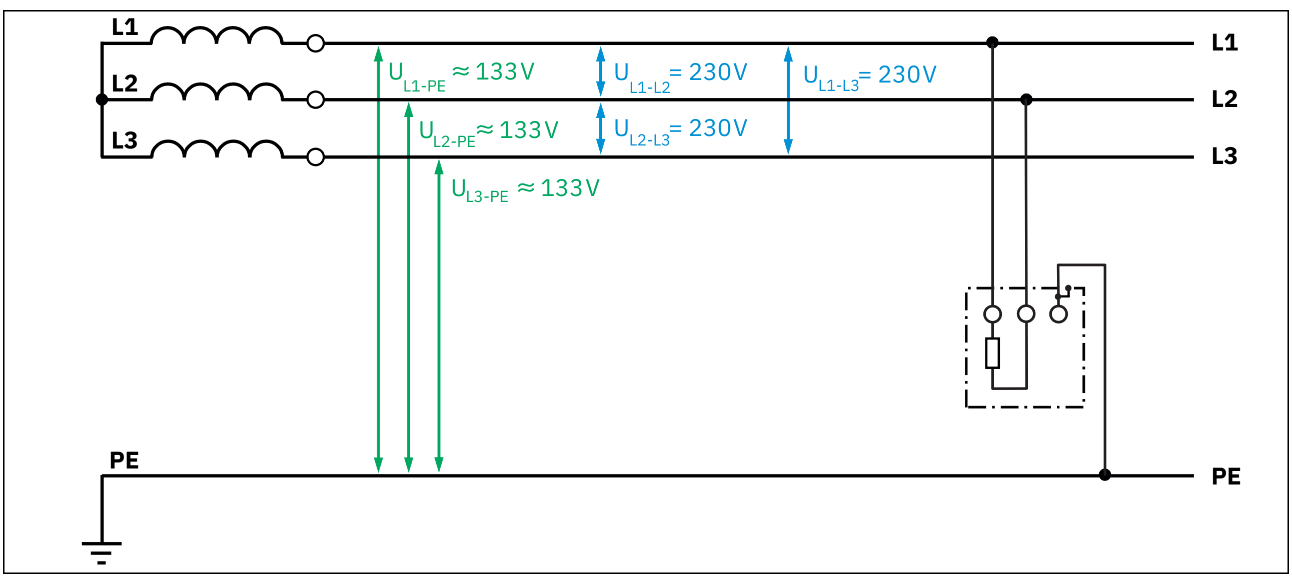
6.4 Single- or three-phase IT systems without neutral conductor

Figure 6-4 Single-phase IT system without neutral conductor, U_N = 230 V



U_{DM}	Differential-mode voltage (line to line)
U_{CM}	Common-mode voltage (line to ground)

Figure 6-5 Three-phase IT system without neutral conductor, U_N = 230 V



Voltage differences

In IT systems, the voltage differences between the individual phase conductors and earth (L–PE) are as follows during error-free operation:

– In three-phase IT systems: Approx. 58% of the voltage between the phase conductors (L-L)
– In single-phase IT systems: Approx. 50% of the voltage between the phase conductors (L-L)

In smaller IT systems, when an earth fault occurs for the first time, this usually only results in low earth fault currents. These currents are usually capacitive earth fault currents. The earth fault currents that occur on the first earth fault are so low that they do not trigger a response from the overcurrent protective devices (OCPDs) in the IT system.

Insulation faults in the IT system (e.g., an earth fault) can be detected and indicated by insulation monitoring devices (IMDs).

In an IT system, the first earth fault has no influence on the relative voltage differences between the phase conductors (L–L). However, it does influence the voltage differences between phase conductors and earth (L–PE).

In IT systems, the voltage differences between the individual phase conductors and earth (L–PE) are as follows after the first earth fault:

– **Phase conductor with earth fault**
  Voltage difference between phase conductor and earth (L–PE): 0 V
– **Phase conductor without earth fault**
  Voltage difference between phase conductor and earth (L–PE): Phase-to-phase voltage

After the first earth fault in an IT system, the phase conductors without earth fault are subject to a voltage increase between phase conductor and earth (L–PE). The voltage increase between phase conductor and earth (L–PE) is as follows:

– In three-phase IT systems: Approx. 73%
– In single-phase IT systems: Approx. 100%

Example: Three-phase IT system without neutral conductor (U_N = 230 V AC)

During error-free operation:

L1–L2: 230 V AC	L1–PE: Approx. 133 V AC
L1–L3: 230 V AC	L2–PE: Approx. 133 V AC
L2–L3: 230 V AC	L3–PE: Approx. 133 V AC

With earth fault from L1 to PE:

L1–L2: 230 V AC	L1–PE: 0 V AC
L1–L3: 230 V AC	L2–PE: 230 V AC
L2–L3: 230 V AC	L3–PE: 230 V AC

Please note that the permissible nominal voltage tolerance may be up to ±10% in many countries.

Selecting equipment for use in an IT system

Select equipment so that the rated voltage of all the equipment is high enough to continuously withstand voltage increases when an earth fault occurs for the first time.

Observe the maximum permissible (continuous) operating voltages (U_R, U_C, MCOV) specified for each individual item of equipment.

7 Surge protection in systems with EMC/EMI filters

7.1 General information

EMC/EMI filters can be used in electrical systems in which transient voltage or current pulses are to be expected. In this case, we recommend equipping the electrical system with suitable surge protective devices (SPDs).

X and Y capacitors

Many input and output circuits of electrical equipment are equipped with X and Y capacitors. EMC/EMI filters can also contain X and Y capacitors. FIL-1S-1 and SFP2-1S-1 type EMC/EMI filters are always equipped with X and Y capacitors. These capacitors are required for the effective filtering of high-frequency interference voltages and interference currents. X and Y capacitors are safety-related components that have self-healing properties.

The conductive metal layers in X and Y capacitors need to be very thin in order for self-healing to be possible. In the event of an internal short circuit, a small part of the metal layers vaporizes at the location of the fault. Due to the very thin metal layers, X and Y capacitors have maximum permissible limit values for the voltage change per unit of time (du/dt, dv/dt).

If the maximum permissible du/dt values for the X and Y capacitors used are exceeded, the very thin metal layers inside X and Y capacitors may be damaged. This can result in the premature aging or destruction of the metal layers. The du/dt values that occur in the event of transient voltage or current pulses are usually so high that the thin metal layers inside X and Y capacitors can be damaged.

To prevent damage or premature aging in the thin metal layers in X and Y capacitors, suitable surge protective devices (SPDs) should be used in electrical systems. This applies to electrical systems in which transient voltage pulses or transient current pulses are to be expected.

Surge protective devices (SPDs)

The amplitude of transient voltage pulses can be greatly reduced by surge protective devices. This can significantly reduce the electrical load on capacitors. If there are several surge protective devices in an electrical system, the du/dt values can be reduced considerably.

If the external lightning protection system of a building is connected to the main earthing busbar (MEB), IEC type 1 surge protective devices are usually used. IEC type 1 surge protective devices are used as the first protection stage and are usually installed in the immediate proximity of the main earthing busbar.

In the case of IEC type 1 surge protective devices, the following surge protection components are often used as the first protection stage:

- Spark gaps
- Gas discharge tubes (GDTs)
- Series connections of spark gaps and varistors
- Varistors

Surge protective devices with spark gaps

Lightning strikes cause rapid transient voltage pulses with a fast rate of rise, sometimes with very high du/dt values. The X and Y capacitors in an electrical system should be protected against these pulses by the most effective means possible. The use of IEC type 1 surge protective devices (SPDs) with spark gaps is recommended here.

During the conductivity phase, surge protective devices with spark gaps have a much lower let-through voltage than surge protective devices with varistors. This is why the protective effect of surge protective devices with spark gaps is usually considerably better than the protective effect of comparable surge protective devices with varistors. The protective effect of spark gaps is also better than that of surge protective devices with an internal series connection consisting of a gas discharge tube (GDT) and a varistor.

7.2 Surge protection in the proximity of EMC/EMI filters

Conventional EMC/EMI filters only protect against low-energy, high-frequency interference. EMC/EMI filters provide little to no protection against transient voltage or current pulses. Voltage pulses with a fast rate of rise can be amplified when they are conveyed through an EMC/EMI filter.

Example

A transient voltage pulse with a fast rate of rise reaches the input side (IN/LINE) of an EMC/EMI filter. The voltage pulse is conveyed through the EMC/EMI filter. When a transient voltage pulse is conveyed through an EMC/EMI filter, the amplitude of the voltage pulse can increase significantly. The amplitude of the voltage pulse can be higher on the output side of the EMC/EMI filter (OUT/LOAD) than on the input side.

If transient voltage or current pulses are conveyed, resonance-related oscillations (ringing) can occur on the output side of an EMC/EMI filter.

If a surge protective device is located upstream of an EMC/EMI filter, it usually provides no protection against transient voltage increases and resonance-related oscillations that may occur on the output side.

If transient voltage pulses or transient current pulses are to be expected in electrical systems, effective protection should be provided for the EMC/EMI filters on the input and output side (IN/LINE and OUT/LOAD).

i Place surge protective devices in the immediate proximity of the input and output side of an EMC/EMI filter.

The following circuit versions have proved to be effective:

- Surge protective device –– EMC/EMI filter –– Surge protective device
- EMC/EMI filter with integrated surge protective device that is effective on the input and output side of the EMC/EMI filter

SFP2... type EMC/EMI filters are equipped with an integrated surge protective device (SPD). The integrated surge protective device is effective on both the input side (IN/LINE) and the output side (OUT/LOAD).

7.3 Insulation measurements for EMC/EMI filters with SPD

SFP2... type EMC/EMI filters (protection class I) are equipped with an integrated surge protective device (SPD). The integrated surge protective device contains voltage-limiting and voltage-switching components. These components can lead to erroneous measurement results for insulation measurements.

After the supply voltage has been switched off and after insulation measurements have been performed, the capacitors contained in EMC/EMI filters may be charged with hazardous contact voltages.

Insulation measurements for EMC/EMI filters with integrated surge protective device

Procedure

- Completely discharge the capacitors contained in EMC/EMI filters and in other equipment at all positions. To discharge the capacitors, use a suitable discharging circuit, e.g., a suitable two-position voltage tester with discharge function for capacitors.
- **Before performing an insulation measurement**: Disconnect the EMC/EMI filter from the electrical system. Only disconnect the EMC/EMI filter from the electrical system once the capacitors contained in the EMC/EMI filter and in other equipment have been completely discharged at all positions and you have verified the absence of voltage at all positions.
- Perform the insulation measurement.
- **After performing an insulation measurement**: Reconnect the EMC/EMI filter to the electrical system.

A Application examples

Protection class I

Protection class II

DANGER: Only use protection class I equipment with PE busbar
- Protection class I equipment must be installed in a control cabinet that is equipped with a local PE busbar
- Installing protection class I equipment in a control cabinet without a local PE busbar is not permitted

A 1 TN system/protection class I control cabinet

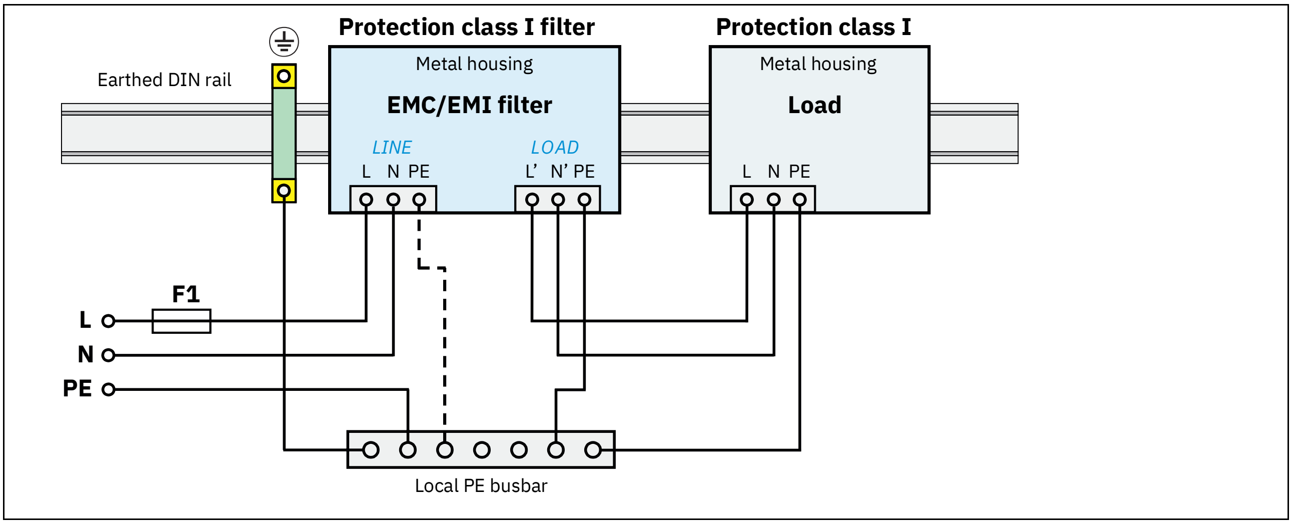
Recommended for protection class I control cabinets: Use the electrically conductive components of a control cabinet as additional connections to the local PE busbar.

Install an earthed, conductive metal 35 mm DIN rail on a surface with excellent electrical conductivity. The surface must be free of lacquer and paint. Suitable surfaces include those made from unlacquered sheet iron, for example. Use sheet iron where the surface has been electroplated to protect against corrosion.

Surfaces made from aluminum usually have an insulating effect due to transparent, non-conductive aluminum oxide present on the surface. Do not install the DIN rail on surfaces made from aluminum.

A 1.1 Protection class I filter/protection class I load

Figure A-1 TN system/protection class I control cabinet/protection class I filter/protection class I load

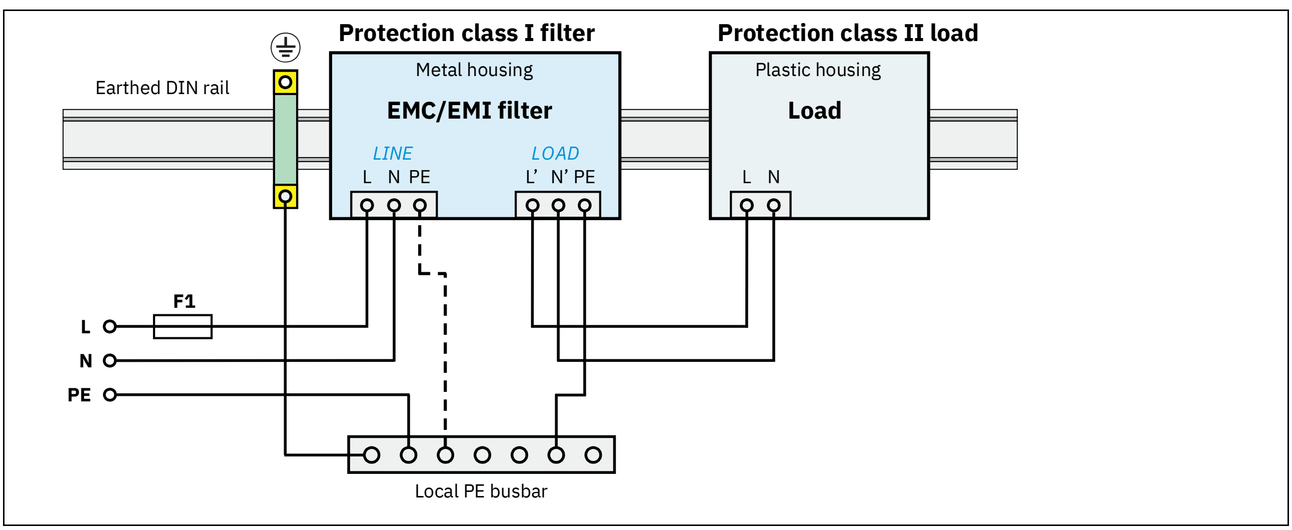


F1 = Fuse or suitable MCB

- - - - - - = Optional for EMC-optimized installation, additional connection to PE

A 1.2 Protection class I filter/protection class II load

Figure A-2 TN system/protection class I control cabinet/protection class I filter/protection class II load

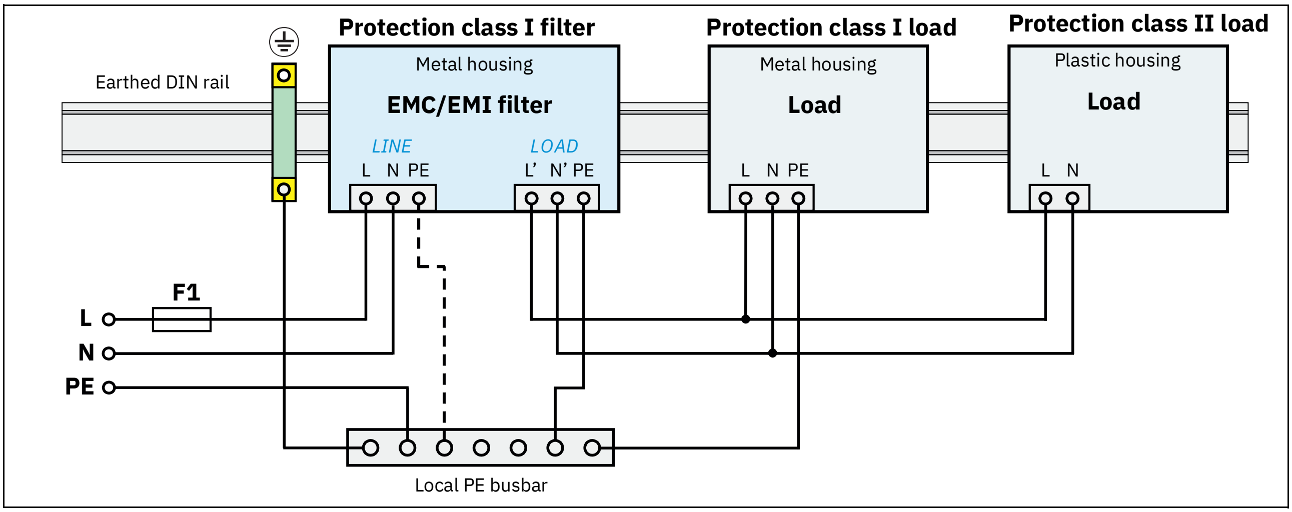


F1 = Fuse or suitable MCB

- - - - - - = Optional for EMC-optimized installation, additional connection to PE

A 1.3 Protection class I filter/protection class I and protection class II load

Figure A-3 TN system/protection class I control cabinet/protection class I filter/protection class I and protection class II load

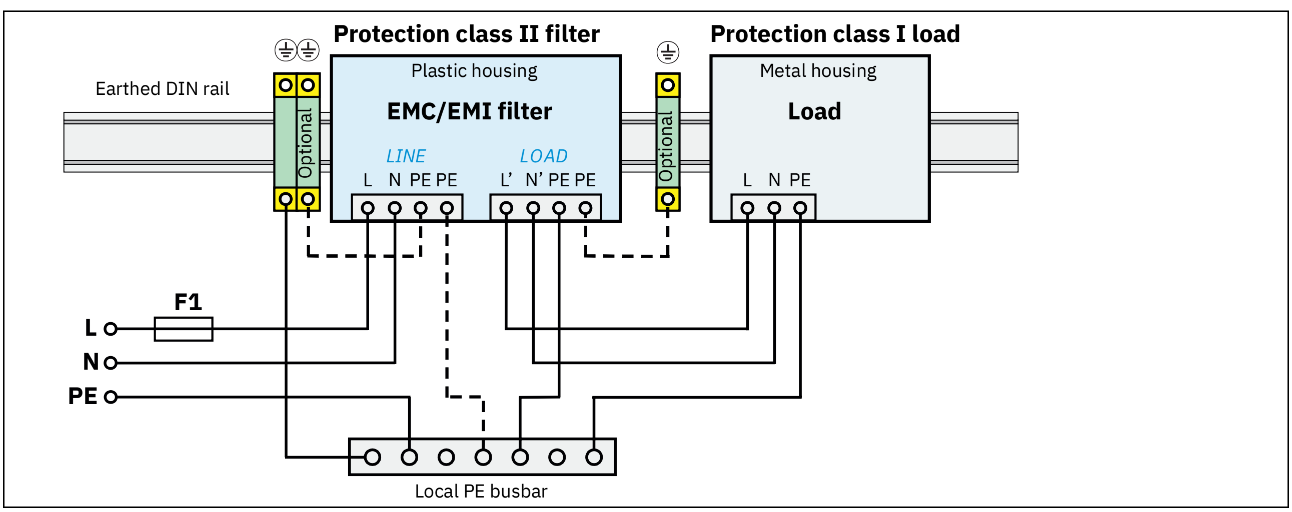


F1 = Fuse or suitable MCB

- - - - - - = Optional for EMC-optimized installation, additional connection to PE

A 1.4 Protection class II filter/protection class I load

Figure A-4 TN system/protection class I control cabinet/protection class II filter/protection class I load

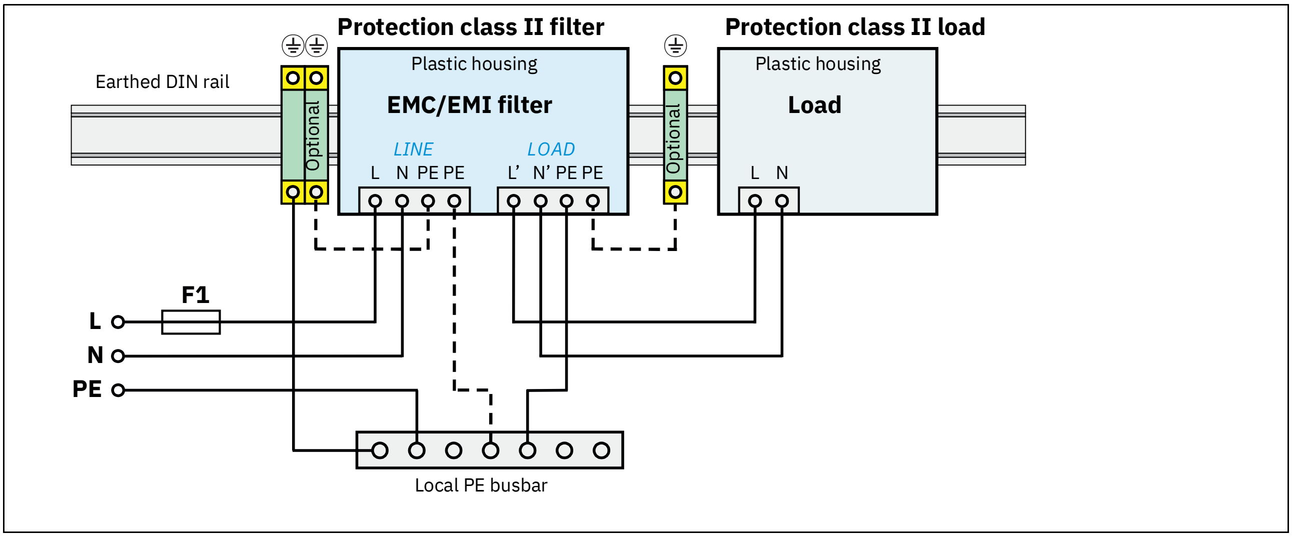


F1 = Fuse or suitable MCB

- - - - - - = Optional for EMC-optimized installation, additional connection to PE

A 1.5 Protection class II filter/protection class II load

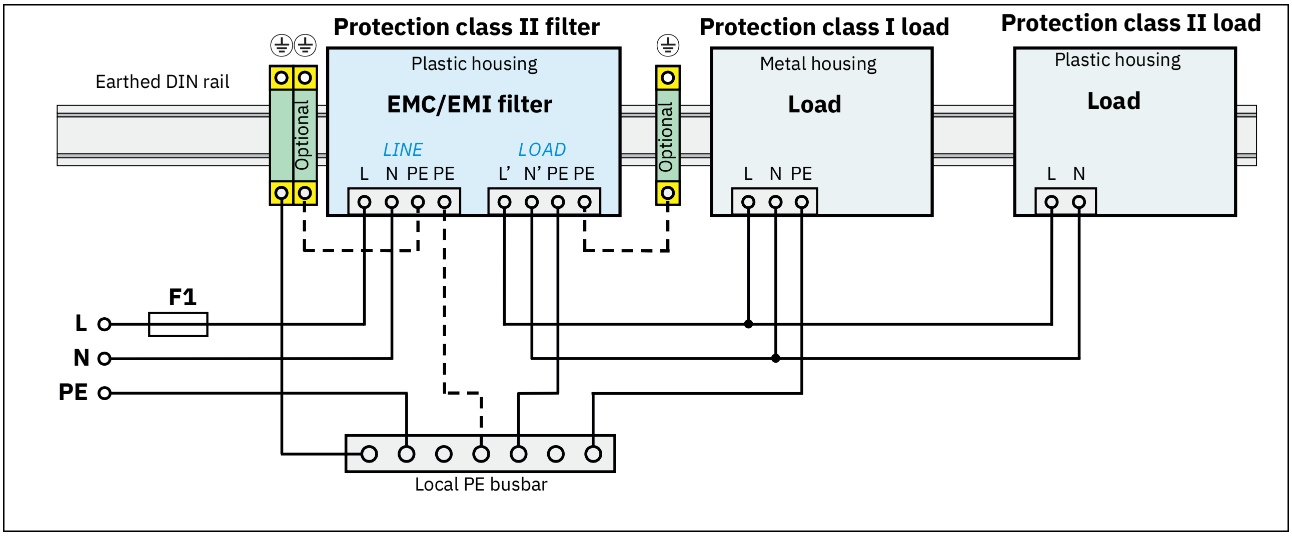
Figure A-5 TN system/protection class I control cabinet/protection class II filter/protection class II load



F1	=	Fuse or suitable MCB
- - - - - -	=	Optional for EMC-optimized installation, additional connection to PE

A 1.6 Protection class II filter/protection class I and protection class II load

Figure A-6 TN system/protection class I control cabinet/protection class II filter/protection class I and protection class II load

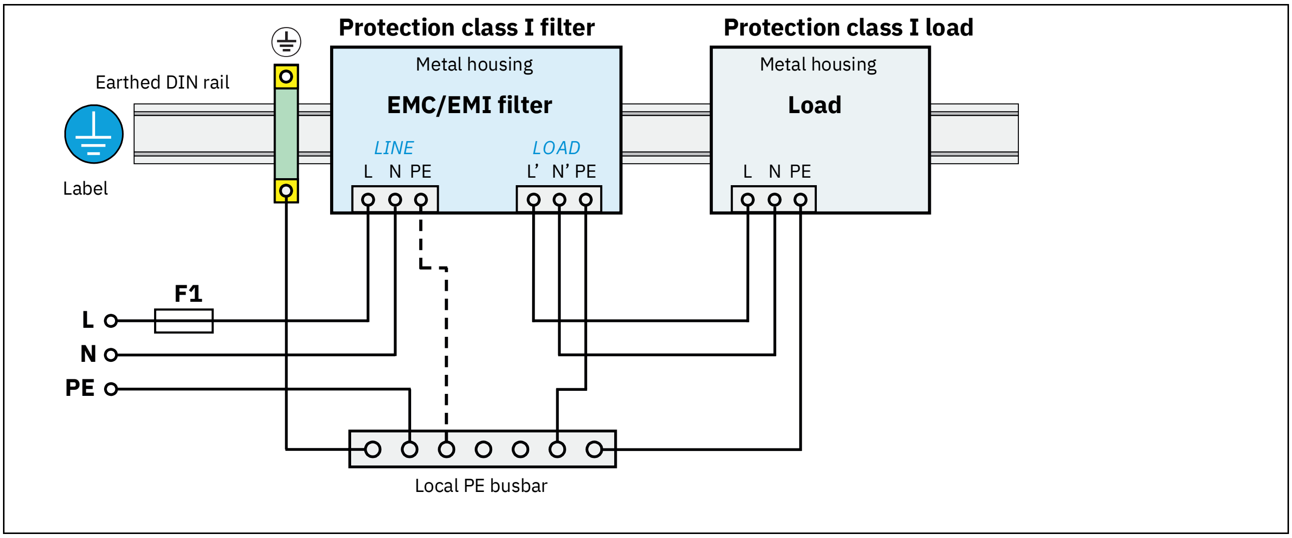


F1	=	Fuse or suitable MCB
- - - - - -	=	Optional for EMC-optimized installation, additional connection to PE

A 2 TN system/protection class II control cabinet

A 2.1 Protection class I filter/protection class I load

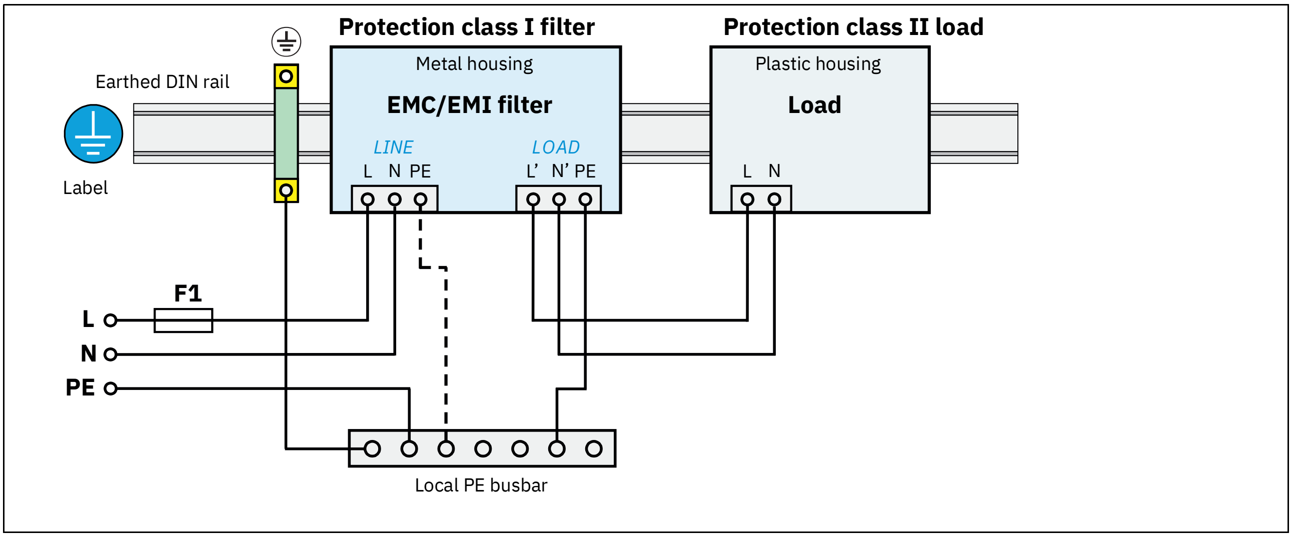
Figure A-7 TN system/protection class II control cabinet/protection class I filter/protection class I load



F1	=	Fuse or suitable MCB
- - - - - -	=	Optional for EMC-optimized installation, additional connection to PE
Important note		Protection class I equipment must be installed in low-voltage switchgear and controlgear assemblies that are equipped with a local PE busbar

A 2.2 Protection class I filter/protection class II load

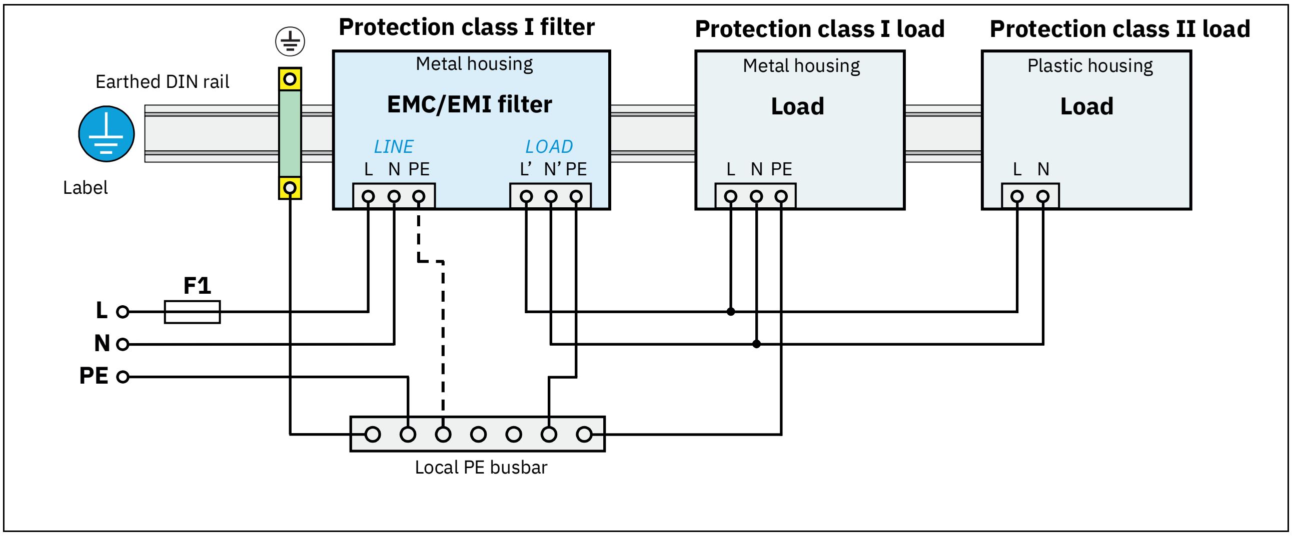
Figure A-8 TN system/protection class II control cabinet/protection class I filter/protection class II load



F1	=	Fuse or suitable MCB
- - - - - -	=	Optional for EMC-optimized installation, additional connection to PE
Important note		Protection class I equipment must be installed in low-voltage switchgear and controlgear assemblies that are equipped with a local PE busbar

A 2.3 Protection class I filter/protection class I and protection class II load

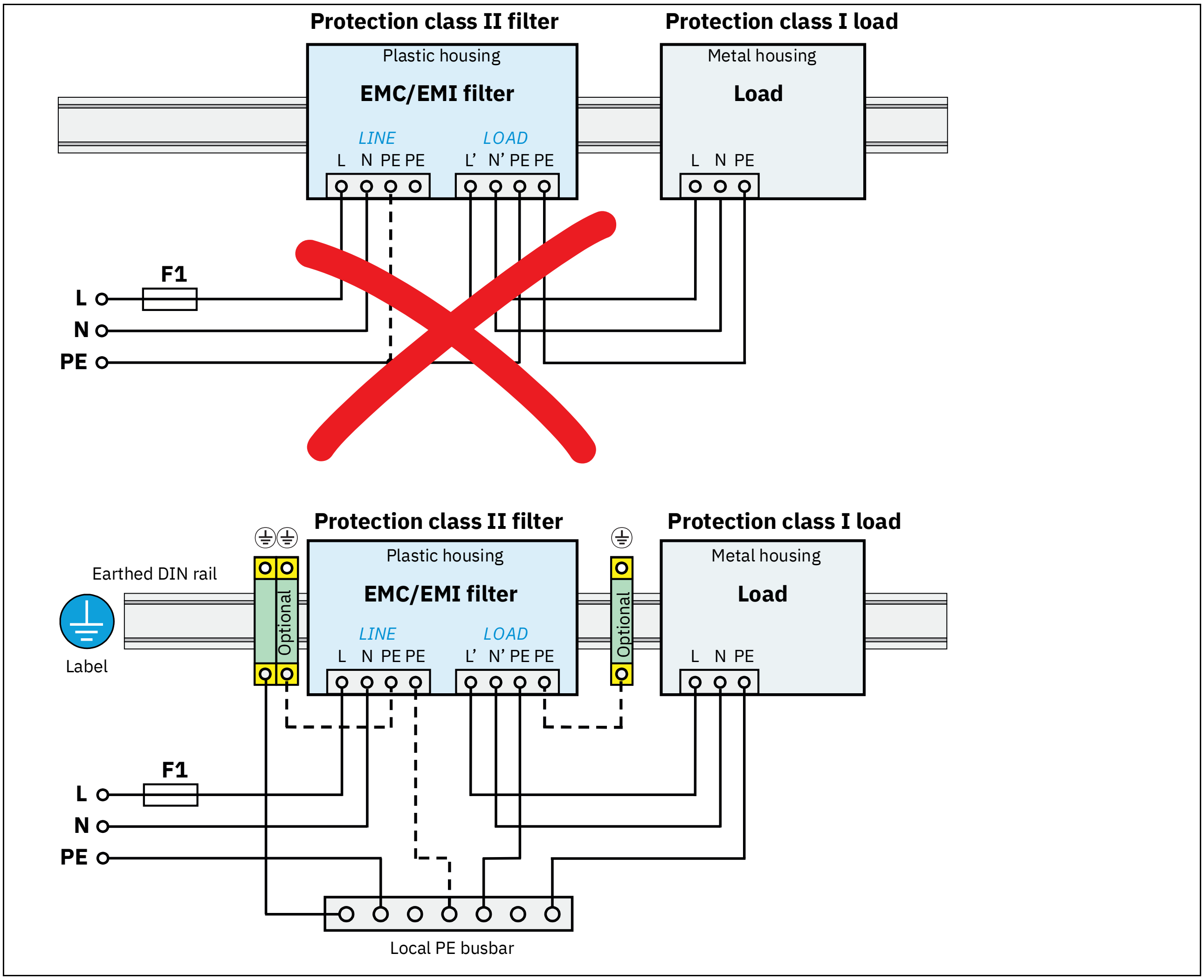
Figure A-9 TN system/protection class II control cabinet/protection class I filter/protection class I and protection class II load



F1	=	Fuse or suitable MCB
- - - - - -	=	Optional for EMC-optimized installation, additional connection to PE
Important note		Protection class I equipment must be installed in low-voltage switchgear and controlgear assemblies that are equipped with a local PE busbar

A 2.4 Protection class II filter/protection class I load

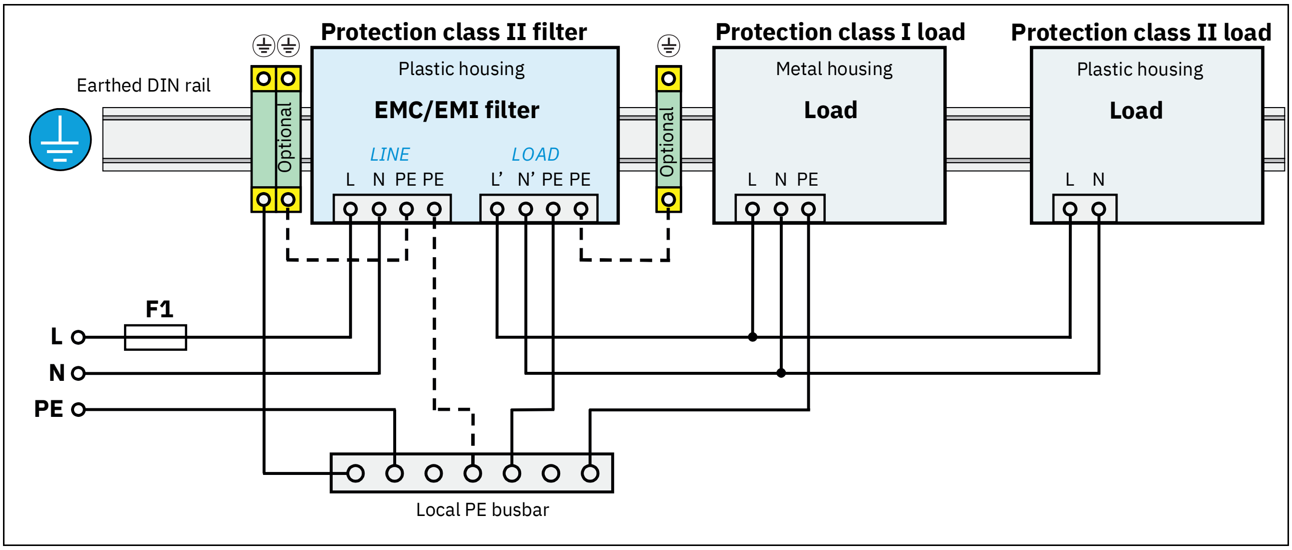
Figure A-10 TN system/protection class II control cabinet/protection class II filter/protection class I load



F1	=	Fuse or suitable MCB
- - - - - -	=	Optional for EMC-optimized installation, additional connection to PE
Important note		Protection class I equipment must be installed in low-voltage switchgear and controlgear assemblies that are equipped with a local PE busbar

A 2.5 Protection class II filter/protection class I and protection class II load

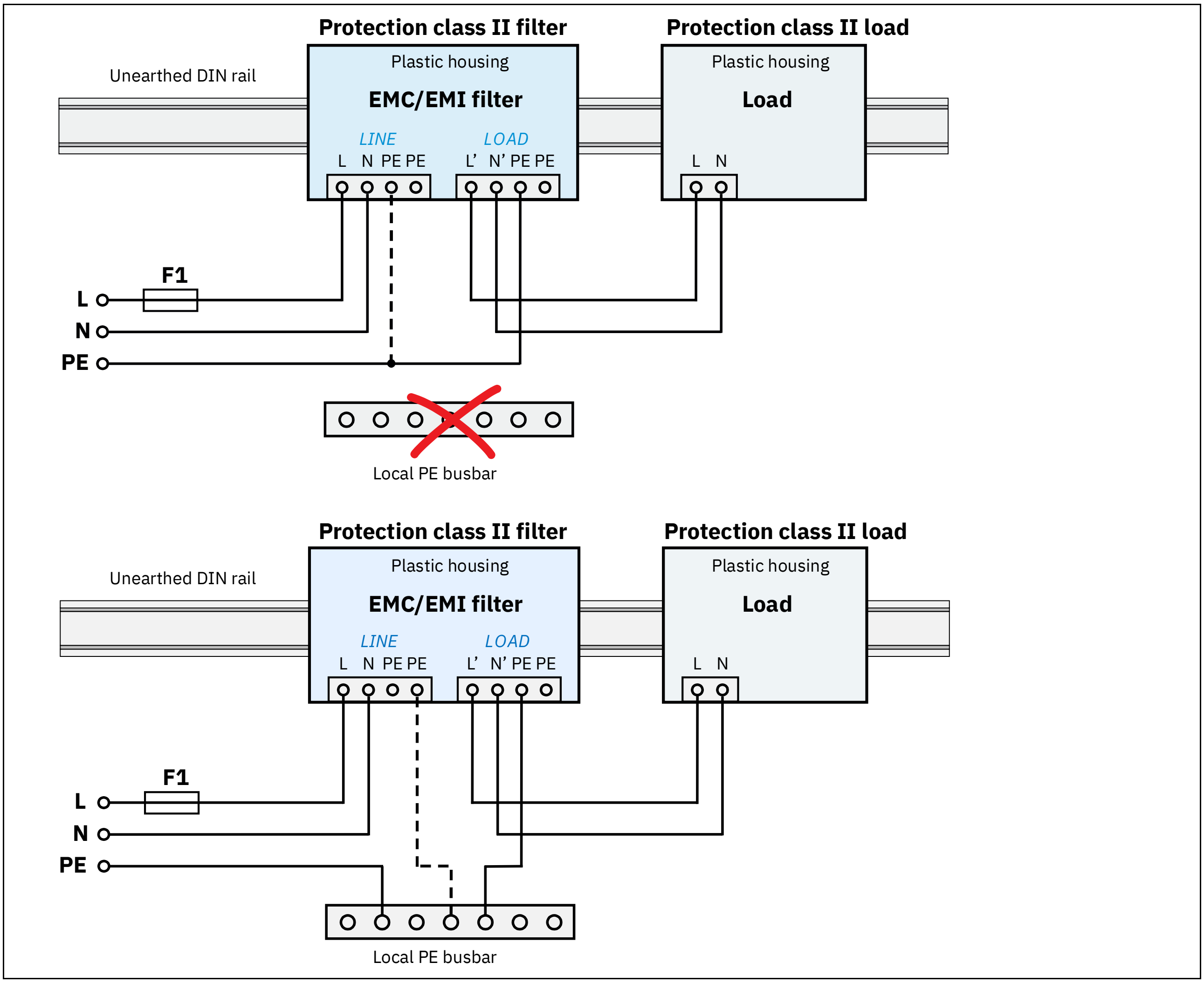
Figure A-11 TN system/protection class II control cabinet/protection class II filter/protection class I and protection class II load



F1	=	Fuse or suitable MCB
- - - - - -	=	Optional for EMC-optimized installation, additional connection to PE
Important note		Protection class I equipment must be installed in low-voltage switchgear and controlgear assemblies that are equipped with a local PE busbar

A 2.6 Protection class II filter/protection class II load

Figure A-12 TN system/protection class II control cabinet/protection class II filter/protection class II load

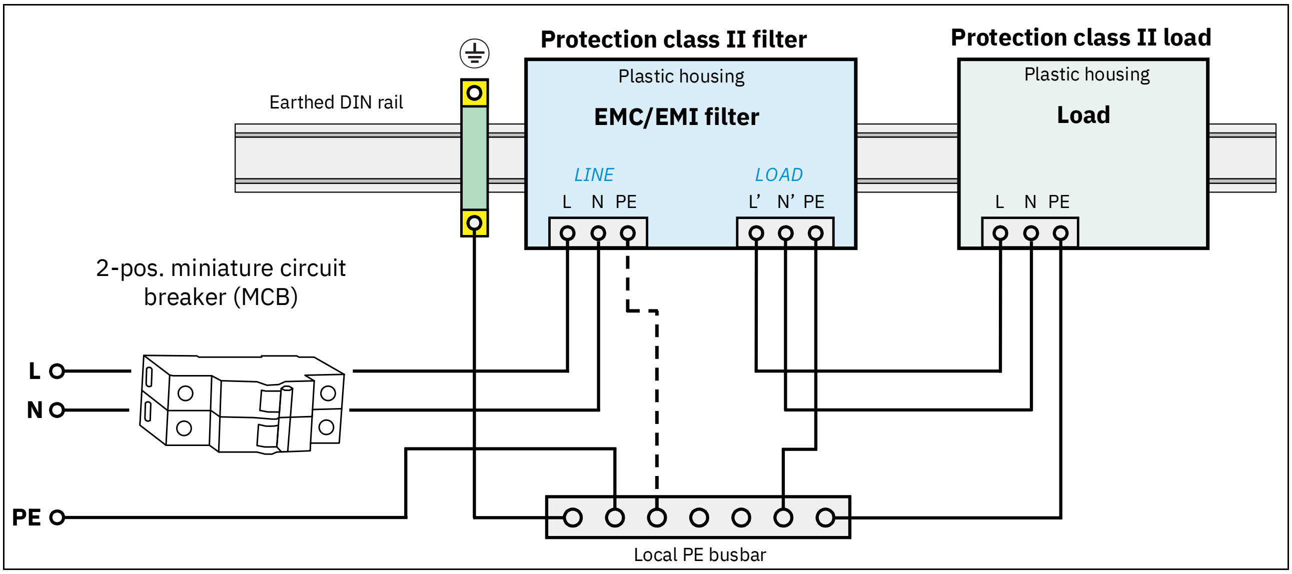


F1 = Fuse or suitable MCB

- - - - - - = Optional for EMC-optimized installation, additional connection to PE

A 3 IT system/protection class I control cabinet

Figure A-13 IT system/protection class I control cabinet/protection class II filter/protection class I load



F1	=	Fuse or suitable MCB
- - - - - -	=	Optional for EMC-optimized installation, additional connection to PE
Important note		Only use 2-pos. miniature circuit breakers in IT systems

B Appendix for document lists

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Section 6

Appendix A

Appendix B

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Published by

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