<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Directives and standards for electromagnetic compatibility</td>
<td>2</td>
</tr>
<tr>
<td>Brief explanation of the most important EMC standards</td>
<td>3</td>
</tr>
<tr>
<td>EMC-compliant configuration of the control cabinet or control box</td>
<td>4</td>
</tr>
<tr>
<td>Selection of devices and notes regarding residual current operated protective devices</td>
<td>5</td>
</tr>
<tr>
<td>References</td>
<td>6</td>
</tr>
</tbody>
</table>
Legal information

Warning notice system

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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>⚠️ DANGER</td>
<td>indicates that death or severe personal injury will result if proper precautions are not taken.</td>
</tr>
<tr>
<td>⚠️ WARNING</td>
<td>indicates that death or severe personal injury may result if proper precautions are not taken.</td>
</tr>
<tr>
<td>⚠️ CAUTION</td>
<td>indicates that minor personal injury can result if proper precautions are not taken.</td>
</tr>
<tr>
<td>☢️ NOTICE</td>
<td>indicates that property damage can result if proper precautions are not taken.</td>
</tr>
</tbody>
</table>

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

Qualified Personnel

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

Proper use of Siemens products

Note the following:

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

Trademarks

All names identified by ® are registered trademarks of Siemens AG. The remaining trademarks in this publication may be trademarks whose use by third parties for their own purposes could violate the rights of the owner.

Disclaimer of Liability

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

1  Introduction ................................................................................................................................... 7  
2  Directives and standards for electromagnetic compatibility ............................................................... 11  
3  Brief explanation of the most important EMC standards ................................................................. 13  
   3.1  The EMC standard 61800-3, EMC requirements ................................................................ 13  
   3.2  EMC standard EN 61000-2-2, low-frequency, conducted interference .............................. 16  
   3.3  The Total Harmonic Distortion (THD) ................................................................................. 19  
4  EMC-compliant configuration of the control cabinet or control box ..................................................... 21  
5  Selection of devices and notes regarding residual current operated protective devices ...................... 29  
6  References ........................................................................................................................................ 31
Introduction

Who is this brochure intended for?
This brochure is mainly aimed at commissioning engineers and installers of drives with low-power frequency converters. Such drives are found in commercial and industrial operations, as they are based in residential areas or mixed residential, office and industrial areas, so-called mixed areas.

The brochure gives information that is easy to implement when selecting equipment and setting up the drives.

In the list of references in the appendix, the brochure refers to more detailed documents, which you can download from the Internet.

Why is this informational brochure important?
Every electrical device affects its environment and other electrical devices.

Figure 1-1  Examples of electrical devices that can be affected
The influencing effect depends on the type, design and size of the device.

Figure 1-2 Possible interference of electronic devices due to non-EMC-conformant design and/or installation
An EMC-conformant design of the device by the manufacturer and correct installation by the system installer allow for the legal limit values of the influencing effect to be complied with without any problems. Thus, no other electrical devices are affected.

![Figure 1-3](image)

**Figure 1-3**  No interference with other devices due to an EMC-conformant design and installation

For interference-free operation of electrical and electronic devices, the requirements and limit values of electromagnetic compatibility (EMC) are defined in directives and standards.
Directives and standards for electromagnetic compatibility

EMC directive 2014-30-EU is the key document within the European Community regarding electromagnetic compatibility. It regulates the requirements which the manufacturers of equipment such as electrical drives must satisfy in regard to EMC.

Put simply, the electrical equipment may only cause electromagnetic interference within specific limit values. On the other hand, this equipment must be immune to electromagnetic interference within defined limit values.

The maximum limit values are defined in the technical standards, which have been harmonized as per the EMC directive.

With a CE mark and an EC declaration of conformity, the manufacturers confirm that the manufactured equipment satisfies the requirements of the EMC directive.

The EMC directive also applies to setting up and operating stationary systems.

The requirements and limit values that apply to setting up drives can be found in the following standards:

- EN 61800-3, Adjustable speed electrical power drive systems - Part 3: EMC requirements and specific test methods, describes the limit values for high-frequency radiated and conducted interference
- EN 61000-2-2, Electromagnetic compatibility (EMC) environment - compatibility levels for low-frequency conducted disturbances and signaling in public low-voltage power supply systems, describes the limit values for low-frequency conducted interference.

In the following chapters, we briefly describe the important contents of the two standards for setting up electric drives in so-called mixed areas.
Brief explanation of the most important EMC standards

3

3.1 The EMC standard 61800-3, EMC requirements

EN 61800-3 describes the EMC requirements for drive systems. It is also called the EMC product standard.

The standard covers the entire drive system (PDS = Power Drive System) of a machine or plant and describes the limit values for high-frequency radiated and conducted interference.
EN 61800-3 assigns the drive systems to various environments according to their usage location.

- The first environment, with residential and business areas in which industrial and small enterprises are based, is connected directly to the public low-voltage power supply system.

- In contrast to the first environment, the second environment is generally characterized by each load being directly connected to the medium or high-voltage power supply system via a transformer.

Additionally, the drive systems (PDS) are divided into four categories.
### Categories of the drive system (PDS)

<table>
<thead>
<tr>
<th>Device category</th>
<th>Brief explanation of the drive system (PDS)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>$V_r &lt; 1000$ V; unrestricted use in the first environment</td>
<td>No special expertise is required for the installation.</td>
</tr>
<tr>
<td>C2</td>
<td>$V_r &lt; 1000$ V; stationary, for use in the second environment</td>
<td>Use in the first environment is possible. The installation and commissioning are done by EMC-specialist personnel, i.e. by you. The warning notes provided by the manufacturer must be observed during this.</td>
</tr>
<tr>
<td>C3</td>
<td>$V_r &lt; 1000$ V; exclusively for use in the second environment</td>
<td>Drive systems in this category are not covered by this informational brochure.</td>
</tr>
<tr>
<td>C4</td>
<td>$V_r \geq 1000$ V or rated currents $\geq 400$ A for use in complex systems in the second environment</td>
<td>Drive systems in this category are not covered by this informational brochure.</td>
</tr>
</tbody>
</table>

You can find the category in the technical data of the device.

**What comprises the drive system (PDS)?**

A drive system consists of

1. the complete drive module (CDM) and
2. the motor and the shielded motor cables.

The complete drive module is installed in an EMC-compliant control cabinet/box and consists of

- the converter with filters and reactors,
- the drive controller and
- switchgear and protective devices.

**How can compliance with the EMC product standard EN 61800-3 be ensured?**

Quite simply, by conscientiously carrying out the actions described in the following:

- Select suitable devices.
- Lay out the control cabinet in an EMC-compliant manner.
- Wire the system in an EMC-compliant manner.

More precise instructions are described in Chapter "EMC-compliant configuration of the control cabinet or control box (Page 21)".
3.2 EMC standard EN 61000-2-2, low-frequency, conducted interference

In addition to the high-frequency electromagnetic interference, there are also the line reactions, which are covered by EN 61000-2-2.

Line harmonics is the generic term for low-frequency and conducted interference.

The loads on the public low-voltage power supply system can be roughly divided into two groups:

<table>
<thead>
<tr>
<th>Loads with nearly sinusoidal current consumption</th>
<th>Loads with a current consumption that clearly deviates from the sinusoidal form</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g. motors, heating devices (fireplace, hair dryer) and nearly all switch-mode power supplies, e.g. for computers, mobile telephones and televisions</td>
<td>e.g. luminescent bulbs and frequency converters with the usual B6 rectifier circuit</td>
</tr>
</tbody>
</table>

The low-frequency line harmonics caused by these loads are low. The low-frequency line harmonics caused by these loads can be considerable.
The following figure (Fig. 3-1) provides a simplified overview of the public low-voltage power supply system and the possible loads. The power supply system is shown as single-pole for a better overview.

1. The ever present transformer is made up of an ideal voltage transformer and a downstream inductivity \( X_{\text{transformer}} \) (simplified)

The power supply system connection consists of:

2.1 PCC: The power supply system connecting point (point of common coupling), shown from the viewpoint of the user, e.g. at the power supply system access of a plant or house

2.2 Line impedance \( X_{\text{line}} \). The value of \( X_{\text{line}} \) mainly depends on the type and length of the cable to the point of common coupling.

3. PCC n: additional points of common coupling

Effect of individual loads (e.g. converter, motor and heater)

4.1 Heaters and motors: The relationship between current and voltage is sinusoidal. The voltage \( V_{\text{PCC}} \) at the point of common coupling PCC (2) is not distorted. The sinusoidal current flow shown in the figure naturally only occurs if the line voltage is not distorted.

4.2 Frequency converter with upstream line reactor \( X_{K} \): The relationship between current \( I_1 \) and the voltage is not sinusoidal, see red current flow in Figure 3-1. The non-sinusoidal current consumption of the converter causes a discontinuous drop in voltage on the power supply system or transformer impedance \( X_{\text{transformer}} \), which in turn results in a distorted / non-sinusoidal line voltage \( U_{\text{PCC}} \).

4.3 We can always only see the total flow of the voltage. The influence of the individual load cannot be determined without additional effort.

The THD value that is explained later in Section 3.3. describes the deviation of voltage flow from the pure sinusoidal form. This is clearly visible in the figure for the comparison of the sinusoidal voltage \( V_{\text{transformer ideal}} \) (blue box) and the distorted voltage \( V_{\text{PCC}} \) (yellow box).

Figure 3-1 Overview of low-voltage power supply systems and loads
Regulations of the standard EN 61000-2-2

The standard EN 61000-2-2 regulates the compatibility level for low-frequency conducted disturbances and the signal transmission in public low-voltage power supply systems.

- The compatibility levels defined in this standard apply to the PCC (point of common coupling) with the public power supply system, e.g. the premises/building connection, see (2.1) in Figure 3-1.

- The standard does not define any limit values for current harmonics. Limit values are only specified for the voltage harmonics and the total distortion factor of the voltage THD(U) (Total Harmonic Distortion).

- The corresponding compatibility level for the total distortion factor of the voltage THD(U) is 8%.
3.3 The Total Harmonic Distortion (THD)

What is the THD?

The Total Harmonic Distortion (THD) is defined as the sum of the outputs $P_h$ of all harmonics to the output of the basic harmonic $P_1$ ratio.

The THD is also determined for power supply systems.

As we described in Figure 3-1 "Low-voltage power supply systems and loads", electrical devices such as switch-mode power supplies, inverters, etc. emit harmonics in a non-linear curve, i.e. they cause a non-sinusoidal current in the power supply system. Non-sinusoidal currents distort the line supply voltage in the line impedances, cause interference in the loads, and increase the loss in the power supply system.

A low total distortion value of the line voltage THD (U) therefore corresponds to good quality voltage in the power supply system.

What will increase the THD (U) value?

Some causes of a high THD (U) are:

- long cables from the power transformer to the PCC,
- tightly dimensioned cross-sections of the supply lines,
- an already high converter load on the transformer; the THD (U) of 8% is exceeded by an additional converter drive without additional measures.
How do excessively high THD (U) values make themselves known in practice?
The following phenomena can occur directly (the following list makes no claim of completeness):

- Suddenly occurring malfunctions of machines and equipment, IT and telephone systems without a discernible cause
- Erroneous tripping of protective switches or circuit breakers
- Frequent failures of switch-mode power supplies, e.g. in IT systems
- Destruction of the capacitors, in reactive power compensation systems and filter systems, for example
- Over-heating of cables, motors and equipment that are directly connected to the power supply system, such as fuses, contactors, etc.
- Noise development (humming), for example in switches, motors and transformers that are connected directly to the power supply system
- Excessive load on the neutral conductor, e.g. in building technology in many single-phase converters/devices on the power supply system with B2 rectifiers (3rd harmonic)

In addition to the direct effects, long-term effects of excessively high THD values can occur:

- Rapid device aging for capacitors and windings, e.g. in reactive power compensation systems and electronic devices (e.g. controllers, computers, cash register systems)
- Poor power factor with increased system losses (not to be confused with cos \( \phi \))

The direct effects occur once the converter drive is running, especially at high drive speeds. The following applies: high speeds = high power consumption = high current = high THD (U)

What remedies are available?

- If the frequency converter is intended to be operated with a line reactor, we always recommend the use of a line reactor.

Depending on the power supply system conditions, additional measures may be necessary based on a power supply system analysis.
EMC-compliant configuration of the control cabinet or control box

Use a control cabinet or box for the EMC-compliant configuration of the drive system. The control cabinet or box prevents interference emissions.

Install the complete drive module (CDM) in the control cabinet with its components (converter and filter, if applicable, controller, switchgear and protective devices) and the cables.

Arrange the components in such a way that they do not interfere with one another.

It is best to plan the arrangement using the EMC zone concept.

The EMC zone concept

The EMC zone concept divides the control cabinet into various sections (zones), which are separated from one another in reference to EMC. The installed units are arranged in these zones according to their assignment to sources of interference or susceptible devices. (see table “Assignment of sources of interference - susceptible devices”)

Assignment of source of interference or susceptible device

Devices that generate interference are designated as a source of interference. Devices that are influenced by interference are called susceptible devices. In order for the source of interference to be able to influence the susceptible device, the interference must reach the susceptible device. The path between the source of interference and the susceptible device is called a coupling or coupling path.
The quality criterion for a signal transmission in EMC is the signal-to-noise ratio. Simply put, the greater the distance between the interference source and the susceptible device, the less the interference. If the distance is insufficient and no other shielding is available, sources of interference can influence susceptible devices.

![Diagram](image)

A Dough-kneading machine  
B Baking oven  
1 Sources of interference, e.g. frequency converters, motor cables  
2 Susceptible device, e.g. controller  
3 Susceptible device, e.g. temperature sensor and sensor cable

The motor cable ① and the frequency converter ① can influence the controller ②, temperature sensor ③ and sensor cable ③ to such an extent that the baking oven does not switch off.

Figure 4-1 Possible EMC interference by an converter

Examples for typical technical sources of interference and susceptible devices can be seen in the following table.

<table>
<thead>
<tr>
<th>Examples of interference sources</th>
<th>Examples of susceptible devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency converters, braking module and un-connected coils of contactors.</td>
<td>Controllers, PLCs, encoders, sensors and their evaluation electronics</td>
</tr>
<tr>
<td><img src="image" alt="Image" /> FC G120 and contactor</td>
<td>Sensors and PLC</td>
</tr>
</tbody>
</table>

Assignment of sources of interference - susceptible devices
Arrangement of the drive system components in the control cabinet or control box according to the EMC zone concept

Configuration notes

- Assign all of the devices that are to be installed in the control cabinet to interference sources or susceptible devices.
- When you have finished making assignments, divide the entire area of the plant or control cabinet into EMC zones.

Specific requirements regarding the interference emission and the interference immunity apply within each zone.

The figure below shows an example of an EMC zone concept in a control cabinet.

Source: EMC design guidelines / Basic system requirements configuration manual, (PH1), 01/2012, 6FC5297-0AD30-0AP3, page 17
• Uncouple the zones electromagnetically. Such uncoupling measures include, for example, large spatial distances (approx. 20 cm). Better and more space-saving is decoupling using separate metal enclosures or large metal partitions.

• Install all of the components on a bare and highly conductive metallic mounting plate. Connect the mounting plate so that it is electrically conductive and flush with the side rails of the cabinet, the grounding rail and EMC shielding rail, e.g. using braided copper bands.

Figure 4-2  Braided copper bands

• The previous statement also applies if you are installing mounting plates or individual components to side plates, rear panels, top and bottom plates. Also connect the cabinet doors to the cabinet side rails with a braided copper band for improved diverting of high-frequency interference.

• Protective grounding must be ensured.

• Ground the entire control cabinet/box in an EMC-compliant manner. In case of doubt, also connect it to ground using a braided copper band.

Note on the use of inductive loads (coils):
If connections are made using mechanical switching contacts, e.g. for the contactor, relay or output contacts of a PLC or converter, connect all of the connected actuators, contact coils, solenoid valves, holding brakes, etc., with over-voltage limits, e.g. RC circuits or varistors, directly at the interference source if possible. This prevents switching overvoltages.
EMC-compliant cabling within and outside of the control cabinet or control box

- All of the communication and similar signal cables and motor cables (cables, no individual conductors) from the converter must be shielded inside and outside the cabinet.
- The supply line of the converter should be shielded from the converter after the filter.

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

- Keep all cables in the control cabinet as short as possible.
- Except for short sections, route the shielded and unshielded power and signal lines separately and with a minimum distance of 20 cm. Lines can be crossed.
- Do not route cables of various zones in shared cable harnesses or cable ducts.

Notes on shielding

Carefully comply with the following information on attaching the cable shielding.

- Always place the shield on both sides so that is planar. In the event of unclear potential conditions, e.g. between the converter and motor, route an equipotential bonding line parallel to the motor line. This is usually not required for short cables.
- If possible, connect shielded cables to the device without intermediate terminals.
- Always place the shield in the control cabinet and on the motor, for example, on the shield support or mounting plate so that it has a good planar connection.
- Clamp the shield down firmly using, for example, shield clamps, cable ties or metallic hose clamps (motor line).
The overview below provides examples of EMC-compliant cable routing.

<table>
<thead>
<tr>
<th>Example of planar shield support with shield clamps</th>
<th>Example of planar shield support with cable ties</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Example of planar shield support with shield clamps" /></td>
<td><img src="image2" alt="Example of planar shield support with cable ties" /></td>
</tr>
</tbody>
</table>

**Example cable shielding**

**EMC-compliant wiring of an converter:**
1. Mains line
2. EMC clamps on the shield plate
3. Shielded line for the braking resistor, if available
4. EMC clamp for the line to the terminal strip
5. Shielded line to the terminal strip
6. Shielded motor cable

**Planar shield support of a data line**

The shield was not interrupted.

**Cable shielding for data line**
### Example of planar shield support with cable ties

The shield is pressed onto the shield support using cable ties. Metal hose clamps may also be used in place of the cable ties.

![Example of planar shield support with cable ties](image)

### Cable shielding with cable ties

![Cable shielding with cable ties](image)

### EMC-compliant motor connection with EMC screw connection

![EMC-compliant motor connection with EMC screw connection](image)

### EMC-compliant motor connection

![EMC-compliant motor connection](image)
Conclusion

If all of the necessary measures have been taken into consideration during the device selection and cabinet design and the motor has been connected in an EMC-compliant manner, the baking machine in our example can be put into operation. No other electrical devices will be disturbed.
Selection of devices and notes regarding residual current operated protective devices

The following chapter proposes devices for the EMC-compliant installation of drives.

Selecting a device

- SINAMICS G120 devices are supplied with line filters which permit operation of the drive system in the categories C1 (depending on the type) and C2.
- If the converters are provided for operating with a line reactor, use a line reactor to reduce the low-frequency line harmonics.
- The motor must be equipped with an EMC-compliant terminal box. (terminal box with metal enclosure and good conductive connection to the motor enclosure in the high-frequency range)

Figure 5-1  SINAMICS converter family + SIMOTICS 1LE1 standard induction motor
Notes on the residual current operated protective device

- In numerous applications (e.g. bakeries, butcher shops or exercise machines, machines in trade and agriculture), converters are operated with residual current operated protective devices (RCD).

- Use universal current-sensitive RCDs Type B or Type B+.

- Ask the plant operator whether the RCD
  - provides personnel protection with an tripping current of, for example, ≤ 30 mA or
  - preventive fire protection with an tripping current of, for example, ≤ 300 mA.

- The line filters of the frequency converters have discharge currents, which the usual RCDs detect as a residual current. They therefore switch off after a specific level of discharge currents.

- For converter outputs of more than 2.2 kW and with the requirement for personnel protection, you probably will have to install a filter with low discharge currents. The requirement for this is the presence of a neutral conductor capable of bearing a load. Only in this case does the converter have to be ordered without a line filter. (Filter A or B)

- Use a separate RCD for each converter.
References


- FAQ: The most common power supplies (power supply system forms) (http://support.automation.siemens.com/WW/view/de/75858207)

- EMC design guideline 01/2012 (http://support.automation.siemens.com/WW/view/de/60612658)

- Video for EMC-compliant control cabinet configuration (https://www.youtube.com/watch?v=OjpVXCHyKZc)
More information

SINAMICS low voltage converters: