Control Panel technical guide

How to protect a machine from malfunctions due to electromagnetic disturbance
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Automatic controls:
Their reliability is related to the level of disturbance.
The electrical control panel is affected.

Severe industrial environments:

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;
> monitoring and control panels.
Automatic controls: their reliability is related to the level of disturbance. The electrical control panel is affected.

Severe industrial environments: when tight control is essential...

Interference, or disturbances of all frequencies, is present everywhere, up to the core of the control 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.

This type of situation occurs when the cable:
- runs along another highly disturbing cable (variable speed drive/motor link, for example);
- is not shielded;
- or when its shielding is inappropriately linked (e.g. flow of "stray" currents caused by earthing of the two ends of shielding, especially in case of a TNC system).

Interference radiated by a device

A processing device is disturbed by a bundle of high-frequency waves: it "crashes", 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.

Worth knowing

Some devices (converters, current choppers, etc.) incorporate oscillators whose voltage, frequency or signal shape makes them capable of emitting interference over variable distances, inside or outside the control panel.

Covering of the equipment and its connection to the panel's frame earth are essential in order to limit radiation.
Panel design in accordance with EMC rules
Electromagnetic compatibility (EMC) of the electrical control panel

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.**

Role of the earthing system: **safety and equipotential bonding**

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 (HF) 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.
Protection of low power signals

Use shielded cables

Analog 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>Type</th>
<th>Protection against low-frequency interference</th>
<th>Protection against high-frequency interference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital sensors</td>
<td>End connected to frame earth:</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>0-10 V analogue output probes</td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4-20 mA analogue output probes</td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Communication bus</td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Variable speed drive/Motor link</td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

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.

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 (LF or HF):
- 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.

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).
Panel design in accordance with EMC rules

Characteristics of an EMC-compliant panel

Interference attenuation characteristics

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 the required attenuation for both effects (electric and magnetic fields) in order to suitably choose the appropriate panel.

![Comparison of AluZinc/steel attenuation](chart.png)

Comparison of AluZinc/steel attenuation

- **Aluzinc**: High attenuation: 60 - 80 dB
- **Steel**: Medium attenuation: 10 - 30 dB
- **Spacial S3HF**
- **Spacial S3D**

**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.

**"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.

**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 / resistance.
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 LF and HF 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.

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).
Panel design in accordance with EMC rules

Reference regulations and standards

Apparatus: radiation and radiation resistance

European directive

EMC 2004/108/EC

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).

Installations: main rules

International

> IEC 61000-5-2:
  Electromagnetic compatibility (EMC)
  Part 5: Installation and attenuation guide.
  Section 2: Earthing and wiring.
> 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.
> UTE C 90-480-2 Guide:
  Installation performance and practical methods inside the building.
Assembly - panel wiring
1 Panel assembly

Optimization of frame earths
For satisfactory discharge of LF and HF disturbance, the panels are interconnected by braids, including the door. The resistance of contact points is reduced by prior cleaning of any trace of paint or other insulating coating.

NB: A wire can in no case be substituted for a braid.

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.

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

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 HF disturbance will thus be reduced.

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.

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.
3 External routing of cables - entry into the panel

1 External routing in metal raceways
   Keep high-power cables away from low-power cables:
   > separate raceways if the cables are unshielded (D ≥ 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 are connected to earth at either end.
Organization of cable entries

Group the cables by type of current:

- high power: power supply, PEN conductors, etc., actuators;
- low power (< 100 mA): analogue communication.

Create specific entries in the panel, one for each type of current.

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

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.

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.

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.

Example: control panels

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. (*)

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

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

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.

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
5 Earth connection of shielding

1. Connection of shielding terminations

The shieldings are stopped as close as possible to the equipment to which the cables are connected. Connection is performed carefully, clamping the shielding with a clamp which will be:
   - fastened to an earth terminal strip or
   - fastened to the panel’s earthing plate.

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.

6 Earth connection of metal raceways

- The raceway is bolted onto the wall
Guide for selection of "EMC" products
**Enclosures and panels with strengthened EMC**

Spacial product range for hostile 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 SMHF**
Monobloc panel
- IP55 - IK10
- from H 1800 x W 800 x D 400 mm to H 2000 x W 800 x D 600 mm

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

The Spacial S3HF, SFHF and SMHF 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 SMHF**: these panels are designed based on a sheet metal skirt executed in one piece. To this is added a reinforced, welded back. The metal sheet consists of 55% aluminium as a surface coating to ensure good reflection of electromagnetic waves. A special metal-sheathed seal ensures the necessary electrical continuity at the level of the panels, doors and associated devices while ensuring overall watertightness.

> **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.

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Guide for selection of “EMC” products
**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 UL94 V0),
- a metal grille attached to the frame,
- a beryllium gasket guaranteeing conductivity between the perimeter of the fan unit and the enclosure.

**Dimensions (mm)**

<table>
<thead>
<tr>
<th>Flow rate (m³/h)</th>
<th>Voltage (V)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>56</td>
<td>230</td>
<td>NSY17990</td>
</tr>
<tr>
<td>130</td>
<td>230</td>
<td>NSY17991</td>
</tr>
<tr>
<td>460</td>
<td>230</td>
<td>NSY17992</td>
</tr>
</tbody>
</table>

**IP54 EMC outlet grille**

Grille equipped with:
- a steel frame covering the plastic elements (self-extinguishing ABS according to standard UL94 V0),
- a metal grille attached to the frame,
- a beryllium gasket guaranteeing conductivity between the perimeter of the grille and the enclosure.

**Dimensions (mm)**

<table>
<thead>
<tr>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSY17996</td>
</tr>
<tr>
<td>NSY17997</td>
</tr>
<tr>
<td>NSY17998</td>
</tr>
</tbody>
</table>

**EMC cover IP55**

- This solution guarantees protection against electromagnetic disruptions and guarantees IP55.
- The EMC cover is installed on the fans or standard IP54 outlet grilles.
- The cover, made from Aluzinc sheet steel, completely covers the fan or outlet grille.
- Conductivity is obtained by means of:
  - a conductive coating (2 Ω),
  - a conductive copper braid.
- Resistance to mechanical impacts: IK10.
- RAL 7035 grey.
- Absorption curve according to standard IEEE 299 1997 (UNE 50147-1).

**Flow rate (m³/h)*

<table>
<thead>
<tr>
<th>Flow rate (m³/h)</th>
<th>Dimensions (mm)</th>
<th>Cover reference</th>
<th>Spare filter for cover reference</th>
<th>Fan reference</th>
<th>Grille reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free</td>
<td>With 1 outlet grille</td>
<td>External</td>
<td>Cut-out</td>
<td>Aluzinc</td>
<td>RAL 7035</td>
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<tr>
<td>74</td>
<td>53</td>
<td>240 x 180 x 60</td>
<td>125 x 125</td>
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<td>NSYCFV85M230PF</td>
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<tr>
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<td>123</td>
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<tr>
<td>350</td>
<td>265</td>
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<td>291 x 291</td>
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<td>NSYCFV850M230PF</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.
Accessories for strengthening EMC

Bonding braid
- Tinned copper.
- Nuts and washers not supplied.
- Unit references but to be ordered in multiples of 10.

<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>
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<tbody>
<tr>
<td>150</td>
<td>17</td>
<td>10</td>
<td>6.5</td>
<td>NSYEB1510D6</td>
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<td>33</td>
<td>50</td>
<td>8.5</td>
<td>NSYEB2050D8</td>
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</tbody>
</table>

EMC coupling kit
- Allows assembly of Spacial SHSF panels.
- Formed of assembly plates and a metal gasket to strengthen EMC (attenuation of 5 db).

<table>
<thead>
<tr>
<th>Panel length (mm)</th>
<th>Panel width (mm)</th>
<th>Kit references</th>
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</thead>
<tbody>
<tr>
<td>1800</td>
<td>400</td>
<td>NSYSFHFBK184</td>
</tr>
<tr>
<td></td>
<td>600</td>
<td>NSYSFHFBK186</td>
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<td>2000</td>
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<td>NSYSFHFBK204</td>
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<td>2200</td>
<td>600</td>
<td>NSYSFHFBK226</td>
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<tr>
<td></td>
<td>800</td>
<td>NSYSFHFBK228</td>
</tr>
</tbody>
</table>

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

Electrical installation guide 2010
According to IEC international standards.
Ref.: EIGED306001EN

Chapter R of the Electrical Installation Guide
EMC guidelines.

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

Useful links

http://www.electrical-installation.org/enwiki/ElectroMagnetic_Compatibility_%28EMC%29

Make the most of your energy™

www.schneider-electric.com