Electromagnetic compatibility of the switchboards
Spacial enclosures
Technical guide

How to protect a machine from malfunctions due to electromagnetic disturbance
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Industrial workshops are places in which there is often a high concentration of electromagnetic disturbance:

- In the metallurgy industry, the electric power required generates very strong magnetic fields in the vicinity of electrolysis tanks and induction furnaces.
- Workshops manufacturing parts in PVC or rubber use high-frequency welding processes to perform assembly.

The propagation of strong magnetic fields and high-frequency waves is not easily controllable. It creates local pollution in the midst of which the monitoring and control equipment must be able to operate.

There are numerous ways of ensuring process electromagnetic compatibility (EMC: capability for operating in a disturbed environment).

To obtain optimal performance, strict rules apply at all levels:
- building earthing system;
- communication cables, sensor cables;
- electrical panel.
Electromagnetic disturbances are present everywhere, up to the core of the electrical panels. Its effects are hard to predict.

Electromagnetic disturbances are potential sources of malfunctions for all electronic equipment:

• Controllers and measuring devices, processing analogue signals;
• PLCs and communication interfaces, processing digital signals.

It will be hard to identify the presence of these disturbances because they may be transient and appear only in certain process conditions. Compliance with the design code is therefore recommended to avoid such problems.

Interference conducted by sensor cables

Interference of various frequencies is superimposed on the original signal. The signal thus becomes not very “understandable” for the equipment that receives it, and as a consequence its processing will be uncertain or impossible.

Configuration examples:

• runs along another highly disturbing cable (variable speed drive/motor link, for example);
• is not shielded;
• shielding is inappropriately linked (e.g. flow of “stray” currents caused by earthing of the two ends of shielding, especially in case of a TN-C system).

Interference radiated by a device

A processing device is disturbed by a bundle of high-frequency waves: it stops suddenly, is reinitialized for no apparent reason or generates abnormal results. And yet the input signals are correct.

This type of situation can occur when the controller’s earthing is incorrect: excessively thin wire, excessively resistive connection (existence of paint at the point of connection). A controller or electrical control panel cover containing too many “windows” can also be the cause of this.
Reference regulations and standards

IEC 61439

It requires no test concerning the electromagnetic compatibility of components (whether it be their immunity to electromagnetic radiation or their emissive power) if the following conditions are met:

• the components installed in the enclosure comply with the requirements laid down by the regulations and standards in force concerning EMC;
• the installation of components in the enclosure and the wiring have been performed in accordance with the manufacturer’s instructions (component layout, cable arrangement, shielding, earthing system, etc.).

If this is not the case, IEC 61439 describes the tests to be performed to check that EMC has been suitably allowed for.

Apparatus:
radiation and radiation resistance

European directive

EMC 2014/30/UE

It relates to all electrical and electronic equipment placed on the market or put into service, excluding equipment covered by a specific directive (e.g. medical equipment).

This equipment must be designed so as not to generate electromagnetic disturbance that could disturb the operation of other equipment.

It must also be capable of operating satisfactorily in the context of the planned application (environment, power supply mode, etc.).

The directive is based on IEC international standards:

• for industrial environments,
  IEC 61000-6-2 (immunity),
  IEC 61000-6-4 (emission);
• for residential, commercial and light industrial environments,
  IEC 61000-6-1 (immunity),
  IEC 61000-6-3 (emission).
Reference regulations and standards

Installations: main rules

International

IEC 61439
Low-voltage switchgear and controlgear assemblies.
Part 1: General rules.
Section 10-5-2: Effective continuity between the exposed conductive parts of the ASSEMBLY and the protective circuit.
Section 10-12: Electromagnetic compatibility (EMC).
Appendix J (normative): Electromagnetic compatibility (EMC).
Part 2: Power switchgear and controlgear assemblies.

IEC 61000
Electromagnetic compatibility (EMC).
Part 5: Installation and attenuation guide.
Section 2: Earthing and wiring.
Section 6: mitigation of external electromagnetic influences.

IEC 60364-4-44
Building electrical installations.
Part 4-44: Protection against voltage disturbance and electromagnetic disturbance.

European

EN 50174-2
Information technologies - Wiring installation.
Part 2: Planning and practices for installation inside buildings.

EN 50310
Application of equipotential bonding and earthing in rooms with information technology equipment.

French

UTE C 15-900 guide
Installation of power and communication networks in buildings.

NF EN 50310
Application of equipotential bonding and earthing in rooms with information technology equipment.

NF EN 50174
Information technology - Cabling installation.
Part 2: Installation planning and practices inside buildings.

Tests

IEC 61587
Mechanical structures for electronic equipment - Tests for IEC 60917 and IEC 60297.
1

Allowing for EMC during switchboard design
The electromagnetic compatibility (EMC) of a panel represents its capability for operating in a disturbed environment while limiting its own disturbing emissions.

Striving for overall efficiency will involve:

• reducing interference at the source, which may also be external to the panel;
• protection of the information exchanged with the process all along its route, including in the panel;
• panel protection against incoming radiated and conducted interference.

3 keys for optimized EMC:

1. **Removal of interference at source**, via a well meshed earthing system.
2. **Protection of low power connecting cables**, by a continuous shielding.
3. **Design and construction of the panel** in compliance with fundamental EMC principles.

The regulations related to human safety require equipotential bonding of the exposed metallic conductive parts of all a building’s equipment. Power and IT systems devices are therefore all connected to the building’s single earthing system. Due to its interconnected meshes, this system also shields against pollution by high-frequency waves.

The connection points distributed symmetrically around the building evenly balance the impedance of the earthing system.

However, even on installations in perfect condition, a flow of 50 Hz current can be observed on certain earth conductors (stray current). It can be as much as several amperes at a few millivolts if the conductor is sufficiently long. This current can interfere with low power analogue circuits (0-10 V sensor lines, etc.) if they are wired without taking precautions. Digital links are not greatly affected.
Allowing for EMC during switchboard design

Protection of low power signals

Shielding

Use shielded cables

Analogue sensor signals and data flows are sensitive to interference. Shielded cables are used to convey them. These cables are also used to execute variable speed drive/motor links generating less interference.

The shielding consists of:

- a braid, which is an effective barrier for frequencies of up to a few megahertz;
- a metal strap, theoretically effective above such frequencies but which can easily be damaged during handling;
- a metal strap + braid for a mechanically strong broad spectrum protection.

<table>
<thead>
<tr>
<th>Connection</th>
<th>Non-shielded</th>
<th>Shielded</th>
</tr>
</thead>
<tbody>
<tr>
<td>End connected to frame earth:</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Digital sensors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-10 V analogue output probes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-20 mA analogue output probes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communication bus (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable speed drive/Motor link</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) IT system: preferably choose optical fibre
TN-C system: shielding of exposed conductive parts on a single side
TN-S and TT systems: shielding of exposed conductive parts on both sides

Connect the shielding to frame earth

This connection can remove interference to earth. The decision to connect one or both ends to earth means priority is given to protection against low or high frequencies:

- at a single end, 50 Hz stray currents cannot flow, moderate HF protection;
- at both ends, possible presence of 50 Hz current, but the barrier against higher frequencies is strengthened.

Filtering

Reducing the conduction of interference

Some devices generate disturbance on their upstream or downstream circuits: variable speed drives, frequency converters, switch mode power supplies, etc.

The most appropriate treatment is to arrange a filter on the disturbed line, as close as possible to the polluting device.

The appropriate filter characteristics are given by the manufacturers according to the voltage, the current in the line and the frequency of the disturbance to be reduced.

Filter ferrite

When passed through by the polluted wire, the ferrite ring or tube represents an effective filter against high frequencies; it is often used to attenuate low-level cable disturbance.

Several windings of the wire in loops around the ferrite ring reinforce the attenuation (while preventing the ring from slipping if the wire is thin).
Enclosure characteristics

Interference attenuation

If an electrical control panel without holes stops radio-frequency waves by "Faraday cage" effect, the magnetic radiation is attenuated by the sheets depending on the nature of the material. The greatest attenuation is obtained with Aluzinc sheets.

It is important to know this attenuation in order to suitably choose the appropriate panel.

All technical information are available in the General Catalogue for Universal Enclosures (UE16MK15EN).

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Example: Electric field attenuation curves for a 2000 x 800 x 600 SF enclosure (tests performed in accordance with the IEC 61587-3 standard, 2006 edition)

**SF enclosure in Aluzinc 150 sheet metal (ref. NSYSFHF20860)**

**SF enclosure in steel (ref. NSYSF20860)**
Composition
Conductive panels, in steel, for example, offer good protection against electromagnetic radiation. Interior linings and partitions in zinc-coated steel or non-lacquered aluminium strengthen this protection at various points.

Electrical continuity
Given the assembled structure of the panel, electrical continuity between the various parts must be achieved so as to offer the lowest possible impedance. Contact points shall be free of paint or any other insulating coating to reduce their impedance.

"Tightness" to interference
All apertures for cable routing, ventilation, indicator lamps, buttons and other components mounted on the front panel, and spaces around the door, could let in HF interference. They should be stopped up insofar as possible. "EMC" seals and accessories are available for this purpose. For the largest apertures, provide for tubes and other metal conduits to form "waveguides" which will prevent high frequencies from entering.
Layout of equipment in a panel

1. Importance of the layout

If high-power and low-power devices are juxtaposed without taking precautions and if cables of different kinds are routed in the same raceways, serious malfunctions are likely. By allowing for the rules described below as of the design stage, one will avoid tedious troubleshooting, the ex-post installation of filters, or even reworking of the layout and wiring.

2. Separate

The dedication of panels by power class is the most efficient measure to obtain an excellent "EMC" result. Moreover, separate routing of disturbing and sensitive cables ensures minimum coupling. A metal raceway ensures equipotential bonding of the panels and efficient conduction of Low and High frequency interference.

3. Partition

Partitioning of the panel into two zones:
• power, and
• low level,
is an alternative. A metal partition will be able to further improve EMC by confining each zone.

For tricky situations

In general, contactors should be kept away from electronic devices. It is recommended to provide wave-trap filters to contactors and relays. A highly disturbing device (variable speed drive, frequency converter, etc.) will have less radiation in the panel if it is "encapsulated" in a small, electromagnetically sealed, unpainted metal enclosure. The enclosure should be carefully connected to the back plate (earth plane).
Assembly and wiring recommendations
1

Panel assembly

Optimization of frame earths
For satisfactory discharge of Low and High frequency disturbance, the panels are interconnected by braids, including the door. One braid would be sufficient, but redundancy ensures better safety for the installation. Braids must have a ratio Length/Width <10 (maximum value) or <5 (recommended value).

Earthing wire
The resistance of contact points is reduced by prior cleaning of any trace of paint or other insulating coating.

Bonding braid
(*) The maximum disturbance levels acceptable in Residential/Service Sector/Small Industry and Industrial environments are defined by the IEC 61000-6-x standard, series 1, 2, 3 and 4, and EC directives.

Earth plane
An unpainted metal plate is placed at the back of the panel to form an earth plane to which will be connected the various braids, the incoming earth cable, cable shielding, etc.

Openings
In an electromagnetic environment in conformity with EMC standards(*), apertures in the panels to receive measuring instruments, displays and screens shall be reduced to what is strictly necessary to limit the entry of high-frequency flows.

2

Installation of enclosures receiving polluted lines

Positioning of filters and power supplies
These components are installed in the panel. When it is presumed that their external connection will take place via a polluted cable, then the enclosures should be arranged so as to allow only a minimum cable length to enter. The radiation of High frequency disturbance will thus be reduced.

Line disturbed by high frequencies
Shielded cables should preferably be used, with the shielding connected to the panel’s earthing plate. If the length of the incoming cable exceeds 1 m, connect its shielding to the entry point and at the filter level.

“Clean” line
The metallic enclosure shall be fastened to the earthing plate, and contact points should be free of paint and any other resistive or insulating material.
Panel wiring

1 External routing in metal raceways

Keep high-power cables away from low-power cables:
• separate raceways if the cables are unshielded $D \geq 5$ cm,
• single raceway possible if the low-power cables are shielded, but maximum spacing.

2 Increasing the efficiency of the shielding on highly disturbing cables

The radiation from a shielded variable speed drive/motor connecting cable will be further reduced if it runs in a closed metal raceway or, even better, in a metal conduit. The raceway and tube need to be connected to earth at either end.
3 Organization of cable entries

Group the cables by type of current:
- Heavy currents: power supply, PEN conductor, etc., actuators,
- Weak currents (< 100 mA): analogue communication.

Create specific incoming feeders in the switchboard, one for each type of current.

In this example, shielded communication signals (*) whose the shielding is connected on both side are less sensitive than analog signals. The least sensitive signals are placed on the same side as the most disturbing signals and vice-versa.
Panel wiring

The disturbances encountered on a site cover a broad frequency spectrum which includes conducted interference (9 kHz to 30 MHz) and radiated interference (> 1 MHz).

In an electrical switchboard, the signals coming from these sources of disturbance will coexist with more sensitive devices. These signals may be classified as follows (Sources: IEC 61000-5-2 and IEC 60364-4-44 standards):

<table>
<thead>
<tr>
<th>Class</th>
<th>Example of connected signals or connected devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sensitive</td>
</tr>
<tr>
<td></td>
<td>• Low-level circuits with analog output units, sensors…</td>
</tr>
<tr>
<td></td>
<td>• Instrument circuits (probe, sensors…)</td>
</tr>
<tr>
<td>2</td>
<td>Not very sensitive</td>
</tr>
<tr>
<td></td>
<td>• Control/command circuits with resistive load</td>
</tr>
<tr>
<td></td>
<td>• Digitalized low-level circuits (Bus…)</td>
</tr>
<tr>
<td></td>
<td>• Low-level circuits with on-off output unit (sensors…)</td>
</tr>
<tr>
<td></td>
<td>• Low-level direct power supply</td>
</tr>
<tr>
<td>3</td>
<td>Not very disturber</td>
</tr>
<tr>
<td></td>
<td>• Control/command circuits with inductive load (relay, contactors, coils, inverter…) with adapted protection</td>
</tr>
<tr>
<td></td>
<td>• Alternating power supply</td>
</tr>
<tr>
<td></td>
<td>• Main power supply connected to power devices</td>
</tr>
<tr>
<td>4</td>
<td>Disturber</td>
</tr>
<tr>
<td></td>
<td>• Welding machines</td>
</tr>
<tr>
<td></td>
<td>• Power circuit</td>
</tr>
<tr>
<td></td>
<td>• Drive, switch mode power supplies…</td>
</tr>
</tbody>
</table>

4 Shielded cable entries

The use of metal cable glands tightened to 360° ideally protects EMC. The cable shielding is connected to the panel’s frame earth over its entire perimeter without being interrupted. It extends over the cable’s entire internal route up to the terminal block, the filter or the variable speed drive where it is again connected to frame earth. The earthing gaskets clamping the shielding at the point of entry are an alternative solution to cable glands.
Cable running in the panel

To be avoided

Inductive loops
An alternating current (50 Hz, harmonics), or pulse current (e.g., lightning) flowing in a panel and forming a loop creates an inductive winding. All the electrical equipment located in this loop will be passed through by a current identical to the original current. Its energy may be significant if the winding is formed by a power cable.

Capacitive effects
Two cables running alongside one another constitute the armatures of a capacitor. The high-frequency components present in one of them (transient surge, pulses, for example) pass into the other cable by going through the stray capacitance.

Local electromagnetic disturbance
The variable electromagnetic fields generated during switching of a contactor coil or at opening of the power contacts disturb the adjacent conductors by coupling effect. The effect is heightened if the disturbing and/or disturbed conductors form windings.

1 Signal separation
Signal separation is necessary to limit coupling between strong signals and weak signals. The minimum distances to be complied with are as follows:

- **Communication cable**
  - Auxiliary power supply
    - DC < 60 V
    - AC < 24 V
  - Minimum distance: 10 cm

- **Power supply**
  - DC > 60 V and < 400 V
  - AC > 25 V and < 400 V
  - Minimum distance: 10 cm

- **Power supply**
  - AC and DC > 400 V
  - Minimum distance: 30 cm

If it is not possible to comply with these distances for want of space, an alternative solution is to cross the signals at a right angle.

Parallel routing

<table>
<thead>
<tr>
<th>Communication cable*</th>
<th>Power cable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication cable*</td>
<td>Power cable</td>
</tr>
</tbody>
</table>

Right angle crossing

<table>
<thead>
<tr>
<th>Communication cable*</th>
<th>Power cable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication cable*</td>
<td>Power cable</td>
</tr>
</tbody>
</table>

*Other possibility:
- Lines protected by an SFO
- Sensitive lines
**Avoid loops**

A loop could develop induced voltage and, as a consequence, an unwanted current on sensitive signals. The best solution is to reduce the length to what is strictly necessary. However, a spare length is often necessary to allow for future extensions. If this is the case, the solution is to place these lengths on a metallic part of the enclosure connected to earth, and reduce the loop surface area, paying attention to the cable radius of curvature.

**Fasten the cables along the metallic parts of the enclosure**

A loop is also created if a cable is placed above a metallic part. Fastening the cables avoids coupling related to this loop. Moreover, if the shielded cable captures a radiated interference and develops an induced current on its shielding, this current will tend to be discharged to frame earth thanks to the natural coupling with the metallic part.
Panel wiring

Example:

The power and earth cables of the panel form a large loop shown in blue. The presence of a surge protective device will facilitate the flow of a high current in the event of a lightning shock. (*)

1. The cables are held against one another to reduce the surface area of the inductive loop.

2. The upstream and downstream power cables of the variable speed drives run alongside one another, creating a transfer of disturbance.

3. The upstream and downstream cables follow separate paths. If necessary, they cross one another at right angles. The disturbing cable is shielded; it is held against the back plate.

4. A time switch is installed between two contactors. It risks malfunctions during contactor switching.

5. The time switch is remote from the contactors.

(*) Refer to the surge arrester wiring instructions: Control Panel Technical Guide • "How to protect a machine from malfunctions due to voltage surge" ref.: CPTG002_EN.
Types of cables

1. Communication cables

Communication cables must be of the SFTP type (Shielded Foiled Twisted Pair) in order to ensure the signal's immunity from conducted interference (from 9 kHz to 30 MHz). Cables of category 5 or 6 may be used, while category 6 cables provide heightened immunity compared with category 5 cables due to the presence of a separate shield on each pair.

- Shielded cable, twisted pairs and with screen
- Shielded cable, twisted pairs and without screen

2. Power cables

Auxiliary power cables must be two-wire in order to control the loop surface area and hence the routing of the + and - conductors (direct current) or phase and neutral (alternating current). A twisted cable provides extra protection and is strongly recommended in confined environments in which separation is not possible.

- Parallel pair cable
- Twisted pair cable
Earth connection of shielding

1 Connection of shielding terminations

For a good connection, adopt 360° shielding (shielding connected to frame earth over its entire circumference, see examples 2 and 3) and eliminate pigtails (shielding connected to frame earth by means of a wire, see example 1). An appropriate mechanical fastener is recommended (see example 3).

A metal cable gland (brass or stainless steel) is the best solution. Take care not to use aluminium in environments that are corrosive or have high humidity levels (> 65%).

Example 1
Shielding connected to frame earth by a wire (pigtail) and no mechanical fastener.
Arrangement to be avoided.

Example 2
Shielding connected to frame earth over its entire circumference, but no mechanical fastener.
Acceptable arrangement.

Example 3
Shielding connected to frame earth over its entire circumference, and a mechanical fastener.
Recommended arrangement.

2 Connection of cables "on standby"

Wires not connected to a potential difference constitute antennas collecting and radiating high-frequency disturbance. This phenomenon can be cancelled by connecting them to the closest frame earth.
Earth connection of panel and metal raceways

1. Panel earth connection

The IEC 61439-2 standard stipulates that earth continuity must be guaranteed by means of a test. A maximum resistance of 0.1 Ohms must be measured between the main earth bar and each metallic part of the enclosure. If this is the case then the green-yellow wires may be directly connected to the casing.

Exceptions: The green-yellow wires coming from a current transformer or power lines (incoming and outgoing) should be connected directly to the earth bar. In any case their length must not exceed 50 cm.
Panel wiring

2 Earth connection of metal raceways

The short connection rule also applies to raceways. In order to ensure earth continuity that is effective in the high frequencies, raceways shall be connected to the enclosure directly, taking the precaution of establishing a metal-on-metal contact without any insulating material adversely affecting electrical continuity.

The raceway is bolted onto the wall.
Auxiliaries power supply
Power supply earth connection

Standard 61439 authorizes earth connection of the enclosure frame if it has earth continuity with a resistance value less than or equal to 0.1 Ohm.

0 V (- or neutral conductor) connection to earth

0 V (- or neutral conductor) connection can limit the common-mode voltage (defined between phases and earth). A single 0 V connection to earth should be made. This connection is possible only if the following conditions are complied with:

- all energized components are located inside the same enclosure;
- all the components located in the same enclosure have the same power supply and none of them have internal connections between their 0 V and earth (to avoid loops);
- the earthing system is TN-S (see p. 38);
- earth is meshed:
  With a meshed earth, all the metallic structures are interconnected.

If one of these conditions is not complied with, it is recommended to leave the +/- or phase/neutral potentials floating. To monitor any possible fault, an insulation tester may be added.
Recommended architecture

General case

The recommended architecture is a star connection to limit common impedance and hence interference between components. Moreover, if a fault were to occur on one of the components, the power supply for the other components will not be disturbed.

To implement a star connection architecture, one solution is to use distribution terminals (Auxigaine).
Enclosure consisting of several racks

In the case of an enclosure consisting of several racks, the power supply for these racks can be implemented by concatenating the connections. Make sure to loop the last rack back to the power supply in order to limit the voltage drop and ensure continuity of service in the event of a fault on one of the racks.
Protection of enclosures
Surge protective devices are used to protect the equipment from lightning. They are installed in parallel to the load to be protected. This is the most widely used and effective means of protection against voltage surge. There are three types of surge protective device:

- **type 1**: used when there is a high risk of lightning shocks. Is accompanied by a lightning arrester.
- **type 2**: very widely used. Dedicated to low-voltage installations.
- **type 3**: complement to type 2. Used to protect sensitive loads when they are installed more than 10 metres from the type 2 surge protective device.

The principle of the surge protective device is to divert part of the lightning current to earth in the event of a lightning shock. The resulting voltage across the terminals of the load to be protected is $U_p$. This protection voltage of the surge protective device should be chosen in relation to the impulse withstand voltage of the equipment to be protected. This withstand voltage is specified by the voltage surge class I, II, III or IV.

Several installation rules shall be complied with to ensure optimal operation of the surge protective device:

- The total length of the surge protective device’s installation cables should not exceed 50 cm;
- The phase and earth conductors must run together so as to limit the equivalent loop;
- The cables should be attached to the enclosure sheets so as to limit the loop and benefit from the enclosure’s natural shielding;
- The contaminated parts of the surge protective device (located upstream) should not be placed near the clean parts to be protected (located downstream), so as to limit cable-to-cable coupling.
**Numeric example**

### Loop

- **Lightning current:** 100 kA/μs
- **D = 100 m**

**Diagram:**
- Lightning strike
- **U = 2.10^{10} S Δi / D Δt = 20 kV !**

**Equation:**

\[ U = \frac{\mu_0}{2\pi} \frac{S \Delta i}{D \Delta t} = 2.10^{10} \frac{10^{10} \Omega}{10^{10} \Omega} = 20 kV \]

*With \( \mu_0 \) = space permeability*

- 1 m cable = 1 μH

**Table:**

<table>
<thead>
<tr>
<th>Lightning Current</th>
<th>L1</th>
<th>L2</th>
<th>dt</th>
<th>V SPD</th>
<th>V PROT</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 kA/μs</td>
<td>0.5 m</td>
<td>1.5 m</td>
<td>10 μs</td>
<td>1200 V</td>
<td>3200 V !</td>
</tr>
</tbody>
</table>

**MC apparatus voltage sustain:** 2000 V

**Formula:**

\[ V \text{ PROT} = V \text{ SPD} + V \text{ L1} + V \text{ L2} \]

\[ V \text{ L1} = L1 x \frac{\Delta i}{\Delta t} = 0.5 \mu H x 10 kA / 10 μs = 500 V \]

\[ V \text{ L2} = L2 x \frac{\Delta i}{\Delta t} = 1.5 \mu H x 10 kA / 10 μs = 1500 V \]

\[ V \text{ PROT} = 500 V + 1500 V + 1200 V = 3200 V ! \]

**L1 + L2 shall be \( \leq 0.5 m \)**

---

**50 cm limit**

- **Apparatus to be protected**
- **Common impedance**

**Diagram:**
- Loop diagram
- Lightning strike

**Equations:**

\[ U = \frac{\mu_0}{2\pi} \frac{S \Delta i}{D \Delta t} = 2.10^{10} \frac{10^{10} \Omega}{10^{10} \Omega} = 20 kV \]

**MC apparatus voltage sustain:** 2000 V

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\[ V \text{ L2} = L2 x \frac{\Delta i}{\Delta t} = 1.5 \mu H x 10 kA / 10 μs = 1500 V \]

**L1 + L2 shall be \( \leq 0.5 m \)**
Schneider Electric’s Acti 9 product range includes surge protective devices. The iQuick series has the advantage of incorporating the circuit breaker for disconnection in the event of a fault such as the loss of the protection function (due to the gradual deterioration of a varistor, or a failure of the neutral conductor on the network, for example). Length L2 at the installation level is therefore zero, which makes it easier to comply with the 50 cm rule. Other characteristics:

- all earthing systems (IT, TN and TT) can be used;
- type of circuit: single-phase, three-phase with or without neutral;
- protection in differential mode (phase-to-phase) possible;
- protection voltage Up: from 2.5 kV to 1.2 kV.
- lightning currents: from 8 kA to 65 kA.

Schneider Electric offer

The surge protective devices targeted by the enclosures of the Spacial range are of type 2. Coordination may be necessary if a surge protective device not incorporating the mechanism of disconnection upon a fault is used (iPRD 20r for example). For this reason, the Schneider Electric coordination table should be used to choose the appropriate circuit breaker.
Surge protective device

5 Voltage surge classes

One of the constraints of equipment design is surge resistance. Accordingly, a product providing a maximum withstand level can be used in all the parts of an installation, and notably in the main protection switchboard (MLVSB). For a product designed to be used in the subdistribution part, it may possibly be necessary to provide for additional protective devices to address all parts of the installation.

The devices are classified in 4 classes (I to IV):

Class I:
Class I impulse withstand devices are equipment or electronic components for which the impulse withstand voltage is low. This impulse withstand voltage is specified by the manufacturer and protective measures must be taken.

Class II:
Class II impulse withstand devices are user equipment designed to be connected to the fixed electrical installation of the building. Their impulse withstand voltage shall be at least equal to 2.5 kV.

Class III:
Class III impulse withstand devices are equipment belonging to the fixed installation and other equipment for which a higher level of reliability is required. Their impulse withstand voltage shall be at least equal to 4 kV.

Class IV:
Class IV impulse withstand devices are used at or near the origin of the installation upstream of the distribution switchboard. Their impulse withstand voltage shall be at least equal to 6 kV.

These concepts are summarized in the IEC 60071-1, IEC 60071-2, IEC 60664-1, IEC 60364-4-44 and IEC 61010 standards. The impulse withstand voltages for equipment selected according to the voltage rating are given to distinguish between the various degrees of equipment availability as a function of continuity of service and the acceptable failure risk. By choosing equipment in the impulse withstand voltage series, appropriate insulation coordination can be obtained in the whole installation, thus reducing the risk of failure to an acceptable level.

For the installation’s voltage rating, a required impulse withstand voltage is given in Table 44.B of IEC 60364-4-44 and Table F.1 of IEC 60664-1.

<table>
<thead>
<tr>
<th>Nominal voltage of the installation (V)</th>
<th>Required impulse withstand voltage for (kV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-phase systems</td>
<td>Equipment at the origin of the installation (OVC IV)</td>
</tr>
<tr>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>230/400</td>
<td>6</td>
</tr>
<tr>
<td>277/480</td>
<td>8</td>
</tr>
<tr>
<td>400/690</td>
<td>12</td>
</tr>
<tr>
<td>1000</td>
<td></td>
</tr>
</tbody>
</table>

The impulse withstand voltage is applied between live conductors and PE.

In Canada and USA, for voltages to earth higher than 300 V, the impulsive withstand voltage corresponding to the next highest voltage in column one applies.

The IEC 60664-1 standard relating to the coordination of equipment insulation in low-voltage systems specifies that this equipment can be used in a higher voltage surge class when a voltage limiter is provided. This attenuation of voltage surge can be achieved by:

- a surge protective device;
- a transformer with isolated windings;
- a tree-structured distribution system with many branches (capable of diverting voltage surge energy);
- great capacity for absorbing voltage surge energy;
- a resistor or a similar damping device capable of dissipating voltage surge energy.
Isolation transformers

It is accepted that an isolation transformer can reduce the voltage surge class as a function of the isolation voltage rating. It must have electrostatic barriers connected to earth.

Schneider Electric proposes the Phaseo offering:

ABL6 and ABT7 transformers of the Phaseo range
Isolation transformers are used to guard against high-frequency disturbances generated by the network power supply (primary circuit). An electrostatic shield is connected to earth by a short link. This link must be free of paint and any other insulating material. Physical separation of the cables of the primary circuit (network power supply) and those of the secondary circuit (power distribution) is also essential.

An isolation transformer also makes it possible to change earthing system. It is recommended to power communicating products with a TN-S system. The EN50310 standard recommends the use of an isolation transformer for EMC for switching from TT and IT systems to TN-S.
Isolation transformers

Earthing arrangement

The earthing systems are defined in international standard IEC 60364 and French standard NF C 15-100. The first letter specifies the type of neutral connection of the MV/LV transformer:
- T = earthed neutral;
- I = isolated neutral.

The second letter specifies the connection of the installation’s exposed conductive parts:
- T = exposed conductive parts earthed directly;
- N = exposed conductive parts connected to neutral at the origin of the installation itself connected to earth.

The IT, TT and TN systems are possible. A distinction is made between TN-C and TN-S for Combined or Separate neutral and earth. The TN-C-S system consists of a TN-C system upstream and TN-S downstream (TN-S-C is prohibited). For copper conductors of cross section less than or equal to 10 mm², TN-S is mandatory.

The TN-C system should not be used if communicating devices are installed. The use of a PEN conductor (combined earth and neutral) adversely affects the EMC protection of sensitive signals. The neutral conductor may convey harmonics and other unwanted currents which could disturb the communicating products. A separation of neutral and earth at the building entrance is recommended. Here again, conversion to TN-S is preferable.
Enclosures and panels with strengthened EMC
Panels

Spacial product range for hostile electrical environments

Spacial S3HF
Monobloc wall-mounting enclosure
- IP55 - IK10
- from H 400 x W 300 x D 200 mm to H 1200 x W 800 x D 300 mm

Spacial SFHF
Composable panel
- IP55 - IK10
- from H 1800 x W 600 x D 600 mm to H 2200 x W 800 x D 800 mm

The Spacial S3HF and SFHF enclosures can attenuate EMC electromagnetic disturbance in industrial environments. These enclosures perform two functions:
1. Provide shielding by acting as a Faraday cage.
2. Provide effective protection for sensitive equipment through galvanized sheet metal frames, in compliance with the installation rules.

Construction
- **Spacial S3HF**: these enclosures consist of a single folded and welded Aluzinc 150 metal sheet.
- **Spacial SFHF**: these panels are designed around a frame consisting of closed galvanized steel sections. This frame receives the doors, panels and a roof, all made of Aluzinc 150 sheet metal.

Fields of application
These enclosures are especially suitable for sensitive equipment:
- programmable logic controllers,
- electronic circuits and cards, etc.
They provide protection from the main disturbing factors: variable speed drives, motors, transformers/rectifiers, power cables, etc.
Fans and accessories for strengthened EMC

**IP54 EMC Fan**
To effectively protect the equipment against electromagnetic disruptions, the EMC fan is equipped with:
- a steel frame covering the plastic elements (self-extinguishing ABS according to standard UL 94 V-0),
- a metal grille attached to the frame,
- a beryllium gasket guaranteeing conductivity between the perimeter of the fan unit and the enclosure.

<table>
<thead>
<tr>
<th>Dimensions (mm)</th>
<th>Flow rate</th>
<th>Voltage</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>External 145 x 145 x 70</td>
<td>Cut-out 126 x 126</td>
<td>61</td>
<td>230</td>
</tr>
<tr>
<td>252 x 252 x 97</td>
<td>224 x 224</td>
<td>156</td>
<td>230</td>
</tr>
<tr>
<td>320 x 320 x 150</td>
<td>292 x 292</td>
<td>480</td>
<td>230</td>
</tr>
</tbody>
</table>

**IP54 EMC outlet grille**
Grille equipped with:
- a steel frame covering the plastic elements (self-extinguishing ABS according to standard UL 94 V-0),
- a metal grille attached to the frame,
- a beryllium gasket guaranteeing conductivity between the perimeter of the grille and the enclosure.

<table>
<thead>
<tr>
<th>Dimensions (mm)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>External 145 x 145 x 70</td>
<td>Cut-out 126 x 126</td>
</tr>
<tr>
<td>252 x 252 x 97</td>
<td>224 x 224</td>
</tr>
<tr>
<td>320 x 320 x 150</td>
<td>292 x 292</td>
</tr>
</tbody>
</table>

**EMC cover IP55**
- This solution ensures protection against electromagnetic interferences. It can also provide IP55 protection for IP54 fans and outlet grilles.
- The EMC cover must be fixed on the standard IP54 fans or IP54 outlet grilles, instead of their external part.
- The cover, designed in sheet-steel painted for outdoor use, completely covers the fan or outlet grille.
- Conductivity is obtained by means of:
  - a conductive coating (2 Ω),
  - a conductive copper braid.
- Ingress protection rating: IP55.
- Mechanical protection rating: IK10.
- RAL 7035 grey.

**Flow rate (m³/h)**

<table>
<thead>
<tr>
<th>Flow rate (m³/h)*</th>
<th>Dimensions (mm)</th>
<th>References EMC cover IP55</th>
<th>Spare filter for EMC cover</th>
<th>Standard IP54 fan</th>
<th>Standard IP54 grille</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free</td>
<td>With 1 outlet grille</td>
<td>External 240 x 180 x 60</td>
<td>Cut-out 125 x 125</td>
<td>Sheet-steel painted RAL 7035</td>
<td>Minor pack. 5 p</td>
</tr>
<tr>
<td>74</td>
<td>53</td>
<td>NSYCAP125LE</td>
<td>NSYCA125L55</td>
<td>NSYCFV85M230PF</td>
<td>NSYCG125LPF</td>
</tr>
<tr>
<td>110</td>
<td>82</td>
<td>NSYCAP223LE</td>
<td>NSYCA223L55</td>
<td>NSYCFV165M230PF</td>
<td>NSYCG223LPF</td>
</tr>
<tr>
<td>165</td>
<td>123</td>
<td>NSYCAP291LE</td>
<td>NSYCA291L55</td>
<td>NSYCFV560M230PF</td>
<td>NSYCG291LPF</td>
</tr>
<tr>
<td>316</td>
<td>265</td>
<td>NSYCAP291LE</td>
<td>NSYCA291L55</td>
<td>NSYCFV850M230PF</td>
<td>NSYCG291LPF</td>
</tr>
<tr>
<td>502</td>
<td>430</td>
<td>NSYCAP560M230PF</td>
<td>NSYCG291LPF</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The impact on the flow rates of the fans with different voltages is similar to the impact of the 230 V fans.
EMC accessories

Bonding braid
• Material: tinned copper.
• Unit references but to be ordered in multiples of 10. Nuts and washers not supplied.

<table>
<thead>
<tr>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Cross section (mm²)</th>
<th>Hole dia. (mm)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>17</td>
<td>10</td>
<td>6.5</td>
<td>NSYE15106D</td>
</tr>
<tr>
<td>155</td>
<td>17</td>
<td>16</td>
<td>8.5</td>
<td>NSYE15166D</td>
</tr>
<tr>
<td>200</td>
<td>27</td>
<td>25</td>
<td>8.5</td>
<td>NSYE20256D</td>
</tr>
<tr>
<td>200</td>
<td>33</td>
<td>50</td>
<td>8.5</td>
<td>NSYE20506D</td>
</tr>
</tbody>
</table>

EMC coupling kit
• Used to join enclosures side-by-side or depthwise.
• Special gasket for EMC solution.
• Attenuation level is decreased by 5 db when enclosures are joined (please consult us).
• Ingress protection rating: IP55.

<table>
<thead>
<tr>
<th>Panel length (mm)</th>
<th>Panel width (mm)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1800</td>
<td>400</td>
<td>NSYSF184</td>
</tr>
<tr>
<td>2000</td>
<td>400</td>
<td>NSYSF186</td>
</tr>
<tr>
<td>2200</td>
<td>600</td>
<td>NSYSF226</td>
</tr>
</tbody>
</table>

EMC cable gland with contact spring
• Type of thread: Metric EN 60423 (other types available on request).
• Material: nickel-plated brass, neoprene seal.
• Degree of protection against intrusion: IP66.
• Fire resistance: V2 as per UL94.
• Working temperature: -20°C to +100°C.
• Unshielded cable.

<table>
<thead>
<tr>
<th>Dimensions (mm)</th>
<th>Ø min/max</th>
<th>Drilling Ø</th>
<th>TD</th>
<th>TL</th>
<th>Key width</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>M12</td>
<td>3/6.5</td>
<td>12 à 12.2</td>
<td>12</td>
<td>6</td>
<td>14</td>
<td>NSYCG12</td>
</tr>
<tr>
<td>M16</td>
<td>5/10</td>
<td>16 à 16.2</td>
<td>16</td>
<td>7</td>
<td>20</td>
<td>NSYCG16</td>
</tr>
<tr>
<td>M20</td>
<td>6/12</td>
<td>20 à 20.2</td>
<td>20</td>
<td>8</td>
<td>22</td>
<td>NSYCG20</td>
</tr>
<tr>
<td>M25</td>
<td>11/17</td>
<td>25 à 25.2</td>
<td>25</td>
<td>8</td>
<td>27</td>
<td>NSYCG25</td>
</tr>
<tr>
<td>M32</td>
<td>15/21</td>
<td>32 à 32.3</td>
<td>32</td>
<td>8</td>
<td>34</td>
<td>NSYCG32</td>
</tr>
<tr>
<td>M40</td>
<td>12/28</td>
<td>40 à 40.3</td>
<td>40</td>
<td>9</td>
<td>43</td>
<td>NSYCG40</td>
</tr>
</tbody>
</table>

Other accessories
Our partner company, Jacques Dubois – www.jacquesdubois.com – is a specialist in the manufacture of products to strengthen EMC:
• sheet gaskets;
• linear gaskets;
• cable shielding;
• aperture shielding, etc.
Useful documents

Cahier technique n°149
EMC: electromagnetic compatibility
Ref.: CT149.pdf

Control Panel Technical Guide
How to present machine malfunctions and electronic damage due to voltage surges?
Ref.: CPTG002_EN

Universal Enclosure General Catalogue
Spacial, Thalassa, ClimaSys offers embedded
Ref.: UE16MK15EN

Useful links

http://www.electrical-installation.org/enwiki/Main_Page