Electrical installation guide

According to IEC
international standards

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Chapter Q

Residential premises and other special locations

1 Residential and similar premises

Electrical installations for residential premises need a high standard of safety and reliability

The international standard reference for electrical installation in buildings is the IEC 60364 series "Low-voltage electrical installations", and its European equivalent, the HD 60364. But these standards are general, applicable to all types of premises, and do not provide simplified and ready-to-use rules for residential premises.

Some of the standards from part 7 of the IEC 60364 address residential premises, such as the IEC 60364-7-701 "Requirements for special installations or locations – Locations containing a bath or shower", which provides mandatory additional safety measures for bathrooms (see section 2).

In practice, most countries have national regulations or standards governing the rules to be strictly observed in the design and realization of electrical installations for residential and similar premises. But these national standards are not harmonized internationally, and may range from very basic requirements to advanced requirements for safety and comfort.

Some of these national regulations and standards also include elements which are not covered or required by the IEC 60364 series:

- additional requirements for safety, like protection against fire risks with smoke detectors, or with the mandatory installation of AFDD (Arc Fault Detection Devices) in bedrooms ...
- requirements for (minimum) comfort, like minimum equipment per type of rooms (socket outlets ...)

Finally, additional requirements are needed to cover new "usages", like Electric Vehicle charging, photovoltaic installations ...

Therefore, the content of this section is an overview of the main requirements or recommendations for residential premises, from an international point of view, based on some advanced local standards from countries like France, Italy, Germany, Spain ...

Always refer to your local regulations and standards for the mandatory requirements applicable for residential or similar premises.

1.1 The power network

The power distribution utility connects the LV neutral point of its MV/LV distribution transformer to earth.
All LV installations must be protected by RCDs. All exposed conductive parts must be bonded together and connected to the earth.

The vast majority of power distribution utilities connect the low voltage neutral point of their MV/LV distribution transformers to earth.

The protection of persons against electric shock therefore depends, in such case, on the principle discussed in chapter F. The measures required depend on whether the TT, TN or IT earthing system is adopted.

For **fault protection**, RCDs are essential for TT and IT earthed installations (see chapter F). For TN installations, high speed overcurrent devices (circuit breakers) or RCDs may provide **fault protection** of the electrical circuits. **Nevertheless**, to extend the protection to flexible leads beyond the fixed socket outlets and to ensure protection against fires of electrical origin **high sensitivity** RCDs shall be installed. AFDDs (Arc Fault Detection Devices) are also recommended (mandatory in some countries) to extend even more the protection against fire risks (see chapter F §9.3).

1.2 Distribution boards components

(see **Fig. Q1, Fig. Q2, Fig. Q3**)

Electrical equipment used in residential premises are commonly certified by third party ensuring conformity with the relevant standards. In this case, equipment shows the certification Mark of the certification body such as VDE, NF, AENOR, IMQ or others. Mark of conformity is a voluntary manufacturer process and implies periodic verifications of the Quality of the products by the third party laboratory. In EU zone CE marking is a mandatory self-declaration for free trade done by the manufacturer/importer.

Distribution boards (generally only one in residential premises) usually include the meter(s) and in some cases (notably where the supply utilities impose a TT earthing system and/or tariff conditions which limit the maximum permitted current consumption) an incoming supply differential circuit-breaker which includes an overcurrent trip. This circuit-breaker is freely accessible to the consumer.

1 Residential and similar premises

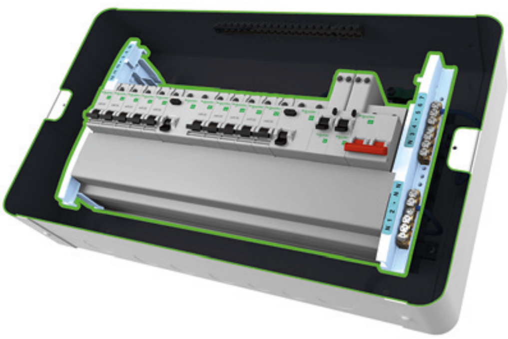

Fig. Q1 Example of typical UK residential distribution board

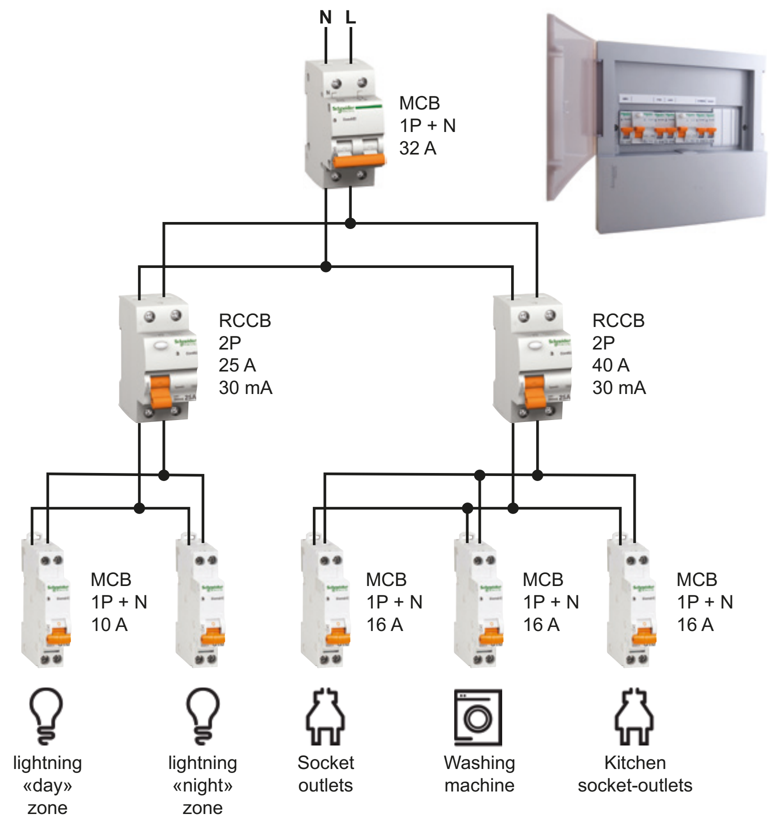

Fig. Q2 Example of Italian residential installation (> 125 m², basic level)

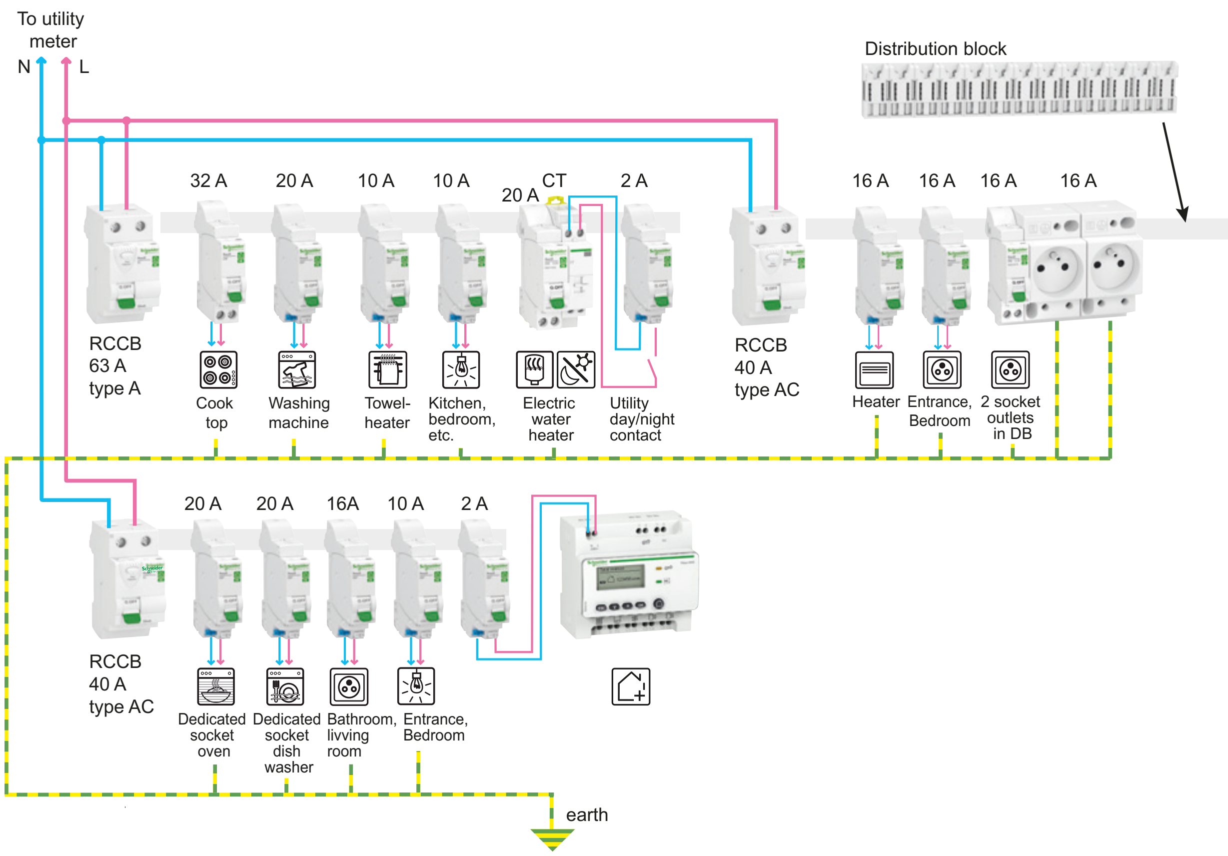

Fig. Q3 Example of French residential installation (3 rooms with electric heater)

1 Residential and similar premises

On installations which are in a TN earthing system, the supply utilities usually protect the installation simply by means of sealed fuse cut-outs immediately upstream of the meter(s) (see **Fig. Q4**). The user has no access to these fuses.

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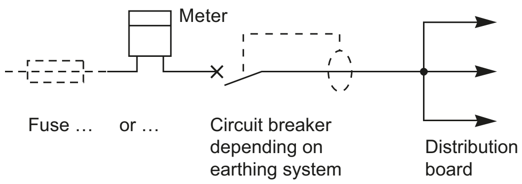

Fig. Q4 Components of a control and distribution board

The incoming supply circuit breaker or main switch (see **Fig. Q5**)

The consumer is allowed to operate this circuit breaker or switch if necessary (e.g. to reclose it if the circuit breaker has tripped due to current consumption exceeded the authorized limit, to open it in case of emergency, or for isolation purposes in case of maintenance in the distribution board).

For TT systems, the rated residual current of the incoming circuit-breaker shall be adapted to the maximum earth impedance:

- For example, if the earth impedance is not more than 100 Ohms, the rated residual current of the main RCBO shall not exceed 500 mA: Idn = 50 V / 100 Ohms = 500 mA
- In some countries, the rated residual current of the incoming circuit-breaker is 300mA. In this case, the earth electrode resistance shall be less than R = 50 V / 300 mA = 166 Ohms
- In practice, the earth electrode resistance of a new installation shall be less than 80 Ω (R/2).

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[a] France (CB)

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[b] UK (switch-disconnector)

Fig. Q5 Examples of incoming-supply circuit breakers or switch from different countries

The control and distribution board (consumer unit) (see **Fig. Q6**)

This board comprises:

- A control panel for mounting (where appropriate) the incoming supply circuit breaker and other control auxiliaries, as required
- A distribution panel for housing the MCBs or fuse units, etc.
- Installation accessories like DIN rails for mounting MCBs, fuses bases, connection accessories like comb busbars to simplify interconnection of devices, accessories for fixing conductors, neutral busbar and earthing bar, and so on
- Service cable ducts or conduits, surface mounted or in cable chases embedded in the wall

Note: to facilitate future modifications to the installation, it is recommended to keep all relevant documents (photos, diagrams, characteristics, etc.) in a suitable location close to the distribution board.

The board should be installed at a height such that the operating handles, indicating dials (of meters) etc., are accessible to users. Heights commonly recommended are between 1 metre (or less in some countries) and 1.80 metres from the floor (1.30 metres in situations where handicapped or elderly people are concerned).

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Fig. Q6 Example of control and distribution board (France)

Surge protective devices

The installation of surge protective devices (SPD) at the service position of a LV installation is strongly recommended for installations which include sensitive (e.g electronic) equipment, which is very common nowadays.

These devices must automatically disconnect themselves from the installation in case of failure or be protected by a MCB. See §1.5.

If, in a TT scheme, the value of 80 Ω for the resistance of the electrode cannot be met, then 30 mA RCDs must be installed to take over the function of the earth leakage protection of the incoming supply circuit breaker

Resistance value of the earth electrode

In the case where the resistance to earth exceeds 80 Ω, one or several 30 mA RCDs should be used in place of the earth leakage protection of the incoming supply circuit breaker.

Where utility power supply systems and consumers' installations form a TT system, the governing standards impose the use of RCDs to ensure the protection of people

1.3 Protection of people

On **TT systems**, the protection of persons is ensured by the following measures:

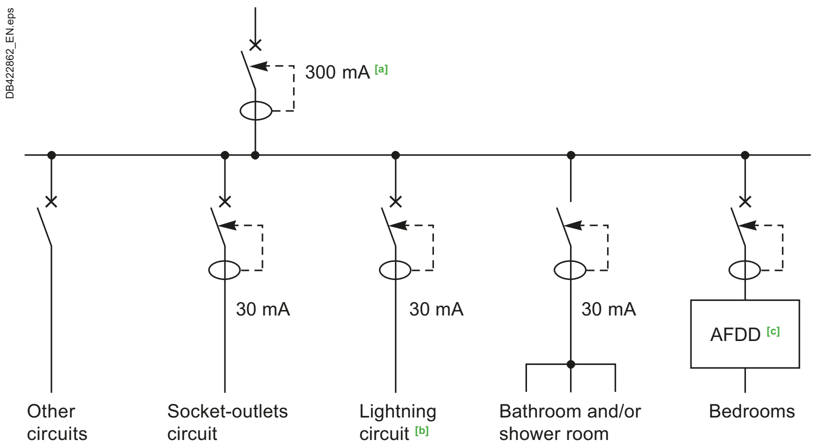
- Protection against indirect contact hazards by RCDs (see Fig. Q7) of medium sensitivity (300 mA) at the origin of the installation (incorporated in the incoming supply circuit breaker or, on the incoming feed to the distribution board).
This measure is associated with a consumer installed earth electrode to which must be connected the protective earth conductor (PE) from the exposed conductive parts of all class I insulated appliances and equipment, as well as those from the earthing contact of all socket outlets
- When the CB at the origin of an installation has no RCD protection, the protection of persons shall be ensured by double or reinforced insulation on all circuits upstream of the first RCDs. In the case where the distribution board is metallic, care shall be taken that all live parts are double insulated (supplementary clearances or insulation, use of covers, etc.) and wiring reliably fixed

In **TN systems**, fault protection is ensured by the following measures:

- Fault Protection is ensured by circuit breaker at the origin of the installation.
- This measure is associated with a consumer installed earth electrode to which must be connected the protective earth conductor (PE) from the exposed conductive parts of all class I insulated appliances and equipment.

For **all earthing systems**:

- mandatory protection by 30 mA high sensitivity RCDs of socket outlet circuits, and circuits feeding bathroom. And recently, the IEC 60364 also requires the use of 30 mA RCD for lighting circuits



[a] RCD required for Fault Protection in TT systems. In TN system a circuit-breaker is used.
[b] Recent evolution of IEC 60364 = 30mA RCDs mandatory for lighting circuits
[c] see chapter F §9.3 related to Arc Fault Detection Devices

Fig. Q7 Requirements of IEC 60364 for protection of people

Incoming supply circuit breaker with instantaneous differential relay

In this case:

■ An insulation fault to earth could result in a shutdown of the entire installation

■ Where a surge protective device is installed, its operation (i.e. discharging a voltage surge to earth) could appear to an RCD as an earth fault, with a consequent shutdown of the installation

Recommendation of suitable Schneider Electric components

■ Incoming supply circuit breaker with 300 mA differential and

■ High sensitivity 30 mA RCD (for example differential circuit breaker 1P+N type resi9) on the circuits supplying socket outlets

■ High sensitivity 30 mA RCD (for example differential load switch type ID'clic) on circuits to bathrooms, shower rooms, laundry rooms, etc. (lighting, heating, socket outlets)

Incoming supply circuit breaker with type S time delayed differential relay

This type of CB affords protection against fault to earth, but by virtue of a short time delay, provides a measure of selectivity with downstream instantaneous RCDs. Tripping of the incoming supply CB and its consequences (on deep freezers, for example) is thereby made less probable in the event of lightning, or other causes of voltage surges. The discharge of voltage surge current to earth, through the surge arrester, will leave the type S circuit breaker unaffected.

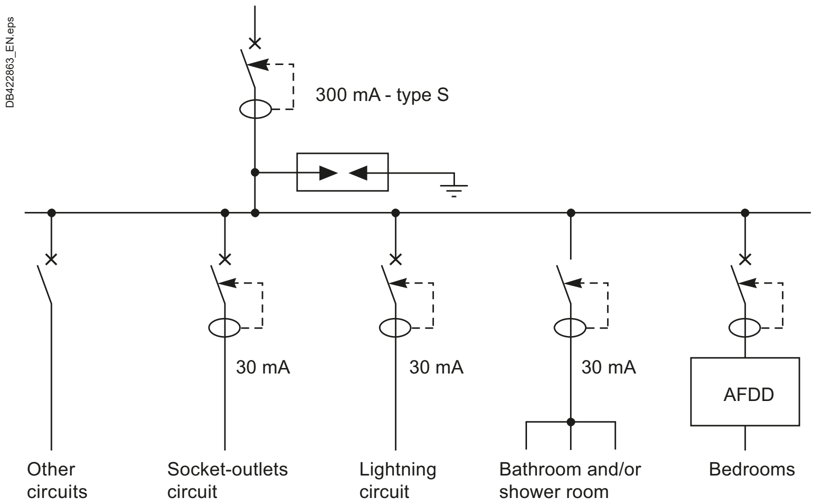


Fig. Q8 Installation with incoming-supply circuit breaker having short time delay differential protection, type S

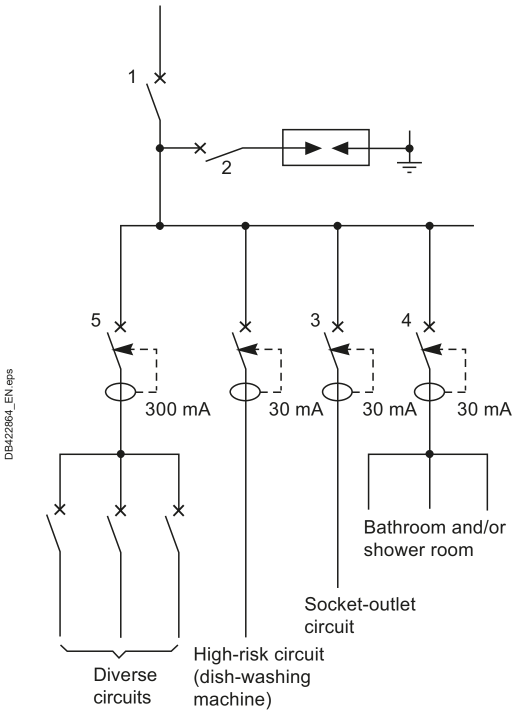


Fig. Q9 Installation with incoming-supply circuit breaker having no differential protection

Incoming supply circuit breaker without differential protection

In this case the protection of persons must be ensured by:

- Class II level of insulation up to the downstream terminals of the RCDs
- All outgoing circuits from the distribution board must be protected by 30 mA or 300 mA RCDs according to the type of circuit concerned as discussed in chapter F.

Where a voltage surge arrester is installed upstream of the distribution board (to protect sensitive electronic equipment such as computers, TV sets, internet access boxes etc.) it is imperative that the device automatically disconnects itself from the installation following a rare (but always possible) failure. Some devices employ replaceable fusing elements; the recommended method however as shown in **Fig. Q9**, is to use a circuit breaker.

Recommendation of suitable Schneider Electric components

Fig. Q9 refers:

1. Incoming-supply circuit breaker without differential protection
2. Automatic disconnection device (if a lightning arrester is installed)
3. 30 mA RCD (for example differential circuit breaker 1P + N type Declic Vigi) on each circuit supplying one or more socket-outlets
4. 30 mA RCD (for example differential load swith type ID'clic) on circuits to bathrooms and shower rooms (lighting, heating and socket-outlets) or a 30 mA differential circuit breaker per circuit
5. 300 mA RCD (for example differential load switch on all the other circuits.

1.4 Circuits

The proper separation of circuits provides service continuity and eases rapid location of fault

Subdivision

National standards commonly recommend the subdivision of circuits according to the number of utilization categories in the installation concerned (see Fig. Q10):

■ At least one lighting circuit, each circuit supplying several rooms for a maximum surface of 50 m²,

■ At least one socket-outlets circuit rated 16 A (rating according to National socket-outlet system), each circuit supplying a reasonable number of socket-outlets in series, taking into account the wiring cross-section area used (1.5 mm² or 2.5 mm²), the wiring lengths (voltage drops) and the temperature rise effects on each connection, according to the foreseeable applications used.

■ One dedicated circuit for each "high load" appliance such as washing machine, dish-washer, cooker etc. Water heater and fixed heater units shall be connected by terminals (not socket-outlet neither connector).

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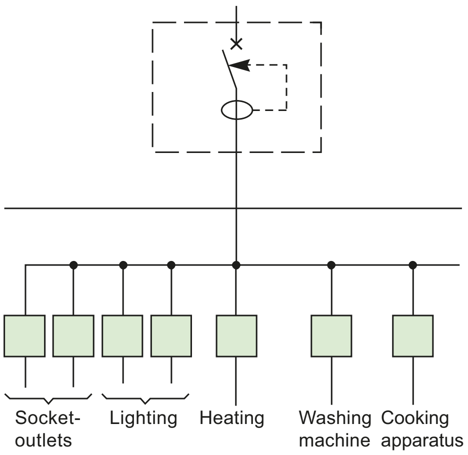


Fig. Q10 Circuit division according to application

Recommended number of socket-outlets and fixed lighting points

An example of recommended number of socket-outlets and fixed lighting points, according to the applications and the locations in dwellings, are given in Fig. Q11

Room type	Minimum number of fixed lighting points	Minimum number of socket-outlets
Living room	1	5
Bedroom, lounge, living and dining room	1	3
Kitchen	2	4 [a]
Bathroom	2	1
Entrance, hall, stairs	1	1
Cellar, storage space	1	1
Laundry room	1	2

[a] Above bench, in addition to those for specialized circuits.

Fig. Q11 Recommended minimum number of lighting and power points in residential premises

Protective conductors

Implementation of a protective conductor (PE) for all circuits is required by IEC and most of national installation rules

IEC 60364 and most national standards require implementation of protective conductor for each circuit. This practice is mandatory where equipment provided for earthing (Class I) may be connected or installed, and shall be seen as the general case for all circuits including circuits supplying socket outlets.
The protective conductors must connect the earthing contact in each socket-outlet to the main earthing terminal at the origin of the installation.
Furthermore, in some countries, 16 A (13 A in UK) household socket-outlets must be provided with shutters, at least in rooms where children are often present, and in places where water is present.

Cross-section area of conductors

The cross-section area of conductors and the rated current of the associated protective device depend on the load(s) connected to the circuit, the ambient temperature, the material of construction where the cables are located, the type of installation, and the influence of neighboring circuits (refer to chapter G).
Moreover, the conductors for the phase, the neutral and the protective conductors of a given circuit must have the same cross section area up to 32 A circuits.

1.5 Protection against overvoltages and lightning

The choice of Surge Protective Devices as well as their installation rules are described in chapter J.
The three following main rules must be respected in particular:

1. It is imperative that the three lengths of cable used for the installation of the surge arrester each be less than 50 cm i.e.:

■ the live conductors connected to the isolating switch

■ from the isolating switch to the surge protective device

■ from the surge protective device to the main distribution board (MDB) earth bar (not to be confused with the main protective-earth (PE) conductor or the main earth terminal for the installation). The MDB earth bar must obviously be located in the same cabinet as the surge protective device.

2. It is necessary to use an isolating switch of a type recommended by the manufacturer of the surge protective device.

3. In the interest of a good continuity of supply it is recommended that the circuit breaker be of the time-delayed or selective type.

1.6 Periodic control of residential electrical installations

IEC installation standard recommends a frequency for periodic verification of dwelling of 10 years. IEC 60364-6: 2016 § 6.5.2

IEC 60364 recommends periodic verification of electrical installations

Electrical risks in new residential buildings are covered by installation and product standards. However, for existing buildings the safety levels in older buildings are often far below current standards.

IEC 60364-6 recommends periodic verification of electrical installations in dwellings. For example, mandatory safety audits are an efficient means to verify if the electrical installation is in safe conditions, and to inform the owner of the safety level of its home.

Why periodic verifications are necessary in dwellings

Existing electrical installations may be dangerous because of:

- Installations complying to standards dating back to the year of construction, and the technical requirements of standards changing over the ensuing years
- Aging of the electrical installation itself, including loose connections, aged insulation material, broken parts such as shutters in socket outlets for example, or flying terminal block for luminaires
- Change of usage of electricity due to changes in the numbers of inhabitants, and the electrical installation was modified by the persons living in the dwelling, and usually not by a qualified electrician

Typical types of dangerous situations may be such as:

- Absence of protective earthing conductor (PE) in dwelling
- Absence of protection against electric shocks at the origin of the installation
- Overcurrent protective devices not adapted to the cross-section of the conductors
- Absence of high-sensitivity residual current device (RCD, 30 mA) in bathrooms and for circuits supplying socket outlet up to 32 A and in dwelling circuits for lighting
- Damaged socket outlets or socket outlet without PE conductor
- Incorrect use of extension cords leading to overloaded socket outlets
- Damaged and outdated electrical equipment

What are the minimum points to check?

Item	Safety check	Rationale	Examples
1	Presence of a main incoming switching device	To disconnect the whole installation in case of emergency	Disconnecting switch, circuit breaker, residual current device with overcurrent protection
2	Presence of overcurrent protective devices adapted to cross-section of conductors in a switchboard	To ensure overload and short-circuit protection	Circuit breakers or fuses
3	Presence of protective earthing conductor and protective device for automatic disconnection of supply in accordance with earth impedance	To ensure protection against electric shocks in case of a fault	Yellow-green PE conductor, circuit breaker (TN-system), medium-sensitivity residual current device (TT system)
4	Presence of high sensitivity residual current devices for socket outlet circuits and outdoor equipment	To ensure additional protection against electric shocks	High sensitivity residual current device (e.g. 30 mA RCD)
5	Specific protective measures for locations containing bath or shower: PE, high sensitivity RCD, volume rules	Specific measures for protection against electric shocks in humid locations	Yellow-green conductor, 30 mA residual current device
6	No risk of direct contact due to old, damaged, overheated electric accessories or conductors	Old electric accessories (switches, socket outlets, terminal blocks) or conductors not mechanically protected create risks of electric shocks	Visual inspection of socket outlets, switches, conductors, switchboard

Fig. Q12 Example of recommend points to check during periodic verification of electrical installations in dwellings

1.7 Requirements and recommendations per type of room - Kitchen

Safe connection of Luminaires

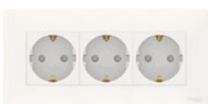
Fixed luminaires shall preferably be connected by plug and socket (DCL: Device for the connection of luminaires) to the fixed installation. DCL outlet will be connected to the fixed wiring, while the luminaire has the plug. This will make the luminaire easy to replace in a safe way.

Dedicated circuits

Cooking tops, stoves, and microwave ovens can be high loads. In most cases the connection used for high consuming devices are dedicated plug and socket-outlets, or fixed connected by terminals, according to the national standards or regulations.

Number of Socket outlets

Socket-outlets for kitchen appliances must be located spread in the kitchen where the appliances are used, e.g. coffee machine, toaster, kettle (water boiler) etc. As this is a practical need for all users, some countries have national requirements for quantities and locations.



Charging station

There are USB chargers available for the fixed installations. The benefit will be to have one charger in a dedicated location for all your devices, e.g. phone, tablet, etc.

The kitchen could be a convenient location for a USB charger in your installation.

Fig. Q13 Example of recommendation - typical circuits and wiring devices to install in a kitchen (refer to your local standards for actual mandatory requirements)

1.8 Requirements and recommendations per type of room – Living room

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Working corner

In a modern home, a location to work is in many situations a part of the living room. Typical devices to be powered are screen(s), computer, router, printer, etc.

This must be considered and prepared by additional fixed socket outlets, avoiding the use of cord extension sets ang giving priority to permanent connection.

Dimmers

To get an atmosphere for different occasions dimming of light is an important factor.

The recommendation is to install dimmers split into zones where light shall be controlled independently.

Movement / presence detector

For light controls it can be very convenient to use movement or presence detectors.

In particular in halls or staircases.

Audio Video corner

Socket outlets must be spread out on the principles that a living room can be furnished in many ways and even refurnished.

One fixed location is anyway the Audio Video corner where there are need for several devices, e.g. TV set, decoder, recorder etc. This must be considered and prepared by additional fixed socket outlets, avoiding the use of cord extension sets and give priority to permanent connection.

Energy efficiency

In a home, the living room is often the biggest room, and potentially the important room when considering energy efficiency.

Electronic thermostats control the temperature, impacting the energy consumption day/night and summer/winter.
Installation must be planned according to the specific need

Fig. Q14 Example of recommendation - typical circuits and wiring devices to install in a linving room (refer to your local standards for actual mandatory requirements)

2 Bathrooms and showers

Bathrooms and shower rooms are areas of high risk, because of the very low resistance of the human body when wet or immersed in water.

Precaution to be taken are therefore correspondingly rigorous, and the regulations are more severe than those for most other locations.

The relevant international standard is IEC 60364-7-701, applicable to the electrical installations in locations containing a fixed bath (bath tub) or shower and to the surrounding zones. Refer to country specific standards (or deviations from the IEC requirements) whenever they exist.

Precautions to observe are based on three aspects:

- The definition of zones, numbered 0, 1 and 2 in which the placement (or exclusion) of any electrical device is strictly limited or forbidden and, where permitted, the electrical and mechanical protection is prescribed
- The strict adherence to the requirements prescribed for each zone, as tabled in §2.3.
- The establishment of an equipotential bond between all exposed and extraneous metal parts in the zones concerned.

2.1 Classification of zones

Sub-clause 701.30 of IEC 60364-7-701 defines the zones 0, 1 and 2, illustrated by the following figures for most common examples. Refer to the standard for a more complete view.

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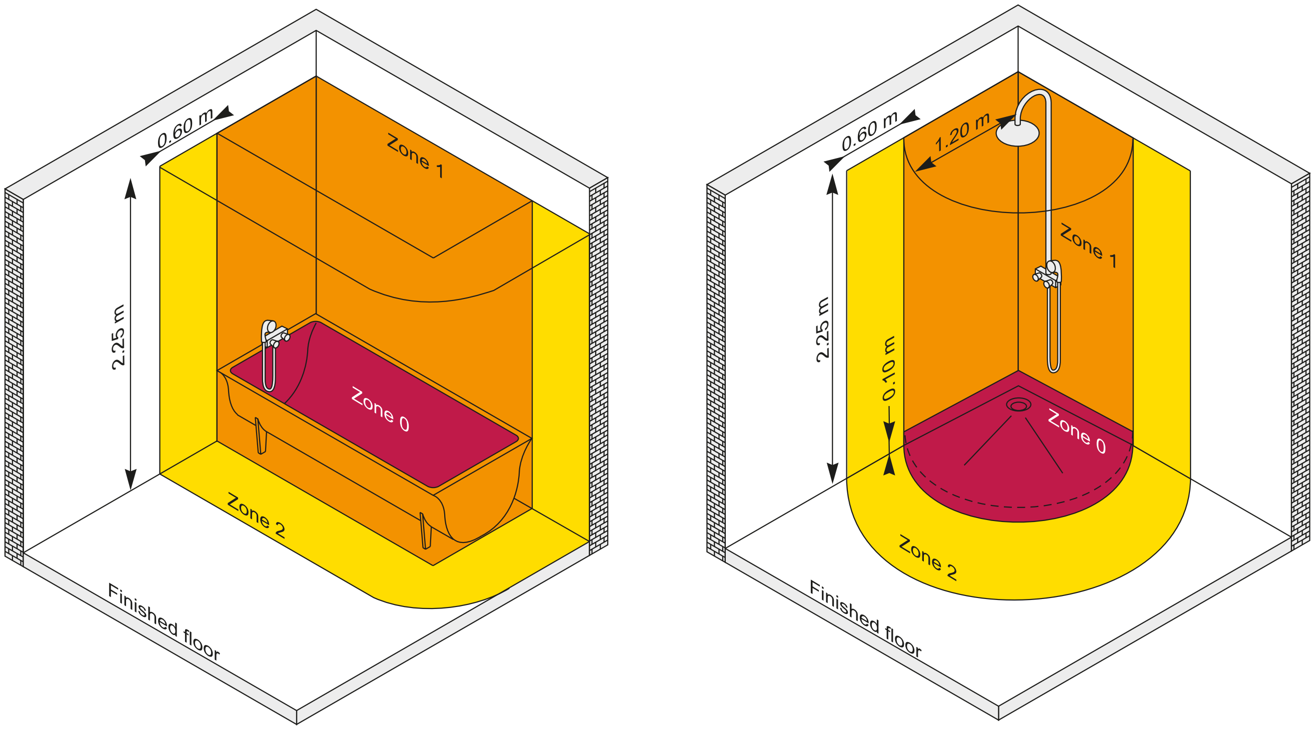

Fig. Q15 Definiton of zones 0, 1 and 2 (global view)

2 Bathrooms and showers

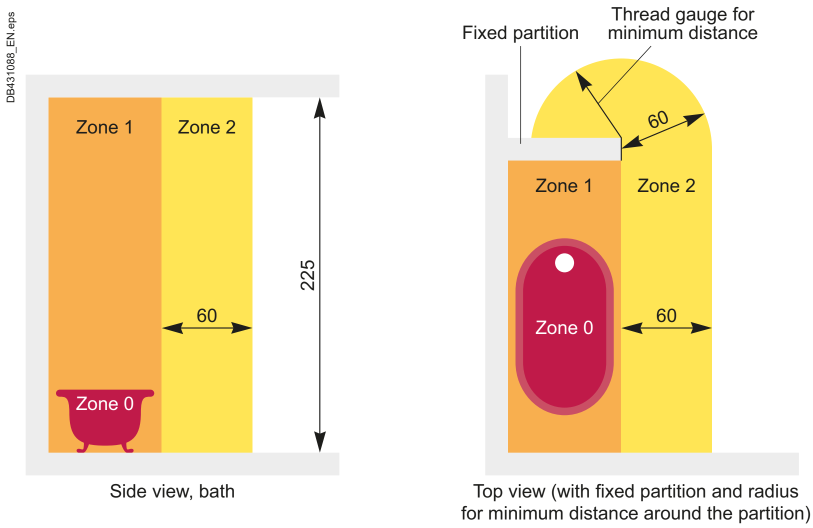

Fig. Q16 Definition of zones 0, 1, and 2 – Bath tub complementary examples

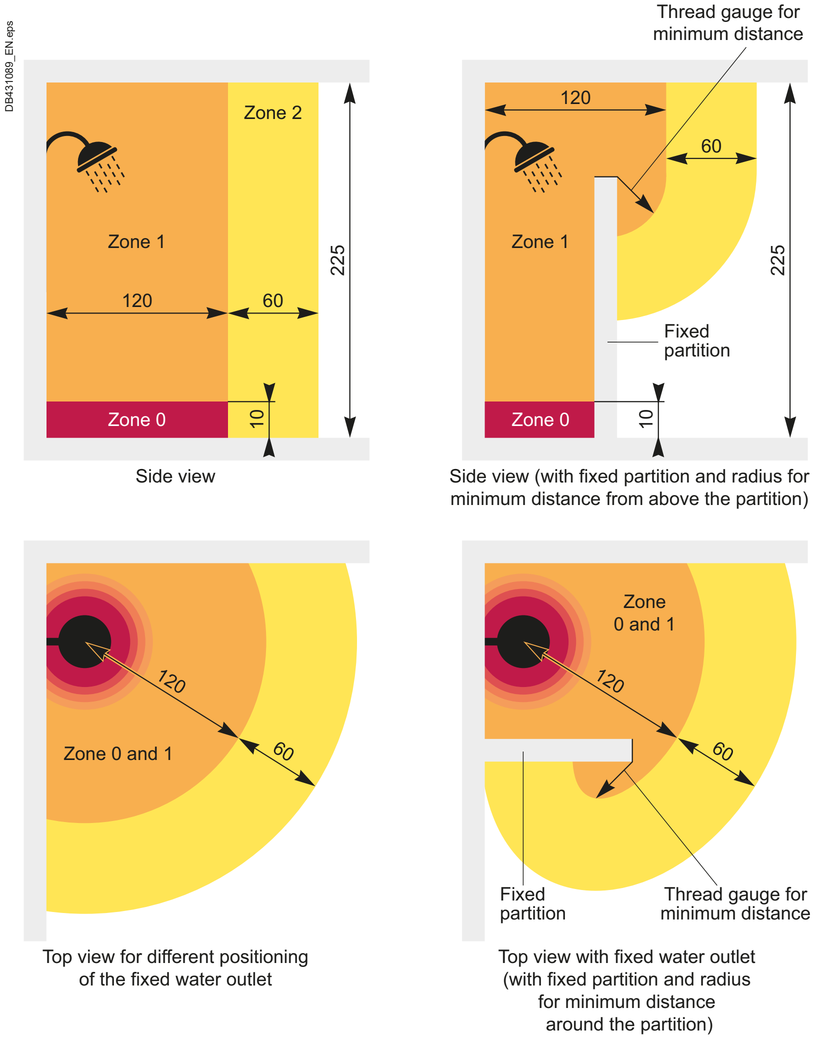

Fig. Q17 Definition of zones 0, 1, and 2 - shower without basin complementary examples

2.2 Requirements prescribed for each zone

The IEC 60364-7-701 provides the specific requirements for the different zones defined in §2.1, applicable to the equipments, circuits …

It is an international standard that has been achieved as a compromise between countries, considering their existing national standards and regulations, thus it includes a significant number of notes providing country specific requirements. It is thus difficult to share a simplified view of these requirements.

Therefore, what you see below is an overview of the requirements for each zone, based on French standard (NFC 15-100). Always refer to your national standards for the applicable local requirements.

Zone	Equipment IP required
Zone 0	IPX7
Zone 1	IPX4[a]
Zone 2	IPX4

[a] IPX5 for showers with horizontal water jets

Fig. Q18 Equipment IP required for each zone

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Type of equipment	Zone 0	Zone 1	Zone 2	Outside zones 0..2
Equipment IP required	IPX7	IPX4 [a]	IPX4	standard
Wiring system (cables and trunking)	-	only to supply circuits authorized in this zone	only to supply circuits authorized in this zone	OK
Junction boxes	-	-	-	OK
Socket-outlet	-	-	-	OK [c]
Shaver supply-unit (20 to 50 VA)	-	-	OK	OK
Switch	-	SELV ≤ 12 Vac [b]	SELV ≤ 12 Vac [b]	OK
Separation transformer for SELV circuit	-	-	-	OK
Luminaire	SELV ≤ 12 Vac [b]	SELV ≤ 12 Vac [b]	Class II ⧈	Class I
Heater, towel rail	-	-	Class II ⧈	Class I
Water heater (water reserve)	-	horizontal and as high as possible	direct cable connexion, no connexion box	OK
Washing machine, tumble dryer	-	-	-	OK

Cells with a grey background indicate that such equipment is forbidden in this zone.
[a] IPX5 for showers with horizontal water jets
[b] Separation transformer of the circuit shall be installed outside zones 0..2
[c] Outside zones 0..2, all circuits shall be protected by 30mA RCDs (or separation transformer, SELV or PELV)

Fig. Q19 Overview of the specific requirements for bathrooms and shower rooms (based on French NFC 15-100 standard) - refer to your local standard for actual and complete requirements

2 Bathrooms and showers

2.3 Equipotential bonding (see Fig. Q20)

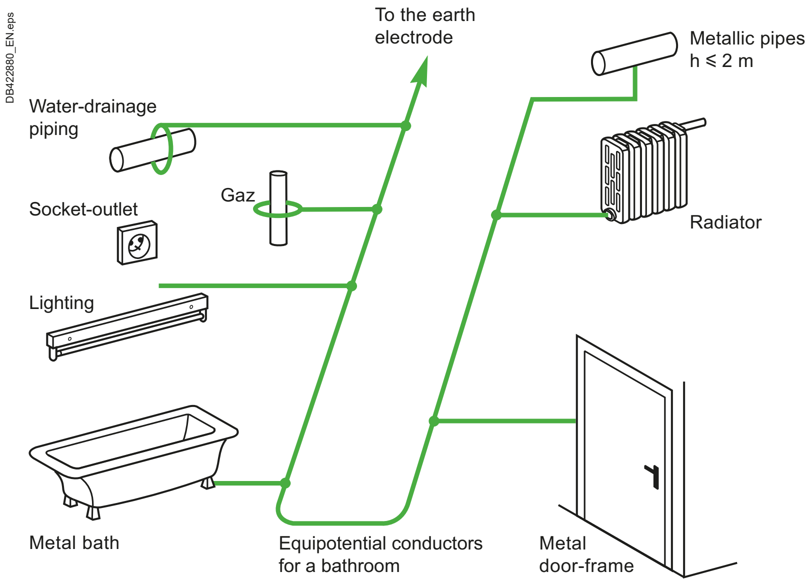

Fig. Q20 Supplementary equipotential bonding in a bathroom

3 Requirements applicable to special installations and locations

The IEC 60364-7-7xx standards (part 7 of the IEC 60364) are detailing the mandatory "Requirements for special installations or locations". These requirements supplement, modify or replace certain of the general requirements of the other parts of IEC 60364.
These parts shall be applied in conjunction with the other parts of IEC 60364: where a Clause is not mentioned in the Part 7, that means the Clause shall be applied as defined in the general part of IEC 60364.

Below is a list of the existing standards in this part 7:

IEC 60364-7-701 Locations containing a bath or shower
IEC 60364-7-702 Swimming pools and fountains
IEC 60364-7-703 Rooms and cabins containing sauna heaters
IEC 60364-7-704 Construction and demolition site installations
IEC 60364-7-705 Agricultural and horticultural premises
IEC 60364-7-706 Conducting locations with restricted movement
IEC 60364-7-708 Caravan parks, camping parks and similar locations
IEC 60364-7-709 Marinas and similar locations
IEC 60364-7-710 Medical locations
IEC 60364-7-711 Exhibitions, shows and stands
IEC 60364-7-712 Solar photovoltaic (PV) power supply systems
IEC 60364-7-713 Furniture
IEC 60364-7-714 External lighting installations
IEC 60364-7-715 Extra-low-voltage lighting installations
IEC 60364-7-717 Mobile or transportable units
IEC 60364-7-718 Communal facilities and workplaces
IEC 60364-7-721 Electrical installations in caravans and motor caravans
IEC 60364-7-722 Supplies for electric vehicles
IEC 60364-7-729 Operating or maintenance gangways
IEC 60364-7-740 Temporary electrical installations for structures, amusement devices and booths at fairgrounds, amusement parks and circuses
IEC 60364-7-753 Heating cables and embedded heating systems

The specific requirements in these standards may include, for example, some of the following:

- Additional equipotential bonding
- Zones where it is forbidden to install any electrical appliance
- Zones with additional requirement on electrical appliances that can be installed (class II)
- Zones where only specific circuits can be used (SELV)
- Mandatory protection of some circuits by 30mA RCDs
- Additional protection against fire risks
- Requirements on the installation position of some equipment (height between x and y)

As an example, see section 2 Bathroom and showers, focused on IEC 60364-7-701.

EMC guidelines

Life Is On | Schneider Electric

1 Electrical distribution

The system earthing arrangement must be properly selected to ensure the safety of life and property. The behaviour of the different systems with respect to EMC considerations must be taken into account. Fig. R1 below presents a summary of their main characteristics.

European standards (see EN 50174-2, EN 50310 and HD 60364-4-444) recommend the TN-S eathing system which causes the fewest EMC problems for installations comprising information-technology equipment (including telecom equipment).

	TT	TN-S	IT	TN-C
Safety of persons	Correct Use of residual current devices (circuit breaker)is mandatory	Correct Continuity of the PE conductor must be ensured throughout the installation		
Safety of property	Correct	Poor	Correct	Poor
	Medium ground-fault current (< about ten amps)	High ground-fault current (about 1 kA)	Low ground-fault current for first fault (< about ten mA), but high for second fault	High ground-fault current (about 1 kA)
Availability of energy	Correct	Correct	Excellent	Correct
EMC performance	Correct - Risk of overvoltages - Equipotential problems - Need to manage devices with high leakage currents	Excellent - Good equipotential situation - Need to manage devices with high leakage currents - High ground-fault currents (transient disturbances)	Poor (to be avoided) - Risk of overvoltages - Common-mode filters and surge arrestors must handle the phase to-phase voltages - RCDs subject to nuisance tripping if common-mode capacitors are present - Equivalent to TN system for second fault	Poor (not recommended) - Neutral and PE are combined - 50/60 Hz and harmonics currents circulate in the earthing and grounding structures - High ground-fault currents (transient disturbances)

Fig. R1 Main characteristics of the different earthing systems

When an installation includes high-power equipment (motors, air-conditioning, lifts, power electronics, etc.), it is advised to install one or more transformers specifically for these systems. Electrical distribution must be organised in a star system and all outgoing circuits must exit the main low-voltage switchboard (MLVS).

Electronic systems (control/monitoring, regulation, measurement instruments, etc.) must be supplied by a dedicated transformer in a TN-S system.

Fig. R2 below illustrates these recommendations.

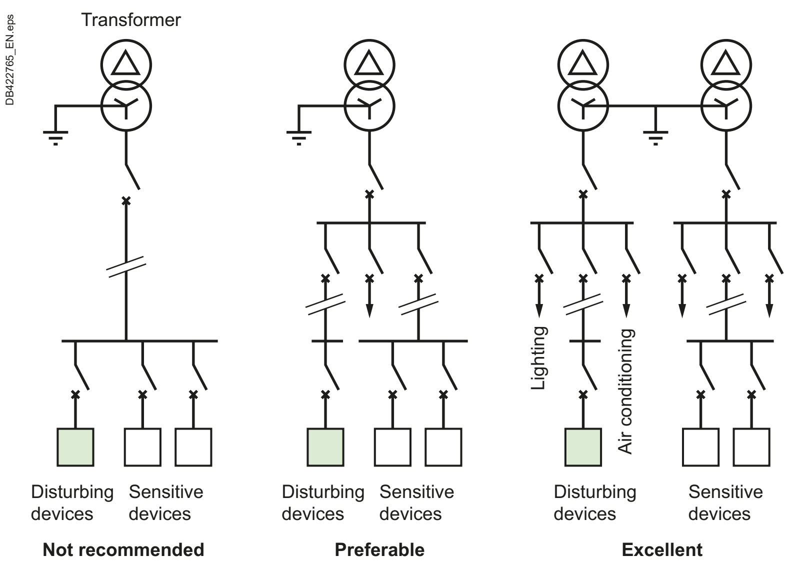

Fig. R2 Recommendations of separated distributions

2 Earthing principles and structures

This section deals with the earthing and equipotential bonding of information-technology devices and other similar devices requiring interconnections for signalling purposes.

Earthing networks are designed to fulfil a number of functions. They can be independent or operate together to provide one or more of the following:

- Safety of persons with respect to electrical hazards
- Protection of equipment with respect to electrical hazards
- A reference value for reliable, high-quality signals
- Satisfactory EMC performance

The system earthing arrangement is generally designed and installed in view of obtaining a low impedance capable of diverting fault currents and HF currents away from electronic devices and systems. There are different types of system earthing arrangements and some require that specific conditions be met. These conditions are not always met in typical installations. The recommendations presented in this section are intended for such installations.

For professional and industrial installations, a common bonding network (CBN) may be useful to ensure better EMC performance with respect to the following points:

- Digital systems and new technologies
- Compliance with the EMC essential requirements of Directive 2004/108/EC (emission and immunity)
- The wide number of electrical applications
- A high level of system safety and security, as well as reliability and/or availability

For residential premises, however, where the use of electrical devices is limited, an isolated bonding network (IBN) or, even better, a mesh IBN may be a solution.

It is now recognised that independent, dedicated earth electrodes, each serving a separate earthing network, are a solution that is not acceptable in terms of EMC, but also represent a serious safety hazard. In certain countries, the national building codes forbid such systems.

Use of a separate "clean" earthing network for electronics and a "dirty" earthing network for energy is not recommended in view of obtaining correct EMC, even when a single electrode is used (see Fig. R3 and Fig. R4). In the event of a lightning strike, a fault current or HF disturbances as well as transient currents will flow in the installation. Consequently, transient voltages will be created and result in failures or damage to the installation. If installation and maintenance are carried out properly, this approach may be dependable (at power frequencies), but it is generally not suitable for EMC purposes and is not recommended for general use.

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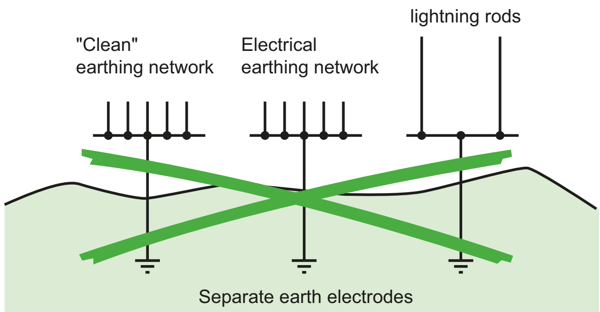

Fig. R3 Independent earth electrodes, a solution generally not acceptable for safety and EMC reasons

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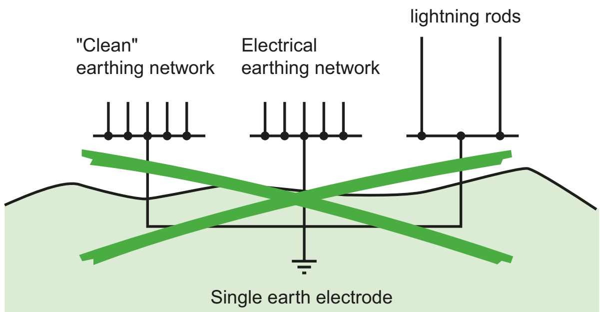

Fig. R4 Installation with a single earth electrode

2 Earthing principles and structures

The recommended configuration for the earthing network and electrodes is two or three dimensional (see **Fig. R5**). This approach is advised for general use, both in terms of safety and EMC. This recommendation does not exclude other special configurations that, when correctly maintained, are also suitable.

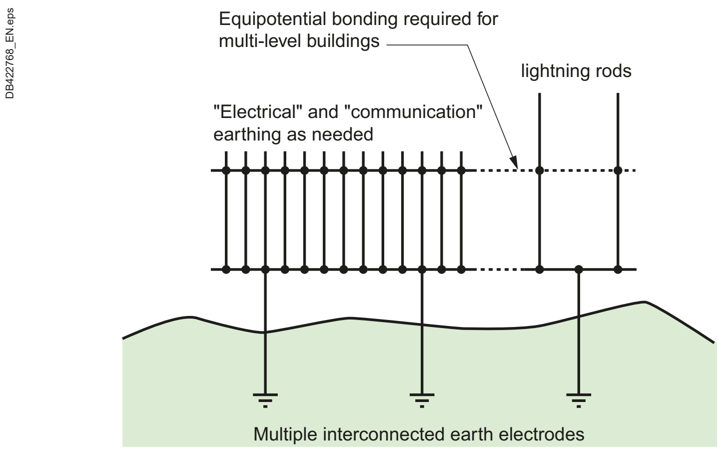

Fig. R5 Installation with multiple earth electrodes

In a typical installation for a multi-level building, each level should have its own earthing network (generally a mesh) and all the networks must be both interconnected and connected to the earth electrode. At least two connections are required (built in redundancy) to ensure that, if one conductor breaks, no section of the earthing network is isolated.

Practically speaking, more than two connections are made to obtain better symmetry in current flow, thus reducing differences in voltage and the overall impedance between the various levels in the building.

The many parallel paths have different resonance frequencies. If one path has a high impedance, it is most probably shunted by another path with a different resonance frequency. On the whole, over a wide frequency spectrum (dozens of Hz and MHz), a large number of paths results in a low-impedance system (see **Fig. R6**).

Each room in the building should have earthing-network conductors for equipotential bonding of devices and systems, cableways, trunking systems and structures. This system can be reinforced by connecting metal pipes, gutters, supports, frames, etc. In certain special cases, such as control rooms or computers installed on false floors, ground reference plane or earthing strips in areas for electronic systems can be used to improve earthing of sensitive devices and protection interconnection cables.

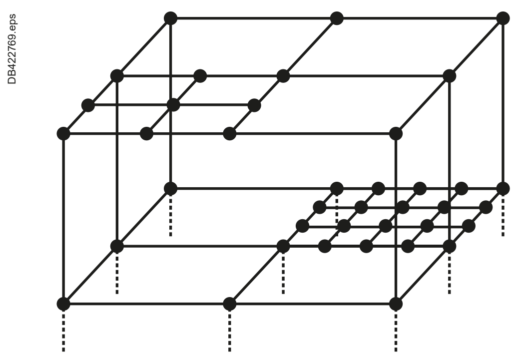

Fig. R6 Each level has a mesh and the meshes are interconnected at several points between levels. Certain ground-floor meshes are reinforced to meet the needs of certain areas

3.1 Equipotential bonding inside and outside buildings

The fundamental goals of earthing and bonding are the following:

- **Safety:** by limiting the touch voltage and the return path of fault currents,
- **EMC:** by avoiding differences in potential and providing a screening effect.

Stray currents are inevitably propagated in an earthing network. It is impossible to eliminate all the sources of disturbances for a site. Earth loops are also inevitable. When a magnetic field affects a site, e.g. the field created by lightning, differences in potential are created in the loops formed by the various conductors and the currents flowing in the earthing system. Consequently, the earthing network is directly affected by any counter-measures taken outside the building.

As long as the currents flow in the earthing system and not in the electronic circuits, they do no damage. However, when earthing networks are not equipotential, e.g. when they are star connected to the earth electrode, the HF stray currents will flow wherever they can, including in control wires. Equipment can be disturbed, damaged or even destroyed.

The only inexpensive means to divide the currents in an earthing system and maintain satisfactory equipotential characteristics is to interconnect the earthing networks. This contributes to better equipotential bonding within the earthing system, but does not remove the need for protective conductors. To meet legal requirements in terms of the safety of persons, sufficiently sized and identified protective conductors must remain in place between each piece of equipment and the earthing terminal. What is more, with the possible exception of a building with a steel structure, a large number of conductors for the ligthning rods or the lightning-protection network must be directly connected to the earth electrode.

The fundamental difference between a protective conductor (PE) and a ligthning rod down-conductor is that the first conducts internal currents to the neutral of the MV/LV transformer whereas the second carries external current (from outside the installation) to the earth electrode.

In a building, it is advised to connect an earthing network to all accessible conducting structures, namely metal beams and door frames, pipes, etc.

It is generally sufficient to connect metal trunking, cable trays and lintels, pipes, ventilation ducts, etc. at as many points as possible. In places where there is a large amount of equipment and the size of the mesh in the bonding network is greater than four metres, an equipotential conductor should be added. The size and type of conductor are not of critical importance.

It is imperative to interconnect the earthing networks of buildings that have shared cable connections. Interconnection of the earthing networks must take place via a number of conductors and all the internal metal structures of the buildings or linking the buildings (on the condition that they are not interrupted).

In a given building, the various earthing networks (electronics, computing, telecom, etc.) must be interconnected to form a single equipotential bonding network.

This earthing-network must be as meshed as possible. If the earthing network is equipotential, the differences in potential between communicating devices will be low and a large number of EMC problems disappear. Differences in potential are also reduced in the event of insulation faults or lightning strikes.

If equipotential conditions between buildings cannot be achieved or if the distance between buildings is greater than ten metres, it is highly recommended to use optical fibre for communication links and galvanic insulators for measurement and communication systems.

These measures are mandatory if the electrical supply system uses the IT or TN-C system.

3.2 Improving equipotential conditions

Bonding networks

Even though the ideal bonding network would be made of sheet metal or a fine mesh, experience has shown that for most disturbances, a three-metre mesh size is sufficient to create a mesh bonding network.

Examples of different bonding networks are shown in **Fig. R7** next page.
The minimum recommended structure comprises a conductor (e.g. copper cable or strip) surrounding the room.

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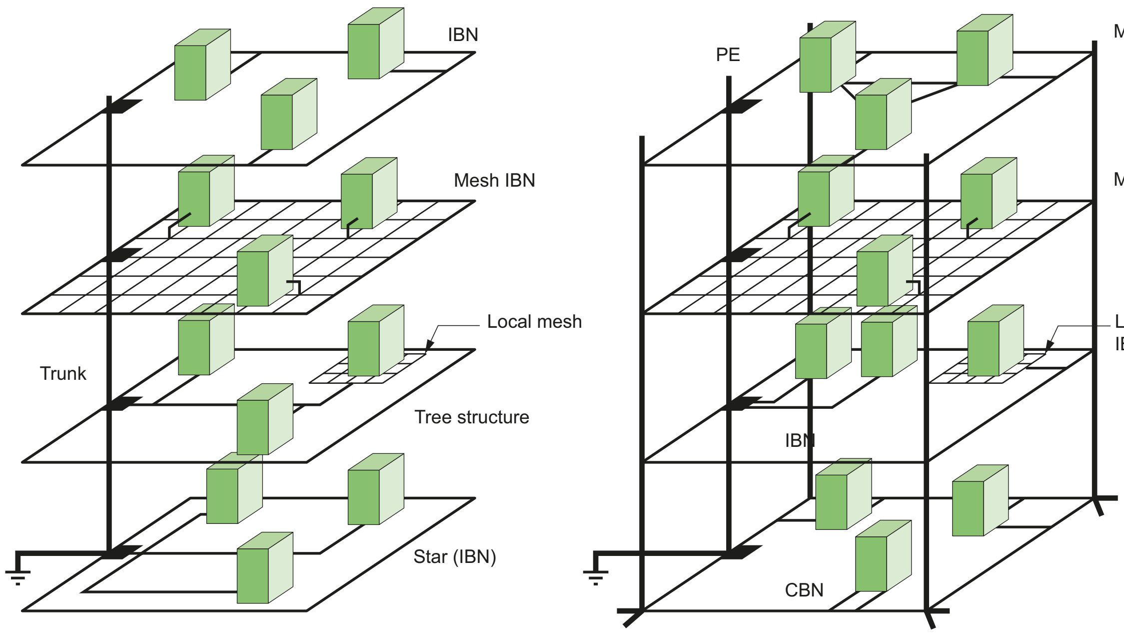

BN: Bonding network
CBN: Common bonding network
IBN: Isolated bonding network

Fig. R7 Examples of bonding networks

The length of connections between a structural element and the bonding network does not exceed 50 centimetres and an additional connection should be installed in parallel at a certain distance from the first. The inductance of the connection between the earthing bar of the electrical enclosure for a set of equipment and the bonding network (see below) should be less than one µHenry (0.5 µH, if possible). For example, it is possible to use a single 50 cm conductor or two parallel conductors one meter long, installed at a minimum distance from one another (at least 50 cm) to reduce the mutual inductance between the two conductors.

Where possible, connection to the bonding network should be at an intersection to divide the HF currents by four without lengthening the connection. The profile of the bonding conductors is not important, but a flat profile is preferable. The conductor should also be as short as possible.

Parallel earthing conductor (PEC)

The purpose of a parallel earthing conductor is to reduce the common-mode current flowing in the conductors that also carry the differential-mode signal (the common-mode impedance and the surface area of the loop are reduced).

The parallel earthing conductor must be designed to handle high currents when it is used for protection against lightning or for the return of high fault currents. When cable shielding is used as a parallel earthing conductor, it cannot handle such high currents and the solution is to run the cable along metal structural elements or cableways which then act as other parallel earthing conductors for the entire cable. Another possibility is to run the shielded cable next to a large parallel earthing conductor with both the shielded cable and the parallel earthing conductor connected at each end to the local earthing terminal of the equipment or the device.

For very long distances, additional connections to the network are advised for the parallel earthing conductor, at irregular distances between the devices. These additional connections form a shorter return path for the disturbing currents flowing through the parallel earthing conductor. For U-shaped trays, shielding and tubes, the additional connections should be external to maintain the separation with the interior (“screening” effect).

Bonding conductors

Bonding conductors may be metal strips, flat braids or round conductors. For high-frequency systems, metal strips and flat braids are preferable (skin effect) because a round conductor has a higher impedance than a flat conductor with the same cross section. Where possible, the length to width ratio should not exceed 5.

3.3 Separating cables

The physical separation of high and low-current cables is very important for EMC, particularly if low-current cables are not shielded or the shielding is not connected to the exposed conductive parts (ECPs). The sensitivity of electronic equipment is in large part determined by the accompanying cable system.

If there is no separation (different types of cables in separate cableways, minimum distance between high and low-current cables, types of cableways, etc.), electromagnetic coupling is at its maximum. Under these conditions, electronic equipment is sensitive to EMC disturbances flowing in the affected cables.

Use of busbar trunking systems such as Canalis or busbar ducts for high power ratings is strongly advised. The levels of radiated magnetic fields using these types of trunking systems is 10 to 20 times lower than standard cables or conductors.

The recommendations in the “Cable running” and “Wiring recommendations” sections should be taken into account.

3.4 Raised floors

The inclusion of the floors in the mesh contributes to equipotentiality of the area and consequently to the distribution and dilution of disturbing LF currents.

The screening effect of a raised floor is directly related to its equipotentiality. If the contact between the floor tiles is poor (rubber antistatic joints, for example) or if the contact between the support brackets is faulty (pollution, corrosion, dust, etc. or if there are no support brackets), it is necessary to add an equipotential mesh.

In this case, it is sufficient to ensure effective electrical connections between the metal pedestals. Small spring clips are available on the market to connect the metal pedestals to the equipotential mesh. Ideally, each pedestal should be connected, but it is often sufficient to connect every other pedestals in each direction. A mesh 1.5 to 2 metres in size is suitable in most cases.

The recommended cross-sectional area of the copper is 10 mm2 or more. In general, a flat braid is used. To reduce the effects of corrosion, it is advised to use tin-plated copper (see **Fig. R8**).

Perforated floor tiles act like normal floor tiles when they have a cellular steel structure.

Preventive maintenance is required for the floor tiles approximately every five years (depending on the type of tile plate and the environment, including humidity, dust and corrosion). Rubber or polymer antistatic joints must be maintained, similar to the bearing surfaces of the floor tiles (cleaning with a suitable product).

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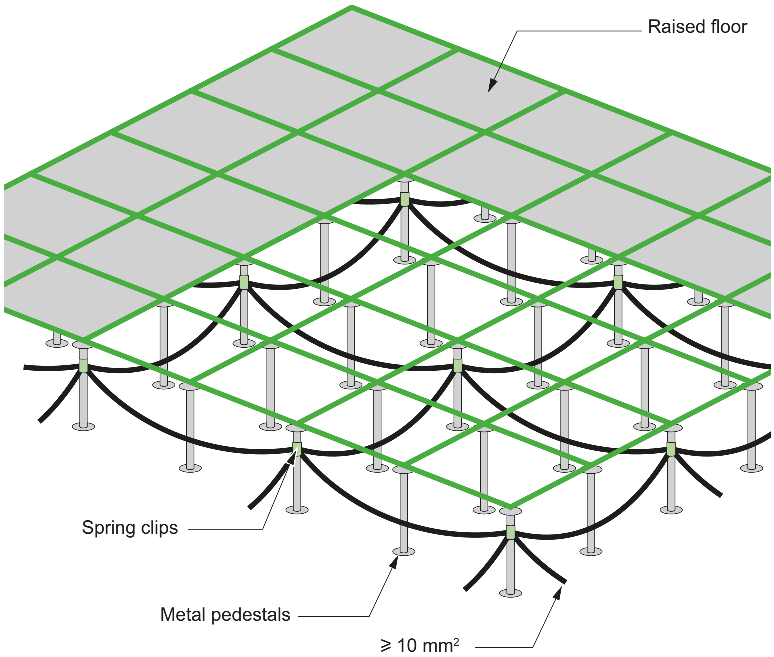

Fig. R8 Raised floor implementation

3.5 Cable running

Selection of materials and their shape depends on the following criteria:

- Severity of the EM environment along cableways (proximity of sources of conducted or radiated EM disturbances)
- Authorised level of conducted and radiated emissions
- Type of cables (shielded?, twisted?, optical fibre?)
- EMI withstand capacity of the equipment connected to the wiring system
- Other environmental constraints (chemical, mechanical, climatic, fire, etc.)
- Future extensions planned for the wiring system

Non-metal cableways are suitable in the following cases:

- A continuous, low-level EM environment
- A wiring system with a low emission level
- Situations where metal cableways should be avoided (chemical environment)
- Systems using optical fibres

For metal cableways, it is the shape (flat, U-shape, tube, etc.) rather than the cross-sectional area that determines the characteristic impedance. Closed shapes are better than open shapes because they reduce common-mode coupling. Cableways often have slots for cable straps. The smaller the better. The types of slots causing the fewest problems are those cut parallel and at some distance from the cables. Slots cut perpendicular to the cables are not recommended (seen **Fig. R9**).

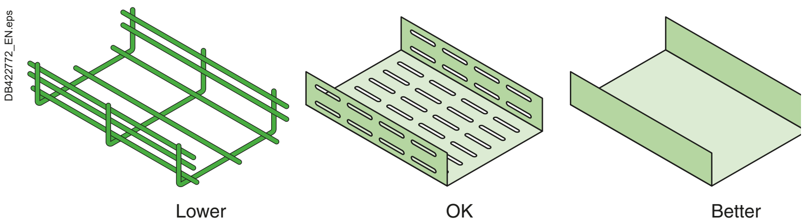

Fig. R9 CEM performance of various types of metal cableways

In certain cases, a poor cableway in EMI terms may be suitable if the EM environment is low, if shielded cables or optical fibres are employed, or separate cableways are used for the different types of cables (power, data processing, etc.).

It is a good idea to reserve space inside the cableway for a given quantity of additional cables. The height of the cables must be lower than the partitions of the cableway as shown below. Covers also improve the EMC performance of cableways.

In U-shaped cableways, the magnetic field decreases in the two corners. That explains why deep cableways are preferable (see **Fig. R10**).

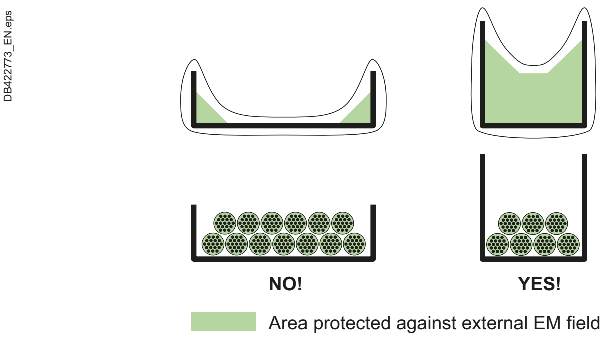

Fig. R10 Installation of different types of cables

Different types of cables (power and low-level cables) should not be installed in the same bundle or in the same cableway. Cableways should never be filled to more than half capacity.

3 Implementation

It is recommended to electromagnetically separate groups from one another, either using shielding or by installing the cables in different cableways. The quality of the shielding determines the distance between groups. If there is no shielding, sufficient distances must be maintained (see Fig. R11).

The distance between power and control cables must be at least 5 times the radius of the larger power cable.

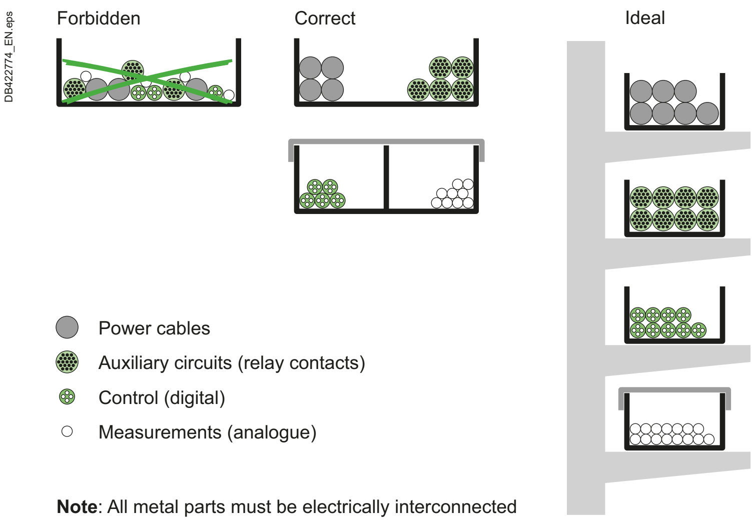

Fig. R11 Recommendation to install groups of cables in metal cableways

Metal building components can be used for EMC purposes. Steel beams (L, H, U or T shaped) often form an uninterrupted earthed structure with large transversal sections and surfaces with numerous intermediate earthing connections. Cables should if possible be run along such beams. Inside corners are better than the outside surfaces (see Fig. R12).

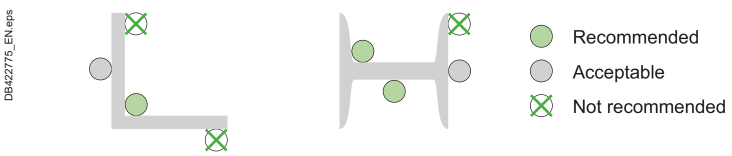

Fig. R12 Recommendation to install cables in steel beams

Both ends of metal cableways must always be connected to local earth network. For very long cableways, additional connections to the earthing system are recommended between connected devices. Where possible, the distance between these earthing connections should be irregular (for symmetrical wiring systems) to avoid resonance at identical frequencies. All connections to the earthing system should be short.

Metal and non-metal cableways are available. Metal solutions offer better EMC characteristics. A cableway (cable trays, conduits, cable brackets, etc.) must offer a continuous, conducting metal structure from beginning to end.

An aluminium cableway has a lower DC resistance than a steel cableway of the same size, but the transfer impedance (Zt) of steel drops at a lower frequency, particularly when the steel has a high relative permeability μ_r. Care must be taken when different types of metal are used because direct electrical connection is not authorised in certain cases to avoid corrosion. That could be a disadvantage in terms of EMC.

When devices connected to the wiring system using unshielded cables are not affected by low-frequency disturbances, the EMC of non-metal cableways can be improved by adding a parallel earthing conductor (PEC) inside the cableway. Both ends must be connected to the local earthing system. Connections should be made to a metal part with low impedance (e.g. a large metal panel of the device case).

The PEC should be designed to handle high fault and common-mode currents.

Implementation

When a metal cableway is made up of a number of short sections, care is required to ensure continuity by correctly bonding the different parts. The parts should preferably be welded along all edges. Riveted, bolted or screwed connections are authorised as long as the contact surfaces conduct current (no paint or insulating coatings) and are protected against corrosion. Tightening torques must be observed to ensure correct pressure for the electrical contact between two parts.

When a particular shape of cableway is selected, it should be used for the entire length. All interconnections must have a low impedance. A single wire connection between two parts of the cableway produces a high local impedance that cancels its EMC performance.

Starting at a few MHz, a ten-centimetre connection between two parts of the cableway reduces the attenuation factor by more than a factor of ten (see **Fig. R13**).

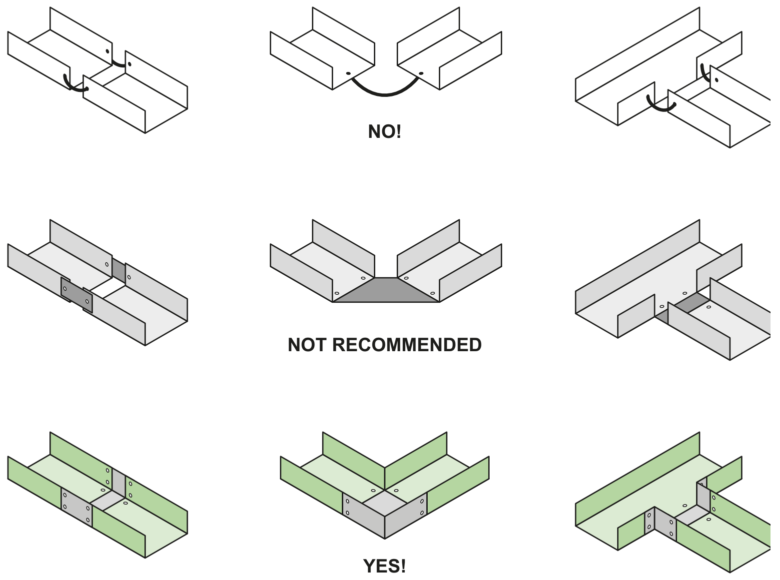

Fig. R13 Metal cableways assembly

Each time modifications or extensions are made, it is very important to make sure they are carried out according to EMC rules (e.g. never replace a metal cableway by a plastic version!).

Covers for metal cableways must meet the same requirements as those applying to the cableways themselves. A cover should have a large number of contacts along the entire length. If that is not possible, it must be connected to the cableway at least at the two ends using short connections (e.g. braided or meshed connections).

When cableways must be interrupted to pass through a wall (e.g. firewalls), low-impedance connections must be used between the two parts (see **Fig. R14**).

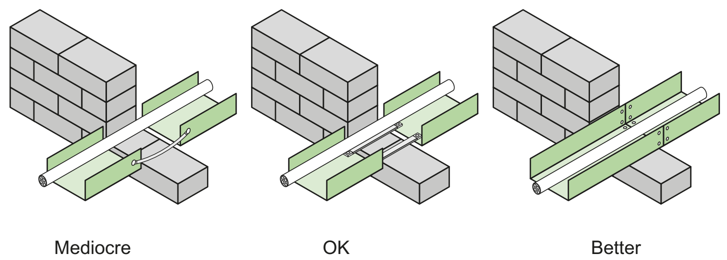

Fig. R14 Recommendation for metal cableways assembly to pass through a wall

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Fig. R15 Power cables and metallic busways magnetic field radiations

3.6 Busway

Busways reduce the risk of exposure to electromagnetic fields.

According to the WHO (World Health Organisation), exposure to electromagnetic fields can be a health hazard starting at levels as low as 0.2 micro-Teslas and could represent a long-term risk of cancer. Some countries have created standards that stipulate limits (e.g. 0.2 µT at 1 metre in Sweden).

All electrical conductors generate magnetic fields proportional to the distance between them. The design of busbar trunking with tightly spaced conductors in a metal enclosure helps to considerably reduce radiated electromagnetic fields.

The electromagnetic field characteristics of busbar trunking are well defined and measurements show that they are far below potentially dangerous levels (see **Fig. R16**).

In specific cases, where particularly low values are required (computer rooms, medical rooms, some offices), it is important to minimize the magnetic induction generated by power cables.

Magnetic induction is:

- proportional to the current
- proportional to the distance between the conductors
- inversely proportional to the square of the distance with respect to the busbar.

Busbar with a steel casing provides a good screening effect compared to power cables: magnetic field reduced from 2 to 30 times, depending on the Canalis model.

This is particularly low because of the short distance between the bars and the additional attenuation provided by the steel casing.

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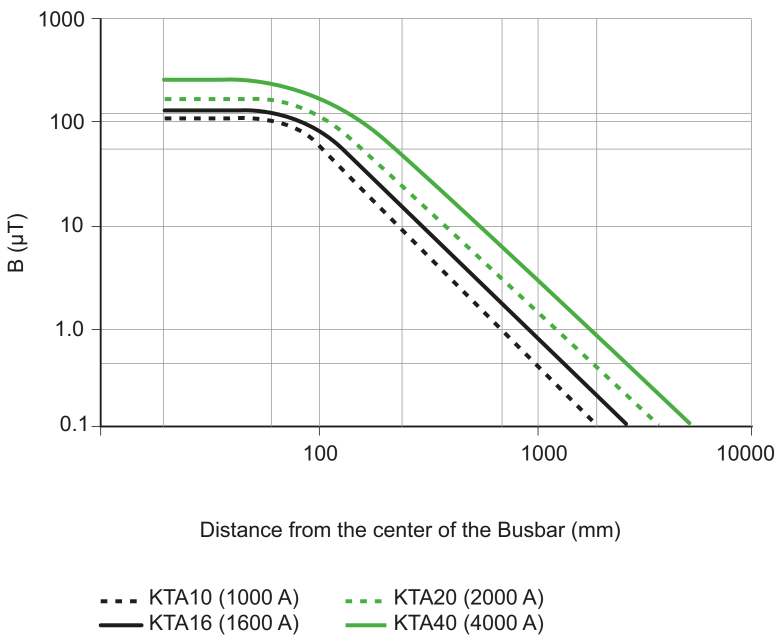

Fig. R16 Canalis busbar trunking system data

3.7 Implementation of shielded cables

When the decision is made to use shielded cables, it is also necessary to determine how the shielding will be bonded (type of earthing, connector, cable entry, etc.), otherwise the benefits are considerably reduced. To be effective, the shielding should be bonded over 360° **Fig. R17** on the next page show different ways of earthing the cable shielding.

For computer equipment and digital links, the shielding should be connected at each end of the cable.

Connection of the shielding is very important for EMC and the following points should be noted.

3 Implementation

If the shielded cable connects equipment located in the same equipotential bonding area, the shielding must be connected to the exposed conductive parts (ECP) at both ends. If the connected equipment is not in the same equipotential bonding area, there are a number of possibilities.

- Connection of only one end to the ECPs is dangerous. If an insulation fault occurs, the voltage in the shielding can be fatal for an operator or destroy equipment. In addition, at high frequencies, the shielding is not effective.
- Connection of both ends to the ECPs can be dangerous if an insulation fault occurs. A high current flows in the shielding and can damage it. To limit this problem, a parallel earthing conductor (PEC) must be run next to the shielded cable. The size of the PEC depends on the short-circuit current in the given part of the installation.

It is clear that if the installation has a well meshed earthing network, this problem does not arise.

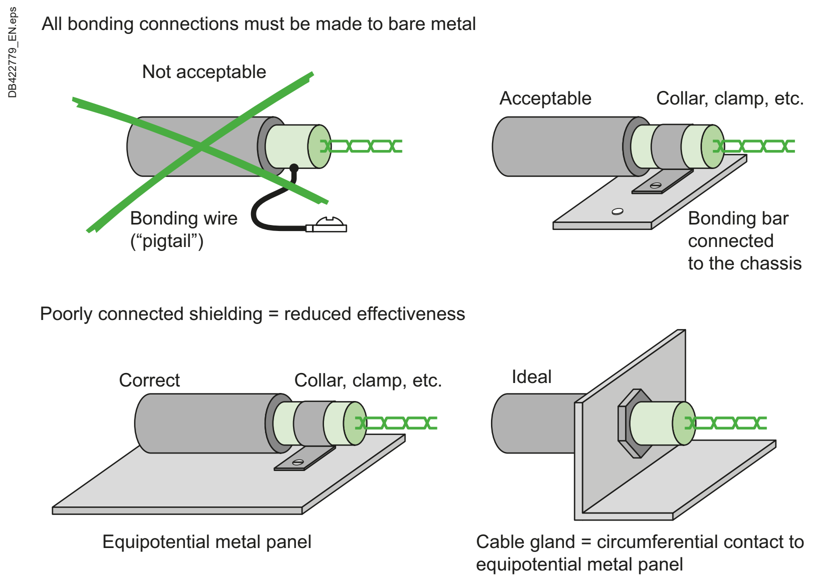

Fig. R17 Implementation of shielded cables

The following **Fig. R18** shows how to prepare the screen when EMC clamps are used.

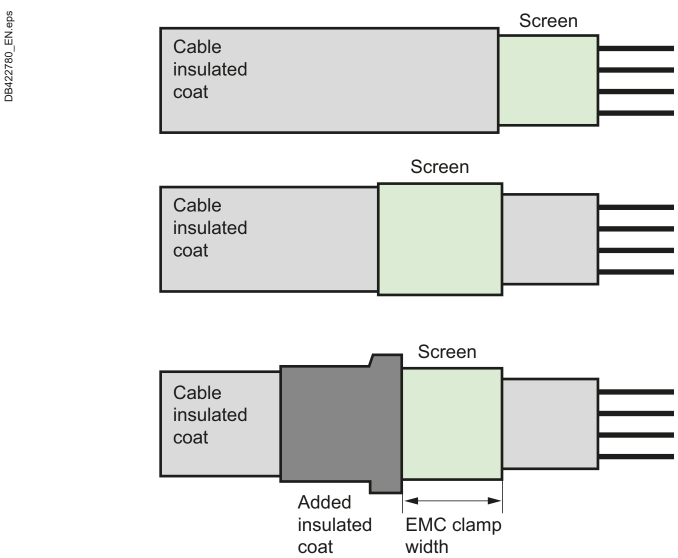

Fig. R18 Recommended screen preparation

3.8 Communication networks

It is highly recommended to follow the European Standards EN 50173 series to perform Information Technology cablings.

To ensure a reliable data transmission, the quality of the whole link shall be homogeneous. That means the category of the different cables shall be the same, the connecting interfaces shall be adapted to the cables.

Cables and connections of different categories may be mixed within a channel however the resultant performance will be determined by the category of the lowest performing component.

The shield continuity of the whole link (patch cords, Terminal Outlets, horizontal cable) shall be ensured and controlled by tests.

The Terminal Outlets (TO) could be used to earth the screen terminations in the cabinet. The choice of these TO is very important.

Communication networks are mostly extensive. They interconnect equipment located in different areas where the feeding power supplies could have different earthing systems.

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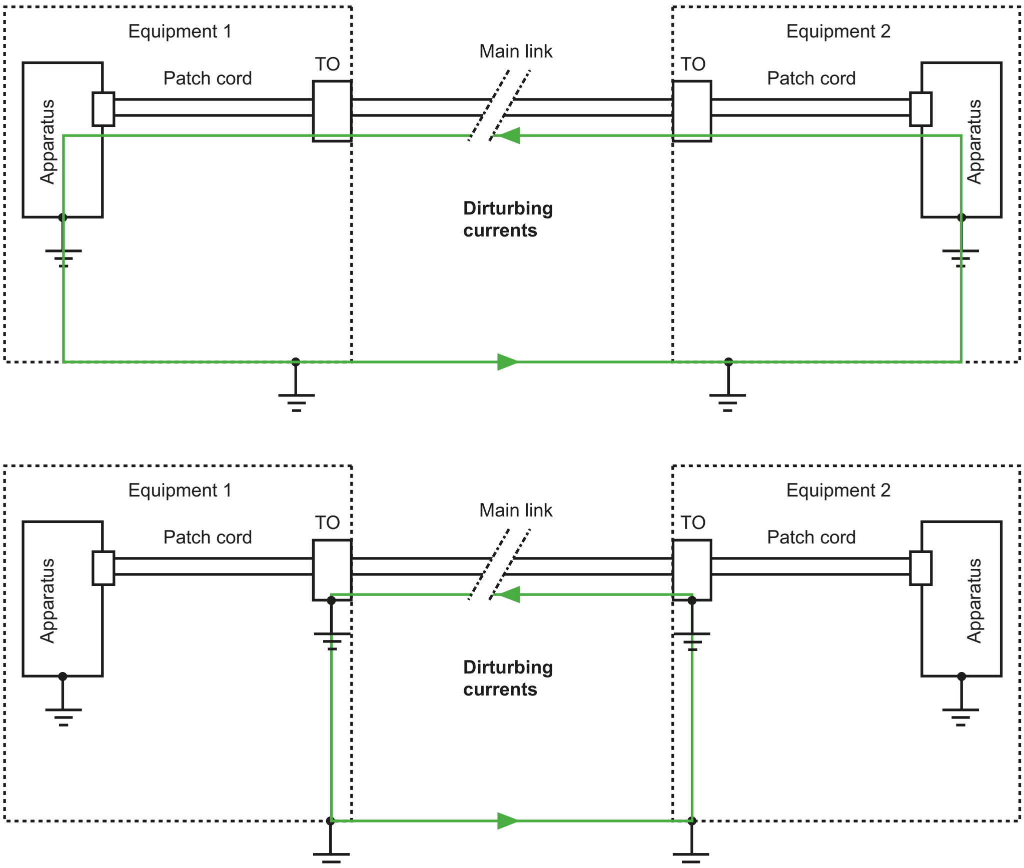

Fig. R19 How to reduce disturbing currents loop

If these different areas are not well equipotential, harsh transient currents could appear (lightning, main power fault, etc.) causing high voltage potential differences between interconnected equipment.

Communication interfaces (board, module, etc.) could be disturbed or damaged by this common mode over voltages.

The use of TN-S earthing system and well equipotential installation minimize this issue.

In any case, the use of Surge Protective Device (SPD) installed in Common Mode and/or Differential Mode is recommended.

3 Implementation

If the different areas/zones are not equipotential, if the power supply earthing system is TN-C or IT, or if there is a doubt and the previous 2 points, optical fiber links are highly recommended.

To avoid electrical safety issue, the optical fiber link should not have any metallic parts.

Protection against coils disturbances

AC and mostly DC Coils (relay, contactor, actuator, etc.) are very disturbing sources (see Fig. R20)

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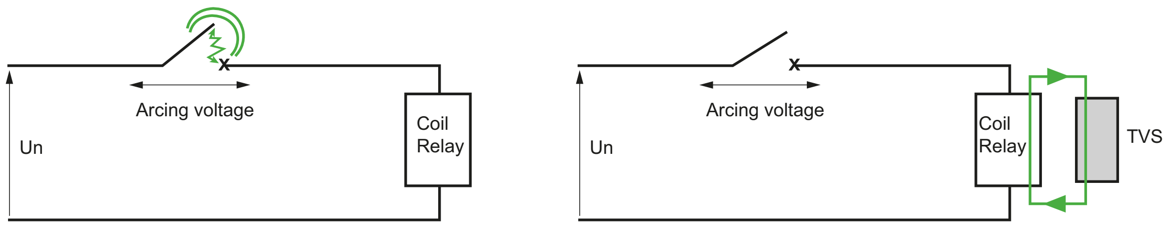


Fig. R20 TVS reduces the arcing voltage

To minimize these High Frequency disturbances the following solutions Fig. R21 could be implemented. (In grey, the preferred choice).

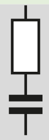
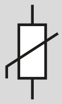
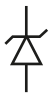
Symbol	Transient Voltage Suppression type	For AC	For DC	Overvoltage limitation	Contact fall time
	R-C network	Y	Y	2 to 3 . Un	1 to 2 times the standard time
	Metal Oxide Varistor	Y	Y	< 3 . Un	1.1 to 1.5 times the standard time
	Transient Voltage Suppression Diode Bidirectional	Y	Y	< 2. Un	1.1 to 1.5 times the standard time
	Transient Voltage Suppression Diode Directional	N	Y	Un + 0.7 V	3 to 10 times the standard time
	Free wheeling diode	N	Y	Un + 0.7 V	3 to 10 times the standard time
	Resistor	Y	Y	< 4 . Un	1.5 to 2.5 times the standard time

Fig. R21 TVS table information

To be efficient, the TVS shall be installed closely to the coil.

3.9 Implementation of surge arresters

Refer to chapter J - paragraph 4 "Installation of SPDs"

3.10 Cabinet cabling (See Fig. R22)

Each cabinet must be equipped with an earthing bar or a ground reference metal sheet. All shielded cables and external protection circuits must be connected to this point. Anyone of the cabinet metal sheets or the DIN rail can be used as the ground reference.

Plastic cabinets are not recommended. In this case, the DIN rail must be used as ground reference.

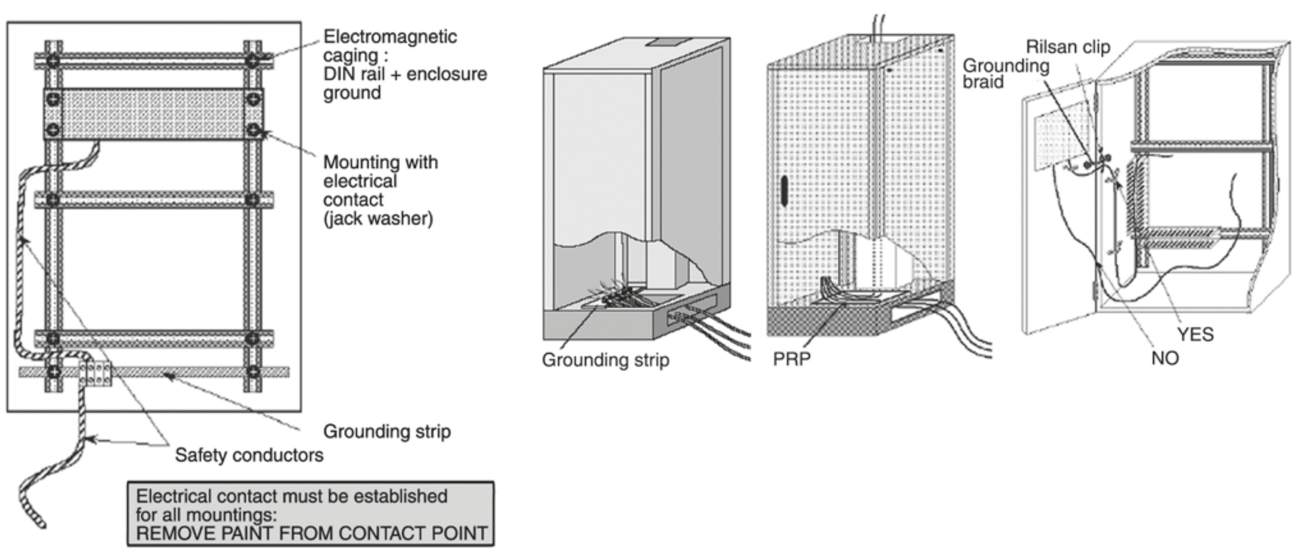


Fig. R22 Grounding and bonding examples

Cabinet cabling recommendations

Each cabinet, cubicle or enclosure shall be fitted, as a minimum, with an earthing bar and a reference metallic plate or grid (grounding plate). All the metallic parts (frames, panels, roof, door, etc.) shall be interconnected together with adapted features.

The use of specific washer is recommended. Some examples of preferred ones are shown below (see Fig. R23)

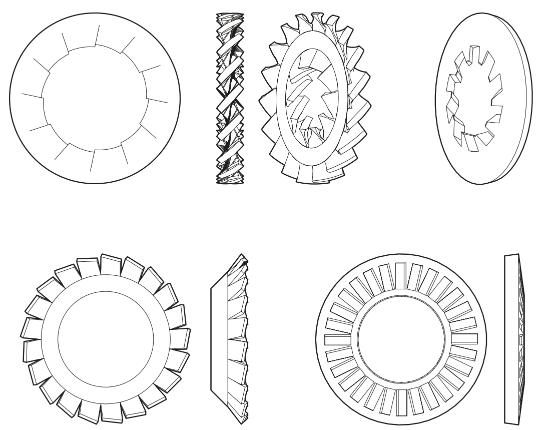


Fig. R23 Preferred washers examples

3 Implementation

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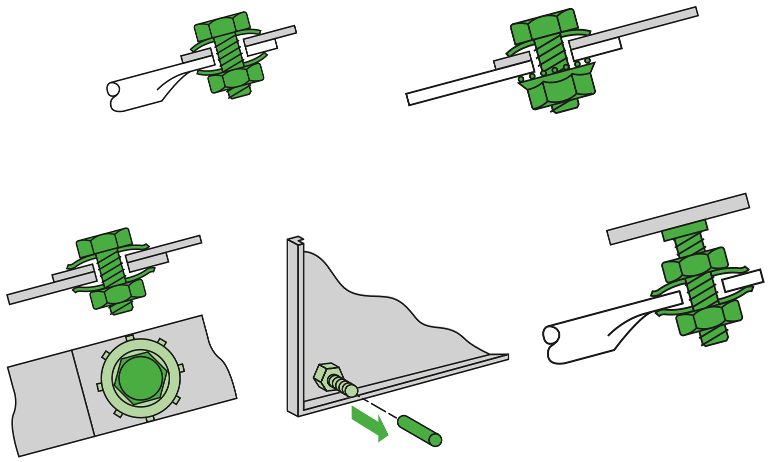

Fig. R24 Some examples of washers, bolt and lugs mounting.

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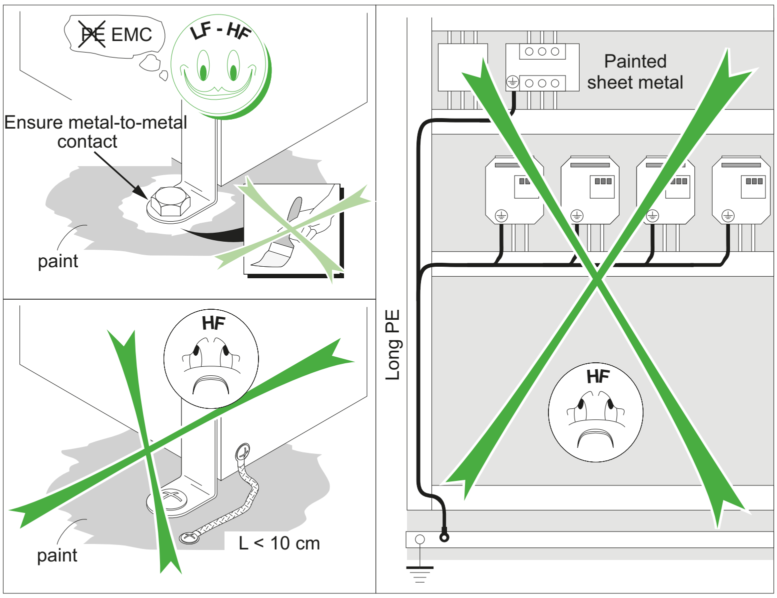

Fig. R25 Earthing and bonding examples

All the cables shall be laid on the grounded/earthed metallic structures.

All EMC components (e.g. EMI filter, EMC clamps) shall be fixed directly on the metallic plates without any insulating coating (e.g. free of paint or varnish).

3 Implementation

Screened cables coming or going out from the cubicle shall be bonded to the earthing bar or grounding plate if these cables are coming from long distance and/ or from non equipotential zones.

The goal is to divert the disturbing currents at the cabinet entrance and not inside the cabinet.

Non metallic cabinet are not recommended for EMC purposes.

To protect electronics equipment against low frequency magnetic field, it is recommended to use (galvanized) steel cabinets.

Non magnetic metals (e.g. aluminum, stainless steel) are more efficient for high frequencies environment.

Power and low level apparatus shall be physically separated and cables segregation and distances between power and sensitive cables shall also be respected as shown on the figures below.

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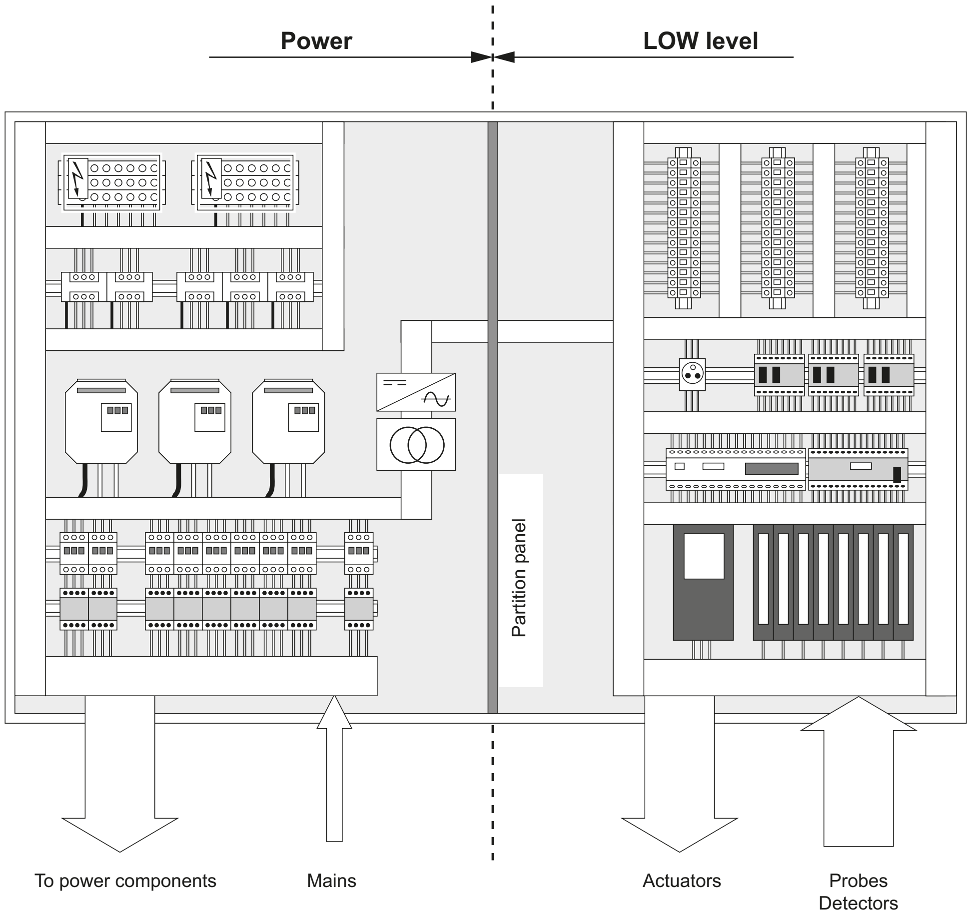

Fig. R26 Correct EMC design inside a same cabinet

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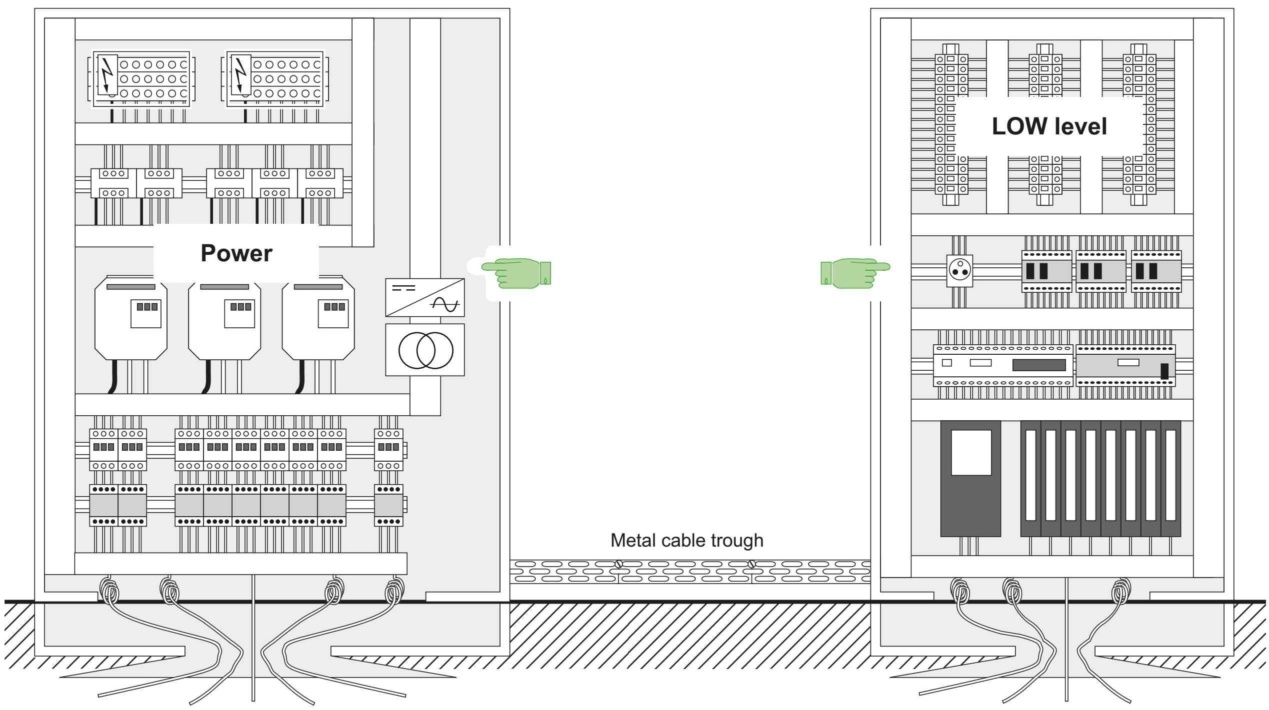

Fig. R27 Correct EMC design inside two separate cabinets

3.11 Standards

It is absolutely essential to specify the standards and recommendations that must be taken into account for installations.

Below are several documents that may be used:

- EN 50174-1 Information technology - Cabling installation. Part 1: Specification and quality assurance
- EN 50174-2 Information technology - Cabling installation. Part 2: Installation planning and practices inside buildings
- EN 50310 Application of equipotential bonding and earthing in buildings with information technology equipment.
- EN 50173 Information Technology - Generic cabling systems
- HD 60364-4-444 Low-voltage electrical installations Part 4-444: Protection for safety - Protection against voltage disturbances and electromagnetic disturbances

3.12 Electrostatic discharge protection

Normally, the use of specific tools or packages is required to handle or carry electronics boards or components (CPU, memory, analog, PCMCIA modules, etc.) which are sensitive to Electrostatic discharge (ESD).

Our products comply with standard ESD tests but ESD conditions are in some cases over the specs.

ESD threat could cause semiconductors aging and failures. Without any care, the semiconductor devices could be damaged or burned without users noticing.

Solution

The use of specific anti ESD wrist strap is highly recommended. This wrist strap shall be installed inside each cabinet and correctly connected to the earthed cabinet metallic frame.

Provide a procedure which depicts the good conditions of use.

An example is shown below.

ESD Wrist Strap (see Fig. R28)

Static electricity is produced by the contact and separation of materials: Shoes and floors, clothes and the human body, parts being moved on or from surfaces. The generated charge will reside on the body until it is discharged - the familiar "zap" that all of us have experienced. It's the "zap" that does the damage. If we can prevent any static charge from building up on the body, then there is essentially nothing to be discharged. A properly grounded wrist strap effectively prevents any static charge from building up. Any static charge that would tend to be created is instantly "drained" by the wirst strap. The wrist strap maintains the potential equilibrium that is accomplished the hard way with the "zap".

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Fig. R28 ESD wrist strap examples

4 Coupling mechanisms and counter-measures

4.1 General

An EM interference phenomenon may be summed up in Fig. R29 below.

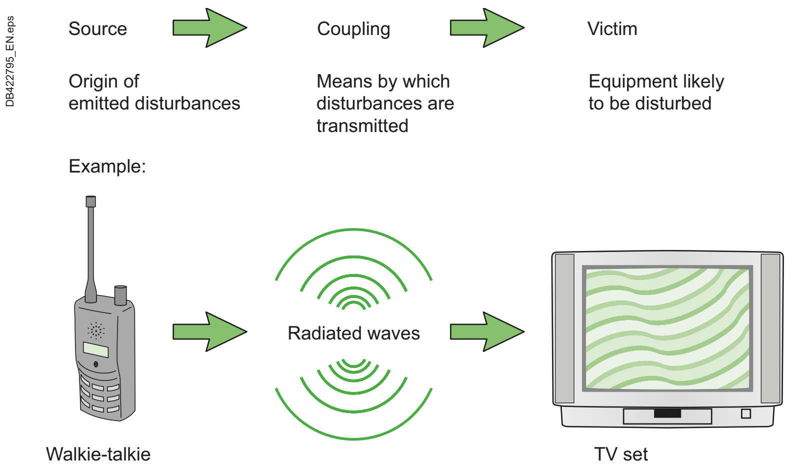

Fig. R29 EM interference phenomenon

The different sources of disturbances are:

- Radio-frequency emissions
  - Wireless communication systems (radio, TV, CB, radio telephones, remote controls)
  - Radar
- Electrical equipment
  - High-power industrial equipment (induction furnaces, welding machines, stator control systems)
  - Office equipment (computers and electronic circuits, photocopy machines, large monitors)
  - Discharge lamps (neon, fluorescent, flash, etc.)
  - Electromechanical components (relays, contactors, solenoids, current interruption devices)
- Power systems
  - Power transmission and distribution systems
  - Electrical transportation systems
- Lightning
- Electrostatic discharges (ESD)
- Electromagnetic nuclear pulses (EMNP)

The potential victims are:

- Radio and television receivers, radar, wireless communication systems
- Analogue systems (sensors, measurement acquisition, amplifiers, monitors)
- Digital systems (computers, computer communications, peripheral equipment)

The different types of coupling are:

- Common-mode impedance (galvanic) coupling
- Capacitive coupling
- Inductive coupling
- Radiated coupling (cable to cable, field to cable, antenna to antenna)

4.2 Common-mode impedance coupling

Definition

Two or more devices are interconnected by the power supply and communication cables (see Fig. R30). When external currents (lightning, fault currents, disturbances) flow via these common-mode impedances, an undesirable voltage appears between points A and B **which are supposed to be equipotential**. This stray voltage can disturb low-level or fast electronic circuits.

All cables, including the protective conductors, have an impedance, particularly at high frequencies.

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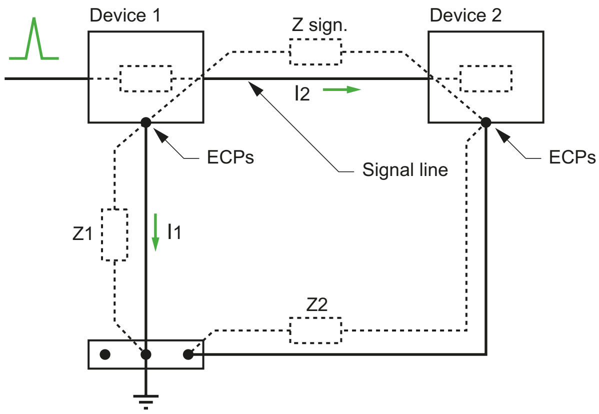

The exposed conductive parts (ECP) of devices 1 and 2 are connected to a common earthing terminal via connections with impedances Z1 and Z2.

The stray overvoltage flows to the earth via Z1. The potential of device 1 increases to Z1 I1. The difference in potential with device 2 (initial potential = 0) results in the appearance of current I2.

$$Z1\ I1 = (Zsign + Z2)\, I2 \Rightarrow \frac{I2}{I1} = \frac{Z1}{(Zsign + Z2)}$$

Current I2, present on the signal line, disturbs device 2.

Fig. R30 Definition of common-mode impedance coupling

Examples (see Fig. R31)

- Devices linked by a common reference conductor (e.g. PEN, PE) affected by fast or intense (di/dt) current variations (fault current, lightning strike, short-circuit, load changes, chopping circuits, harmonic currents, power factor correction capacitor banks, etc.)
- A common return path for a number of electrical sources

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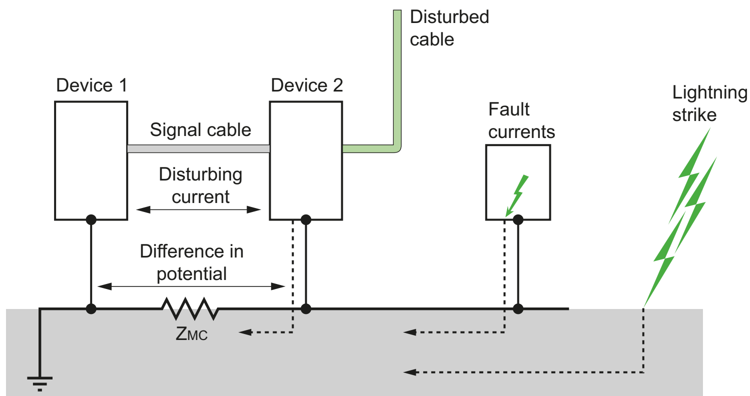

Fig. R31 Example of common-mode impedance coupling

Counter-measures (see Fig. R32)

If they cannot be eliminated, common-mode impedances must at least be as low as possible. To reduce the effects of common-mode impedances, it is necessary to:

- Reduce impedances:
  - Mesh the common references,
  - Use short cables or flat braids which, for equal sizes, have a lower impedance than round cables,
  - Install functional equipotential bonding between devices.
- Reduce the level of the disturbing currents by adding common-mode filtering and differential-mode inductors

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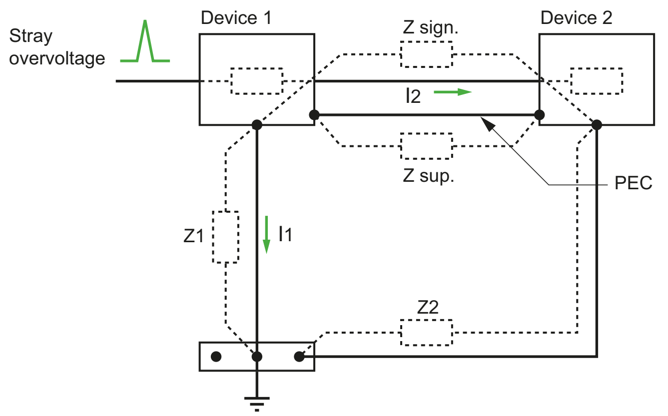

If the impedance of the parallel earthing conductor PEC (Z sup) is very low compared to Z sign, most of the disturbing current flows via the PEC, i.e. not via the signal line as in the previous case.
The difference in potential between devices 1 and 2 becomes very low and the disturbance acceptable.

Fig. R32 Counter-measures of common-mode impedance coupling

4.3 Capacitive coupling

Definition

The level of disturbance depends on the voltage variations (dv/dt) and the value of the coupling capacitance between the disturber and the victim.

Capacitive coupling increases with:

- The frequency,
- The proximity of the disturber to the victim and the length of the parallel cables,
- The height of the cables with respect to a ground referencing plane,
- The input impedance of the victim circuit (circuits with a high input impedance are more vulnerable),
- The insulation of the victim cable (ε_r of the cable insulation), particularly for tightly coupled pairs.

Fig. R33 shows the results of capacitive coupling (cross-talk) between two cables.

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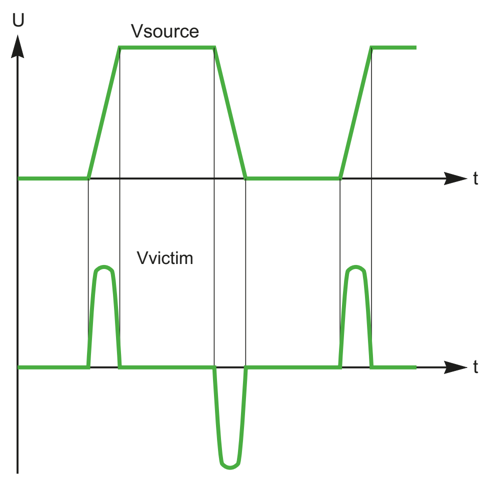

Fig. R33 Typical result of capacitive coupling (capacitive cross-talk)

Examples (see Fig. R34 opposite page)

- Nearby cables subjected to rapid voltage variations (dv/dt),
- Start-up of fluorescent lamps,
- High-voltage switch-mode power supplies (photocopy machines, etc.),
- Coupling capacitance between the primary and secondary windings of transformers,
- Cross-talk between cables.

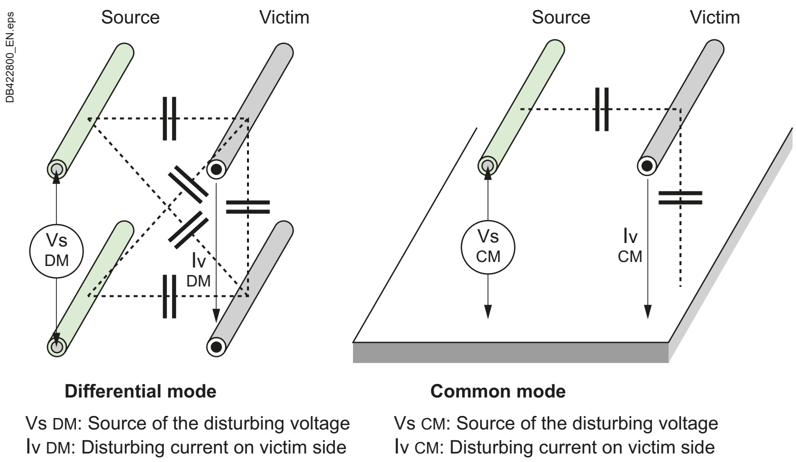

Fig. R34 Example of capacitive coupling

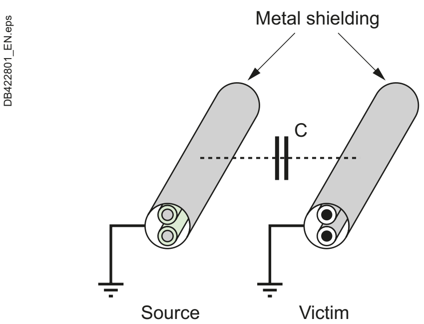

Fig. R35 Cable shielding with perforations reduces capacitive coupling

Counter-measures (see Fig. R35)

- Limit the length of parallel runs of disturbers and victims to the strict minimum.
- Increase the distance between the disturber and the victim.
- For two-wire connections, run the two wires as close together as possible.
- Position a PEC bonded at both ends and between the disturber and the victim.
- Use two or four-wire cables rather than individual conductors.
- Use symmetrical transmission systems on correctly implemented, symmetrical wiring systems.
- Shield the disturbing cables, the victim cables or both (the shielding must be bonded).
- Reduce the dv/dt of the disturber by increasing the signal rise time where possible.

4.4 Inductive coupling

Definition

The disturber and the victim are coupled by a magnetic field. The level of disturbance depends on the current variations (di/dt) and the mutual coupling inductance.

Inductive coupling increases with:

- The frequency,
- The proximity of the disturber to the victim and the length of the parallel cables,
- The height of the cables with respect to a ground referencing plane,
- The load impedance of the disturbing circuit.

Examples (see Fig. R36 next page)

- Nearby cables subjected to rapid current variations (di/dt)
- Short-circuits.
- Fault currents.
- Lightning strikes.
- Stator control systems.
- Welding machines.
- Inductors.

4 Coupling mechanisms and counter-measures

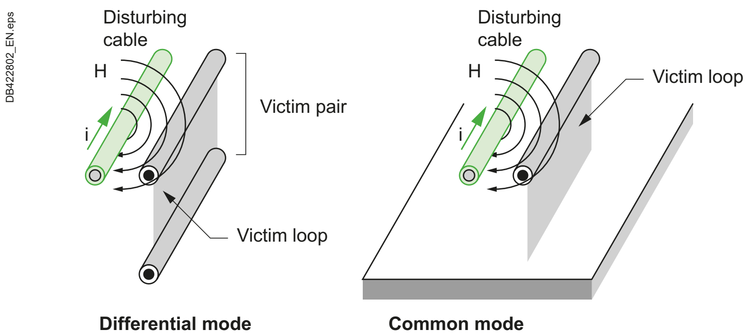

Fig. R36 Example of inductive coupling

Counter-measures

- Limit the length of parallel runs of disturbers and victims to the strict minimum.
- Increase the distance between the disturber and the victim.
- For two-wire connections, run the two wires as close together as possible.
- Use multi-core or touching single-core cables, preferably in a triangular layout.
- Position a PEC bonded at both ends and between the disturber and the victim.
- Use symmetrical transmission systems on correctly implemented, symmetrical wiring systems.
- Shield the disturbing cables, the victim cables or both (the shielding must be bonded).
- Reduce the dv/dt of the disturber by increasing the signal rise time where possible (series-connected resistors or PTC resistors on the disturbing cable, ferrite rings on the disturbing and/or victim cable).

4.5 Radiated coupling

Definition

The disturber and the victim are coupled by a medium (e.g. air). The level of disturbance depends on the power of the radiating source and the effectiveness of the emitting and receiving antenna. An electromagnetic field comprises both an electrical field and a magnetic field. The two fields are correlated. It is possible to analyse separately the electrical and magnetic components.

The electrical field (E field) and the magnetic field (H field) are coupled in wiring systems via the wires and loops (see **Fig. R37**).

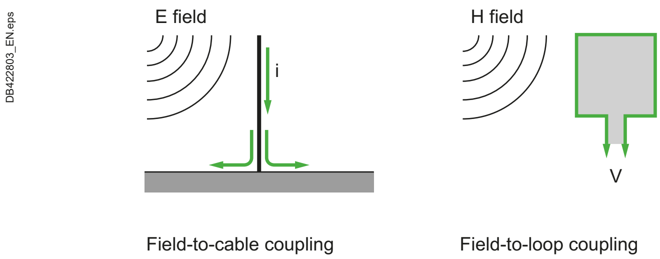

Fig. R37 Definition of radiated coupling

4 Coupling mechanisms and counter-measures

When a cable is subjected to a variable electrical field, a current is generated in the cable. This phenomenon is called field-to-cable coupling.

Similarly, when a variable magnetic field flows through a loop, it creates a counter electromotive force that produces a voltage between the two ends of the loop. This phenomenon is called field-to-loop coupling.

Examples (see Fig. R38)

■ Radio-transmission equipment (walkie-talkies, radio and TV transmitters, mobile services).
■ Radar.
■ Automobile ignition systems.
■ Arc-welding machines.
■ Induction furnaces.
■ Power switching systems.
■ Electrostatic discharges (ESD).
■ Lighting.

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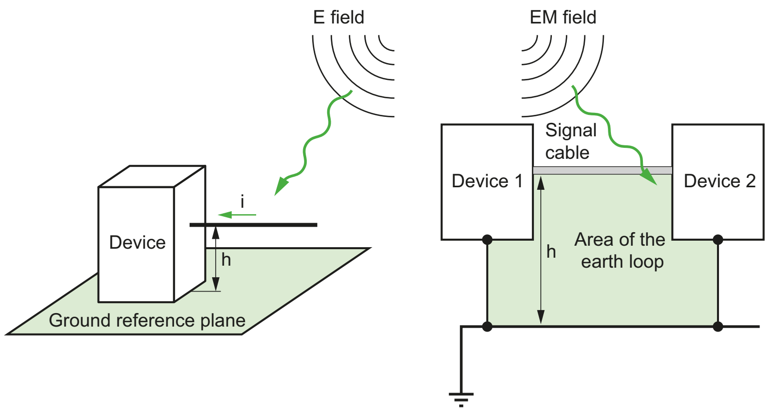

Example of field-to-cable coupling

Example of field-to-loop coupling

Fig. R38 Examples of radiated coupling

Counter-measures

To minimise the effects of radiated coupling, the measures below are required.

For field-to-cable coupling

■ Reduce the antenna effect of the victim by reducing the height (h) of the cable with respect to the ground referencing plane.

■ Place the cable in an uninterrupted, bonded metal cableway (tube, trunking, cable tray).

■ Use shielded cables that are correctly installed and bonded

■ Add PECs.

■ Place filters or ferrite rings on the victim cable.

For field-to-loop coupling

■ Reduce the surface of the victim loop by reducing the height (h) and the length of the cable. Use the solutions for field-to-cable coupling. Use the Faraday cage principle.

Radiated coupling can be eliminated using the Faraday cage principle. A possible solution is a shielded cable with both ends of the shielding connected to the metal case of the device. The exposed conductive parts must be bonded to enhance effectiveness at high frequencies.

Radiated coupling decreases with the distance and when symmetrical transmission links are used.

5 Wiring recommendations

5.1 Signal classes (see Fig. R39)

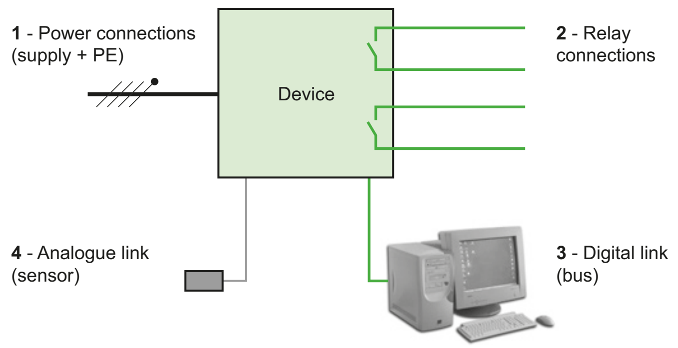

Fig. R39 Internal signals can be grouped in four classes

Four classes of internal signals are:

- Class 1
Mains power lines, power circuits with a high di/dt, switch-mode converters, power-regulation control devices.
This class is not very sensitive, but disturbs the other classes (particularly in common mode).
- Class 2
Relay contacts.
This class is not very sensitive, but disturbs the other classes (switching, arcs when contacts open).
- Class 3
Digital circuits (HF switching).
This class is sensitive to pulses, but also disturbs the following class.
- Class 4
Analogue input/output circuits (low-level measurements, active sensor supply circuits). This class is sensitive.

It is a good idea to use conductors with a specific colour for each class to facilitate identification and separate the classes. This is useful during design and troubleshooting.

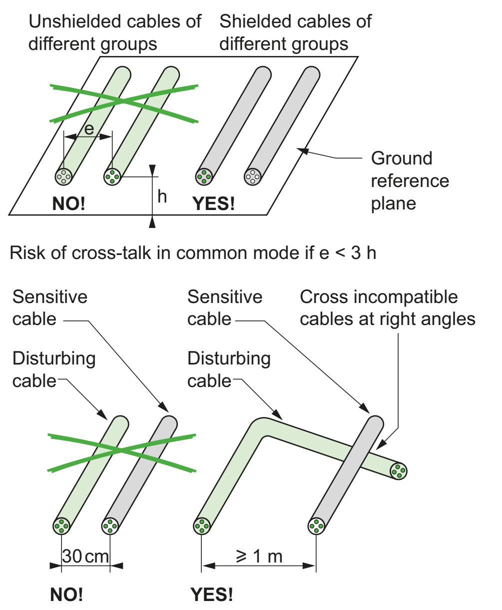

Fig. R40 Wiring recommendations for cables carrying different types of signals

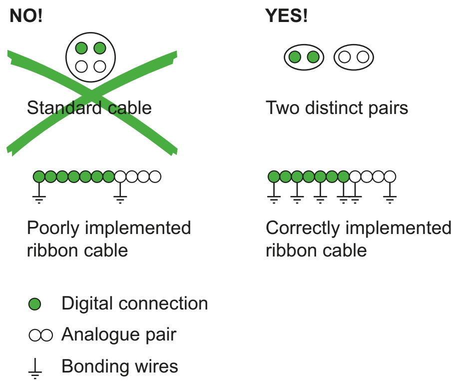

Fig. R41 Use of cables and ribbon cable

5.2 Wiring recommendations

Cables carrying different types of signals must be physically separated (see Fig. R40)

Disturbing cables (classes 1 and 2) must be placed at some distance from the sensitive cables (classes 3 and 4) (see Fig. R40 and Fig. R41)

In general, a 10 cm separation between cables laid flat on sheet metal is sufficient (for both common and differential modes). If there is enough space, a distance of 30 cm is preferable. If cables must be crossed, this should be done at right angles to avoid cross-talk (even if they touch). There are no distance requirements if the cables are separated by a metal partition that is equipotential with respect to the ECPs. However, the height of the partition must be greater than the diameter of the cables.

5 Wiring recommendations

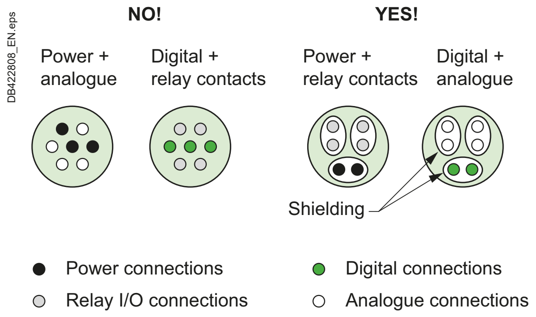

Fig. R42 Incompatible signals = different cables

A cable should carry the signals of a single group (see **Fig. R42**)

If it is necessary to use a cable to carry the signals of different groups, internal shielding is necessary to limit cross-talk (differential mode). The shielding, preferably braided, must be bonded at each end for groups 1, 2 and 3.

It is advised to overshield disturbing and sensitive cables (see **Fig. R43**)

The overshielding acts as a HF protection (common and differential modes) if it is bonded at each end using a circumferential connector, a collar or a clampere. However, a simple bonding wire is not sufficient.

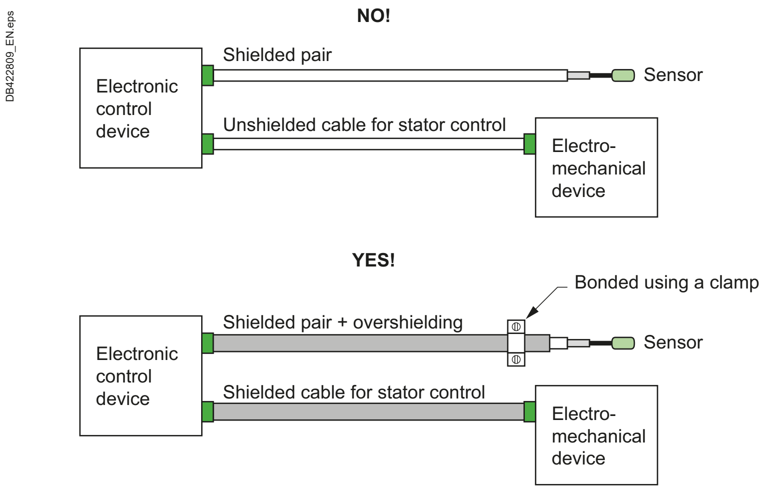

Fig. R43 Shielding and overshielding for disturbing and/or sensitive cables

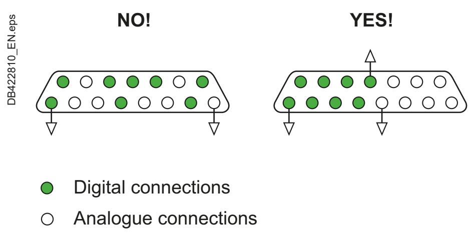

Fig. R44 Segregation applies to connectors as well!

Avoid using a single connector for different groups (see **Fig. R44**)

Except where necessary for groups 1 and 2 (differential mode). If a single connector is used for both analogue and digital signals, the two groups must be separated by at least one set of contacts connected to 0 V used as a barrier.

All free conductors (reserve) must always be bonded at each end (see **Fig. R45**)

For group 4, these connections are not advised for lines with very low voltage and frequency levels (risk of creating signal noise, by magnetic induction, at the transmission frequencies).

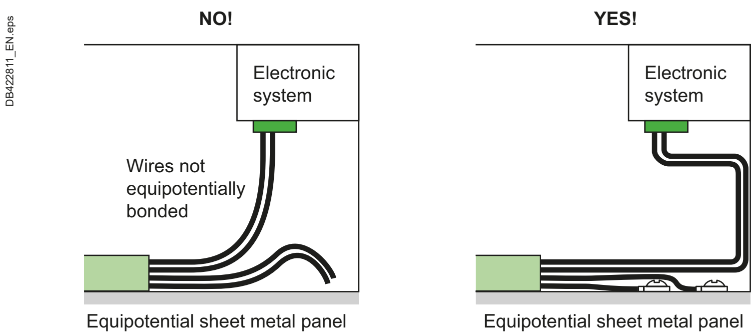

Fig. R45 Free wires must be equipotentially bonded

5 Wiring recommendations

The two conductors must be installed as close together as possible (see Fig. R46)

This is particularly important for low-level sensors. Even for relay signals with a common, the active conductors should be accompanied by at least one common conductor per bundle. For analogue and digital signals, twisted pairs are a minimum requirement. A twisted pair (differential mode) guarantees that the two wires remain together along their entire length.

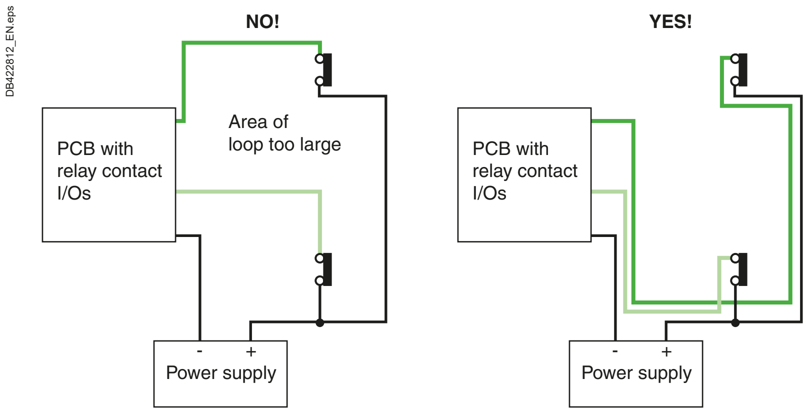

Fig. R46 The two wires of a pair must always be run close together

Group-1 cables do not need to be shielded if they are filtered

But they should be made of twisted pairs to ensure compliance with the previous section.

Cables must always be positioned along their entire length against the bonded metal parts of devices (see Fig. R47)

For example: Covers, metal trunking, structure, etc. In order to take advantage of the dependable, inexpensive and significant reduction effect (common mode) and anti-cross-talk effect (differential mode).

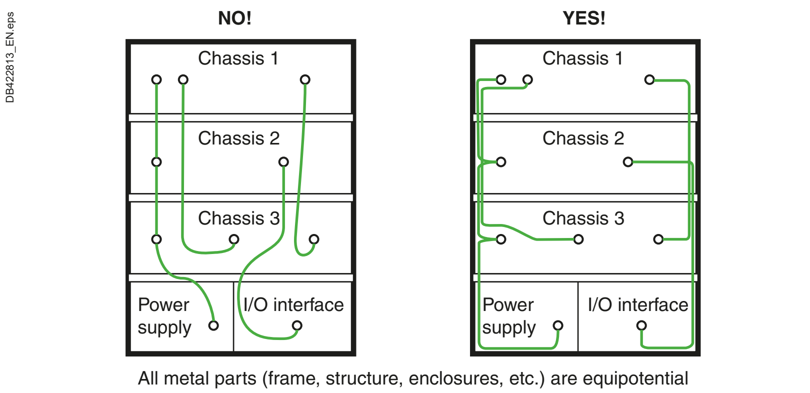

Fig. R47 Run wires along their entire length against the bonded metal parts

The use of correctly bonded metal trunking considerably improves internal EMC (see Fig. R48)

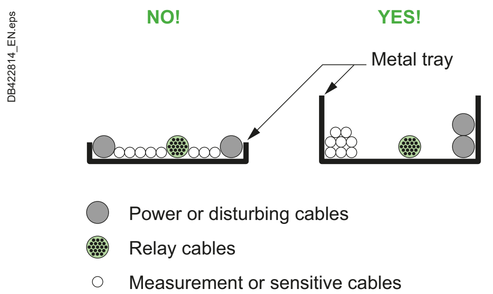

Fig. R48 Cable distribution in cable trays

Measurement

1 Measurement applications

This chapter is an introduction to the different applications of measurements, and to the main standards relevant for these different applications.

There are different kinds of application that need measurement. Basically, applications can be split between 5 categories, as described in **Fig. S1**.

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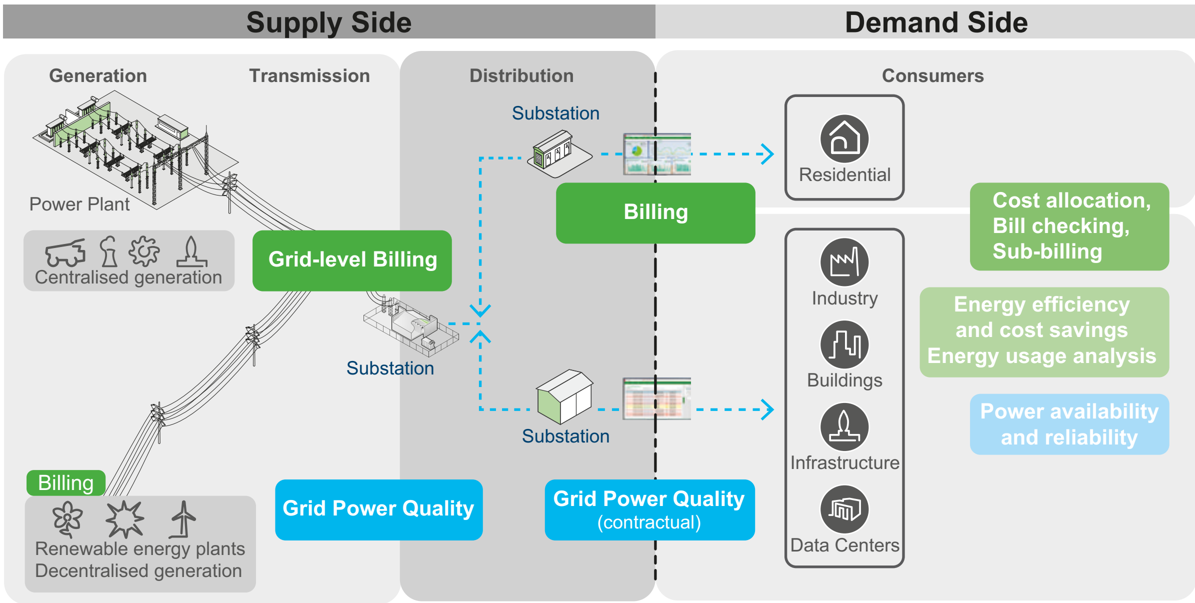

Fig. S1 The five main measurement applications in relationship to the supply side and the demand side

2 Description of applications

2.1 Energy efficiency and cost savings

For this application, energy needs to be measured in order to make it more efficient, to allocate it within a plant, or to reduce its cost.

Energy efficiency aspects are dealt with in more details in chapter K.

The main standards are specified below.

See also recommendations provided in Focus on IEC 61557-12 standard.

Assessment of a complete site	Assessment tools	Devices used to assess the site
ISO 50001 Energy Management Systems – Requirements with guidance for use	**ISO 50006** Energy Baseline (EnBs) & Energy Performance Indicators (EnPIs) **IEC 60364-8-1** Low voltage installations – Part 8-1: Energy Efficiency afnor **FD X30-147**[a] Measurement plan for energy performance monitoring	**PMD (Power Meters)** **IEC 61557-12** Power Metering and Monitoring devices (PMD) **Gateways, energy servers, data loggers** **IEC 62974-1** Monitoring and measuring systems used for data collection, gathering and analysis – Part 1: Device requirements

[a] FD X30-147 is a guide published by AFNOR (French national organization for standardization), which specifies the requirements, methodology and deliverables for the design, implementation, operation, maintenance and improvement of a metering system.

Fig. S2 Standards for Energy Efficiency, cost allocation & optimization

PB117051.eps

Acti9 iEM2000 series energy meters
Schneider Electric

PB117052.eps

Acti9 iEM3000 series energy meters
Schneider Electric

Fig. S3 Examples of products compliant with IEC 61557-12, for Energy Efficiency

2.2 Power availability and reliability

In order to operate an electrical installation, it is recommended that measurement of the main characteristics of the supply such as voltage, current, frequency, and/or active power are provided as a minimum.

Some electrical phenomena can have an impact on both installation assets and operations within a plant (e.g. unbalance can reduce the life time of motors, dips can stop a process, etc.)

The following table describes the main problems that can occur in a network:

Parameter	Measurement	Influence on installation energy efficiency	Influence on installation performance
Power Factor (PF or cos φ)	PF	Low PF generates additional losses in the installation. Energy provider is charging penalties to the customer	Cables heating (cables need to be oversized)
Voltage and current harmonics	THDu THDi	Negative sequence harmonics (u2) are slowing motors down. Harmonics generates extra losses in the installation	Early failure of some devices, mainly motors
Permanent or frequent deviations of voltage	U	Devices may work outside their specified range, and they may over consume, mainly motors	Early failure of some devices, mainly motors
Voltage unbalance	Uimb	Voltage unbalance generates extra losses in motors.	Early failure of some devices, mainly motors
Dips and interruptions	Udip Uint	---	Process interruption with financial impacts
Frequency	f	---	Rotating machines may change their speed according to frequency
Flicker or RVC	Pst RVC	---	These phenomena can generate disturbing phenomena on lighting

Fig. S4 Main problems that can occur in an electrical network, and their potential consequences

The main standards are specified below:

Installation needs /standard	Measuring methods standard	Product standard
Voltage, current and frequency indication	---	**Analog meters** **IEC 60051** Direct acting indicating analog electrical measuring instruments
Electrical Distribution Monitoring	---	**PMD (Power Meters)** **IEC 61557-12** Power Metering and Monitoring devices (PMD)
	IEC 61000-4-30 Testing and measuring techniques – Power quality measurement methods	**PMD (Power Meters) with class A or S methods** **IEC 61557-12** Power Metering and Monitoring devices (PMD) **and** **IEC 62586-2** NEW Power quality measurement in power supply systems - Functional tests and uncertainty requirements (Compliance to IEC 62586-2 means compliance to IEC 61000-4-30)

Fig. S5 Standards for power availability and reliability

PB117053.eps

PB117054.eps

PB117055.eps

Compact NSX circuit breaker equipped with a Micrologic trip unit, Schneider Electric

PowerLogic PM5000 series power meters Schneider Electric

PowerLogic PM8000 series power meters Schneider Electric

Fig. S6 Examples of products compliant with IEC 61557-12, for Electrical Distribution Monitoring

2.3 Grid power quality

Some regulations or specific contracts require energy providers to keep voltage characteristics at any supply terminal within specified limits. These specifications cover limits or values related to voltage, frequency, rapid voltage changes, harmonics, interharmonics, unbalance, dips, swells, interruptions, flicker, ...

Measurements are typically made on the energy provider side (to check delivered energy complies to the contract) and on the consumer side (to check received energy complies with the contract) with Power Quality Instruments class A according to IEC 61000-4-30.

Application assessment standard	Measuring methods standard	Product standard
CENELEC **EN 50160** Voltage characteristics of electricity supplied by public electricity networks IEC **IEC/TS 62749** NEW Assessment of Power Quality – Characteristics of electricity supplied by public electricity networks	IEC **IEC 61000-4-30 class A** Testing and measuring techniques – Power quality measurement methods	**PQI (Power Quality Instruments)** IEC **IEC 62586-1** NEW Power quality measurement in power supply systems - Power Quality Instruments (PQI) **and** IEC **IEC 62586-2** NEW Power quality measurement in power supply systems - Functional tests and uncertainty requirements (Compliance to IEC 62586-2 means compliance to IEC 61000-4-30)

Fig. S7 Standards for Grid power quality assessment

PB117056.eps

PB117057.eps

PB117058.eps

PowerLogic ION7550/ION7650 Power Quality Device Schneider Electric

PowerLogic ION8800 Power Quality Device Schneider Electric

PowerLogic ION8650 Power Quality Device Schneider Electric

Fig. S8 Examples of products compliant with IEC 61000-4-30 for Grid Power Quality

S5

2 Description of applications

2.4 Billing

Billing is the process that allows energy suppliers or their representatives to invoice their customers according to a defined contract, for measured usages or services.

These applications are covered by international, regional or local standards in addition to utility specifications. Regulations such as MID in Europe or NMI M-6 in Australia, LBM-EG-07 in Canada, JJG 596 in China… can apply additionally.

Devices for billing applications are devices with specific legal metrology requirements, and are then subject to specific requirements such as periodic verification (usually every 6 to 10 years) according to local regulations.

2.5 Cost allocation, bill checking and sub-billing

Sub-billing is the process that allows a landlord, property management firm, condominium association, homeowner association or other multi-tenant property to spread out an invoice over tenants, for measured usages or services.
This fee is usually combined with other fees within a tenant's facility fee.

Since the meter used for sub billing is typically installed in electrical room not accessible by the tenant, the risk of fraud is very limited. This is why devices complying with IEC 61557-12 as well as devices used for billing applications can be used for sub-billing applications. Attention should be put on environmental aspects where the device used for sub-billing needs to fit EMC, temperature and mechanical environment. In any case, measuring devices used in for sub-billing in switchboards and panels need to comply with IEC 61557-12.

Cost allocation is the process that allows a facility manager to allocate energy costs to internal cost centers that consume energy (e.g. plants, workshop, …)

Bill checking is the process that allows customers to check invoice sent by energy suppliers or their representatives is correct.

3 Focus on IEC 61557-12 standard

Increasingly, digital equipment is replacing analog equipment in electrical installations. It supports more accurate measurement of new values and is able to make these available to users at both local and remote locations.

Devices intended to perform monitoring have various characteristics which require a shared reference system. This system must allow users to make easier choices in terms of performance levels, dependability and to interpret different measured parameters.

All these various measuring devices (referred to as “PMD” for “Power Metering and Monitoring Device”) have to meet the requirements of international standard IEC 61557-12: "Electrical safety in low voltage distribution systems up to 1000 V a.c. and 1500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 12: Power Metering and monitoring devices (PMD)".

The standard gives a list of the main requirements applicable to PMD with guidance about sensors to use (in case sensors are requested).

3.1 PMD functions

All the possible electrical parameters to be measured are listed.
For each parameter, a list of requirements is specified, such as the rated range of operation, the range of influence quantities, the measurement techniques, etc.

The considered electrical parameters are given here:

- Active energy (classes are equivalent to the classes defined in IEC 62053-21 and IEC 62053-22),
- Reactive energy (classes are equivalent to the classes defined in IEC 62053-23)
- Apparent energy,
- Active, reactive and apparent power,
- Frequency,
- r.m.s. phase and neutral current,
- r.m.s. voltage,
- Power factor,
- Voltage dip and swell,
- Voltage interruption,
- Voltage unbalance,
- Harmonic voltage and distortion,
- Harmonic current and distortion,
- Maximum, minimum, peak, average, demand and values.

3 Focus on IEC 61557-12 standard

3.2 Marking

According to this standard, devices have a code denoting their installation options, operating temperature range and accuracy class. As a result, it has become significantly easier to select and identify these devices (see Fig. S9).

PowerLogic PM8000 series power meter complying with IEC 61557-12 as:
PMD/SD/K70/0,2 and PMD/SS/K70/0,2

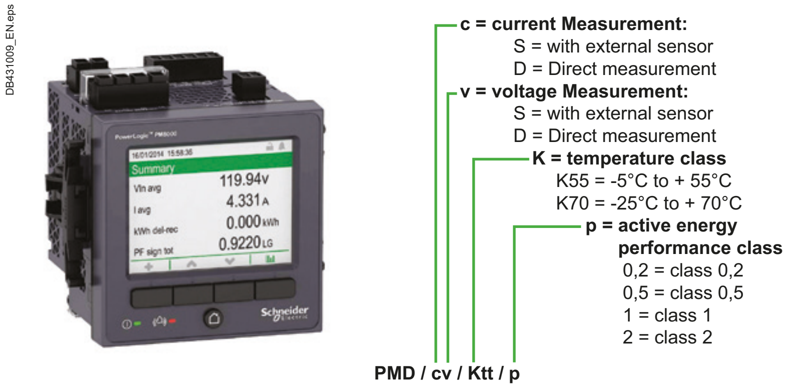

Fig. S9 Identifying measuring devices in accordance with IEC 61557-12

3.3 Uncertainty over a measuring range

The notion of performance classes (e.g. class 1 for active energy measurement) specified by IEC 61557-12 is much more than a requirement related to uncertainty at nominal current.

- intrinsic uncertainty: compliance covers performance under two sets of reference conditions
- operating uncertainty: compliance covers performance under 12 environmental and electromagnetic influence quantities which typically affect PMD operation
- overall system uncertainty: some information is provided about how to estimate uncertainty of a PMD operating with external sensors.

3.3.1 Intrinsic uncertainty

Intrinsic uncertainty is the uncertainty of a measuring instrument when used under reference conditions (e.g. at 23°C) for different Power Factor values.
In this standard, it is a percentage of the measured value (readings).

Fig. S10 specifies intrinsic uncertainty limits for class 1 and class 0,2 active energy measurement at Power Factor = 1, according to Table 8 of IEC 61557-12.

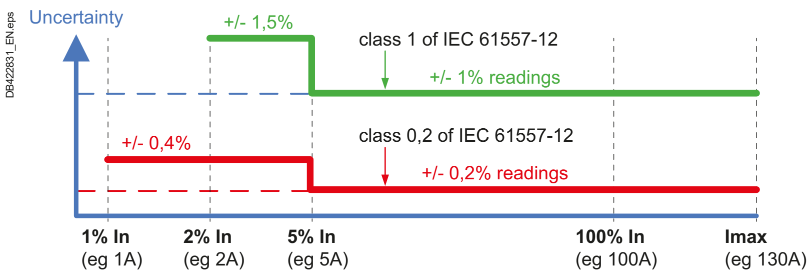

Fig. S10 Uncertainty limits for active energy at Power Factor = 1

3 Focus on IEC 61557-12 standard

Fig. S11 specifies intrinsic uncertainty limits for class 1 and class 0,2 active energy measurement at Power Factor = 0,5 inductive and 0,8 capacitive, according to Table 8 of IEC 61557-12.

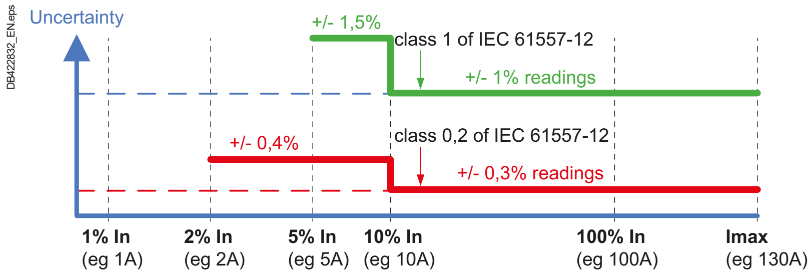

Fig. S11 Uncertainty limits for active energy at Power Factor = 0,5 inductive and 0,8 capacitive

IEC 61557-12 also specifies requirements about no-load conditions and starting current.

3.3.2 Operating uncertainty (based on variations due to influence quantities)

Operating uncertainty is the uncertainty under the rated operating conditions (including drifts related to temperature, frequency, EMC, ….)

IEC61557-12 specifies tests and uncertainty maximum variation of uncertainty due to various influence quantities such as ambient T°, frequency, unbalance, harmonics and EMC.

	Maximum uncertainty variation for active energy measurements according to table 9 of IEC 61557-12		
Influence quantities	**Conditions**	**for class 1**	**for class 0,2**
Ambient T°	PF = 1	0,05% / °K	0,01% / °K
	PF = 0,5 Ind	0,07% /°K	0,02% / °K
Aux Power supply	24Vdc +/-15%	0,1%	0,02%
Voltage	PF = 1; 80% / 120% Un	0,7%	0,1%
	PF = 0,5Ind; 80% / 120% Un	1%	0,2%
Frequency	49Hz 51Hz / 59Hz 61Hz PF = 1	0,5%	0,1%
	49Hz 51Hz / 59Hz 61Hz PF = 0,5	0,7%	0,1%
Reversed phase sequence		1,5%	0,05%
Voltage unbalance	0 to 10%	2%	0,5%
Phase missing	One or 2 phase missing	2%	0,4%
Harmonic in current and voltage	10%Un 5th 20%Imax 5th	0,8%	0,38%
	Odd harmonic in current	3%	0,6%
	Odd harmonic in tension	3%	0,6%
Common mode voltage rejection		0,5%	0,2%
Permanent a.c. magnetic induction 0,5 mT		2%	2%
Electromagnetic RF fields		2%	0,98%
Conducted disturbances induced by RF fields		2%	0,98%

Fig. S12 Tests related to influencing quantities

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