

EMC and variable speed drives

EMC stands for electromagnetic compatibility – the ability of electric and electronic devices to work properly in the environment for which they are designed. For this purpose the environment is defined as the expected level of radio frequency disturbances present. The term usually is considered to refer to high frequency disturbances, both conducted and radiated, in the frequency range 9 kHz to 400 GHz, although technically low level issues (< 2 kHz) are included.

The compatibility consists of two parts: immunity (a product may not be disturbed when used in its proper environment) and emission (a product may not emit too much when installed in its proper environment). The following picture illustrates the relative levels required for immunity and emissions in various environments. Note the logarithmic vertical scale.

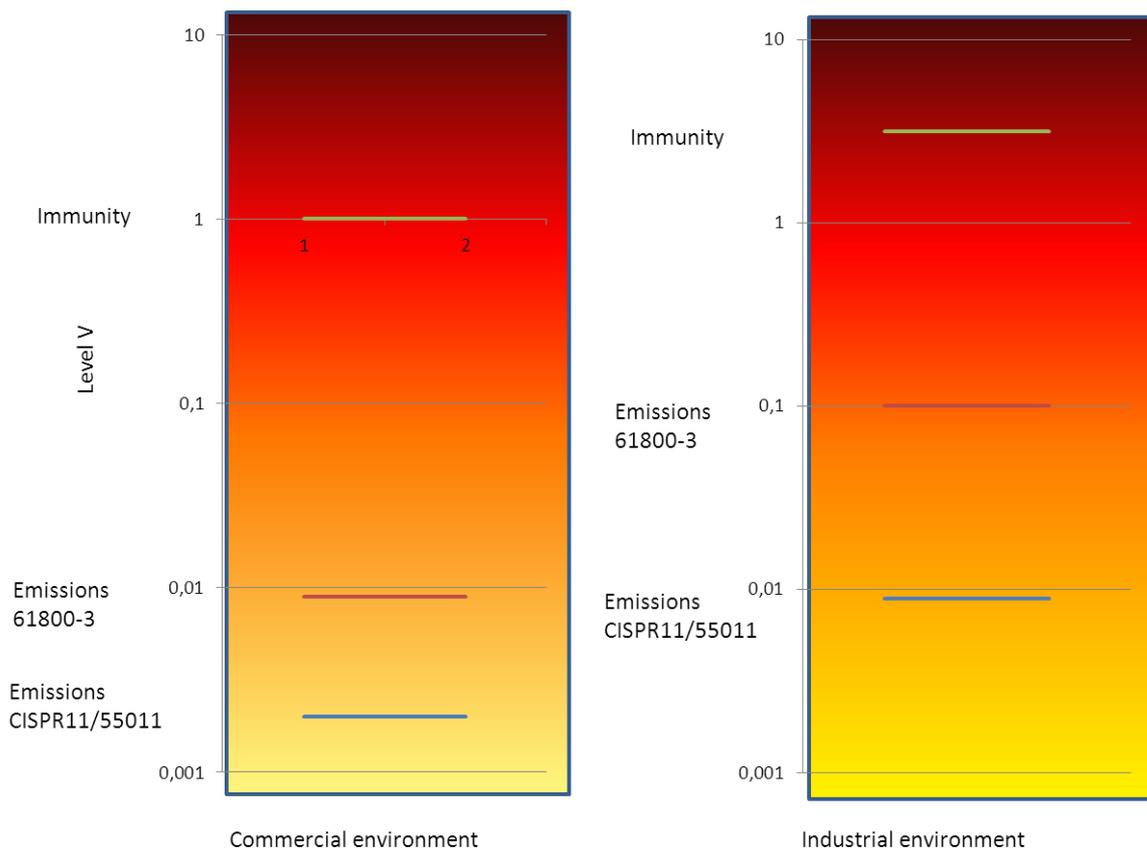


Figure 1: Allowed levels of emission and required levels of immunity.

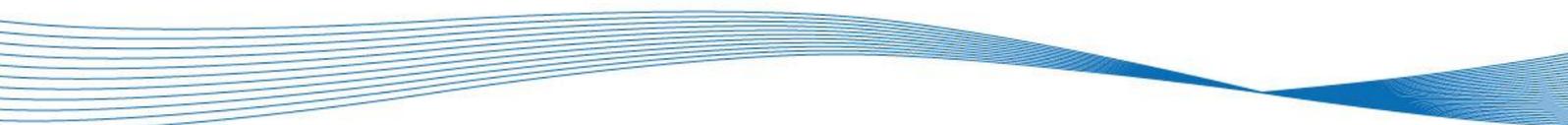
The fundamental global standard in the field is CISPR11, also known as EN55011. This standard is applicable in all countries to so called ISM equipment = equipment or appliances designed to generate and use locally radio frequency energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of telecommunications.

CISPR is charged with protecting the radio spectrum against interference, so it can be used for communication purposes. Therefore the focus is on how much background noise can exist in the environment and still allow radio transmissions to be heard clearly. Technically, the standard concerns itself with conducted emissions on the mains cables and other cables in the frequency range 150 kHz to 30 MHz and radiated emissions in the area 30 MHz to 1 GHz – no limits at present exist for higher frequencies, although they are being discussed for edition 6 of the standard. Exceeding the allowed limits by equipment sold in large numbers would have a deleterious influence on radio communications, which is not an acceptable situation.

The focus on conducted emissions for the lower frequencies (0.15 to 30 MHz) is due to the fact that the wavelength is such that parts of the grid can function as an antenna and radiate disturbances. The wavelength at 150 kHz is about 2000 m – a quarter wave antenna would be about 500 m long. The corresponding values for 30 MHz are 10 m and 2.5 m, respectively. These are lengths that clearly exist in the grid supplying the device. This band covers the common long wave, medium wave and short wave bands.

At higher frequencies the emphasis shifts to direct radiated disturbances – the impedance in the mains at these frequencies becomes so high that it dampens any disturbance. Here the radiation comes directly from either the motor cables or from the switching elements themselves. The bands from 30 MHz to 1 GHz (HF, VHF, UHF) (later up to 400 GHz) cover services like TV, FM radio, WLAN, mobile phones, radar etc.

Based on the global noise levels that can be accepted and do not endanger radio communications limits have been set on how many individual devices can transmit. In this context the transmitters are defined as non-intentional transmitters, i.e. equipment in which the use of RF energies is not central to the functioning of the said equipment. In this calculation the expected number of transmitters has been taken into account, so that if a large number of emitters are expected in a given location their individual limits are low, whereas if the number is small the individual levels can be slightly higher, without exceeding the total allowed level. This implies that household goods (TVs, radios, cooking ranges, lighting equipment, which are connected in large numbers to the grid) have low limits whereas industrial equipment (whose numbers are much lower) have higher limits.



The standard does differentiate between devices of different rated power, as larger devices generally generate more noise than smaller ones. This, however, is only generally true – badly designed small devices can generate much higher levels of emissions than well-designed larger ones – i.e. a badly designed electronic ballast for a fluorescent lamp (power about 50 W) can generate more emissions than a well-designed 11 kW drive. In addition, aging of components in commercial equipment constitutes an unknown risk, as the emission levels might increase as the product ages.

CISPR 11 divides equipment into two groups:

Group 1 equipment: Group 1 contains all equipment in the scope of the standard which is not classified as Group 2 equipment.

Group 2 equipment: Group 2 contains all ISM RF equipment in which radio-frequency energy in the frequency range 9 kHz to 400 GHz is intentionally generated and used or only used, in the form of electromagnetic radiation, inductive and/or capacitive coupling, for the treatment of material or inspection/analysis purposes.

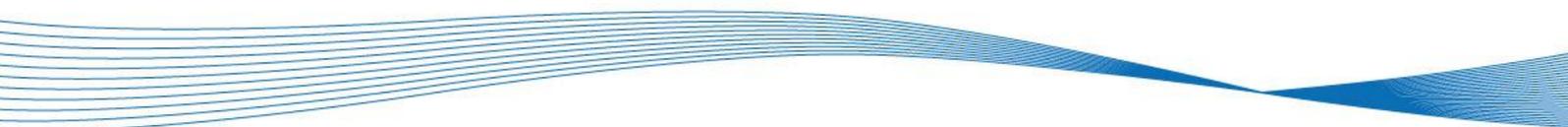
All variable speed drives fall into Group 1.

The number and location of the equipment being considered is reflected in the division into classes:

Class A equipment is equipment suitable for use in all establishments other than domestic and those directly connected to a low voltage power supply network which supplies buildings used for domestic purposes.

Class B equipment is equipment suitable for use in domestic establishments and in establishments directly connected to a low voltage power supply network which supplies buildings used for domestic purposes.

Translated: Class B equipment is intended for use in domestic and similar environments (houses, apartment blocks, possibly shopping malls, light industry etc.), Class A equipment in an industrial environment. The background of the definition is in the fact that in such an environment the power supply owner has no control of who connects what to his supply whereas in Class A the supply transformer and what is connected to it is under some degree of control.



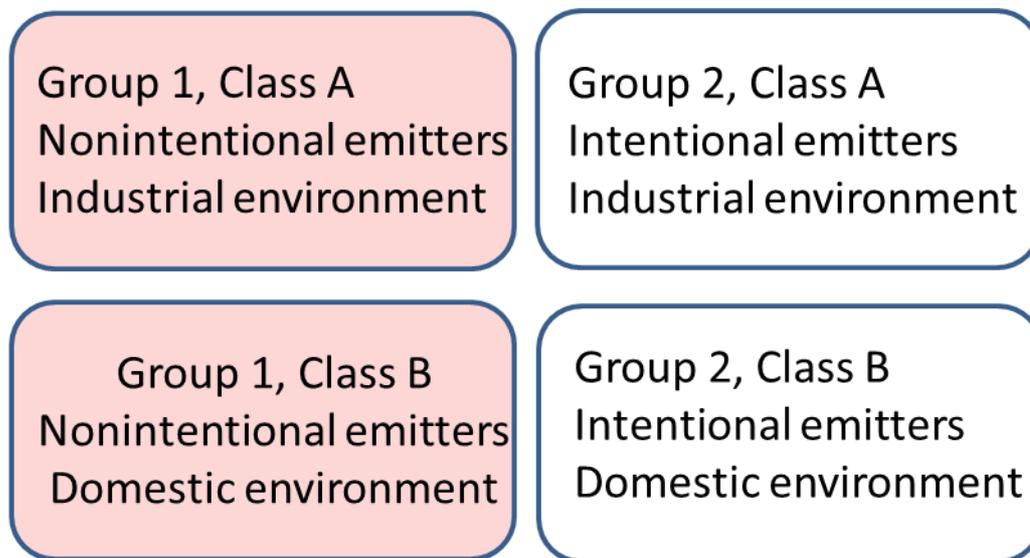


Figure 2: Classification in CISPR 11.

CISPR 11 is a global standard – according to the introduction product standards (for specific product groups) can be made – and they will then take precedence over the requirements of CISPR 11. The need for product standards may come from some specific issue related to that product group – in the case of variable speed drives the fact that their numbers in commercial environments is relatively low. IEC SC22G, responsible for variable speed drives has written a VSD specific EMC standard, IEC 61800-3, now in edition 2, edition 3 is being prepared in a normal maintenance cycle. In this standard the basic assumption has been that variable speed drives are limited in number compared to household and similar equipment and that they need a professional to install them, a professional who can be trusted to understand the need for a correct installation of EMC related parts and components. The standard is valid for a as PDS (power drive systems) consisting of drive and motor plus all other required auxiliary components – the actual driven machine is excluded. Drives with a rated current > 400 A, rated voltage > 1000 V and drives used in IT (floating) networks are excluded, as are drives where the required filter could have a negative impact on the dynamic performance of the system. The two first ones are due to the fact that no defined measurement setups exist (due to high voltages and currents), the IT exclusion comes from the impossibility of making reliable voltage measurements from a phase to ground. Under the European EMC Directive the supplier is still responsible for making sure that the product and installation does not disturb others.

This standard defines the following environments where the drive is installed:

First environment

Environment that includes domestic premises, it also includes establishments directly connected without intermediate transformers to a low-voltage power supply network which supplies buildings used for domestic purposes.

NOTE! Houses, apartments, commercial premises or offices in a residential building are examples of first environment locations.

(This is equivalent to the Class B in CISPR 11.)

Second environment

Environment that includes all establishments other than those directly connected to a low voltage power supply network which supplies buildings used for domestic purposes.

NOTE! Industrial areas, technical areas of any building fed from a dedicated transformer are examples of second environment locations.

(This is equivalent to Class A in CISPR 11.)

It further defines the following classes of PDS:

PDS of category C1

PDS of rated voltage less than 1 000 V, intended for use in the first environment.

PDS of category C2

PDS of rated voltage less than 1 000 V, which is neither a plug in device nor a movable device and, when used in the first environment, is intended to be installed and commissioned only by a professional.

NOTE! A professional is a person or an organisation having necessary skills in installing and/or commissioning power drive systems, including their EMC aspects.

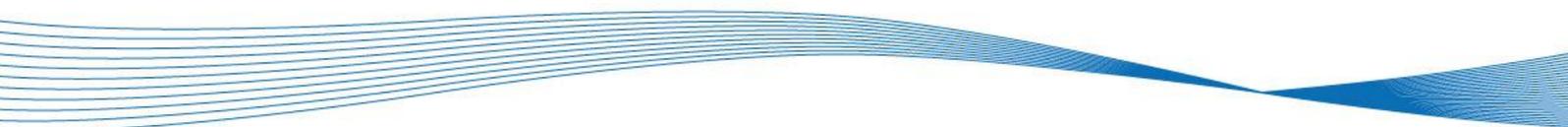
PDS of category C3

PDS of rated voltage less than 1 000 V, intended for use in the second environment and not intended for use in the first environment.

PDS of category C4

PDS of rated voltage equal to or above 1 000 V, or rated current equal to or above 400 A, or intended for use in complex systems in the second environment.

Translated: These definitions mean that variable speed drives intended for use in the first environment fall into category 1 only if they are plug in



devices equipped with factory installed cables and plugs for the supply, motor and control – such solutions have not yet been seen on the market.

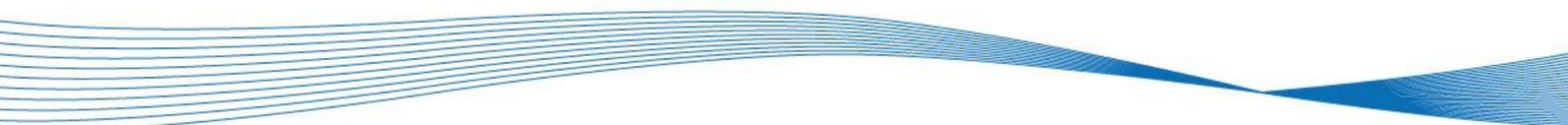
According to the combined expertise within the standardization bodies (manufacturers, regulators and academia are represented), C2 for PDS is the correct and most cost-effective solution for all environments.

There are drives on the market claiming to be C1 compliant. In many cases a closer study of the specifications show that this is valid only for conducted emissions, they do not necessarily comply with the limits for radiated emissions.

As a matter of fact the installation has a large influence on the actual achieved emission level: motor cable length and type, the grounding system as well as the voltage supply system used all influence the final result. One installation might comply, but another installation otherwise similar but with poorly made grounding or the wrong type of cable will fail.

All VSDs meant to be installed by a professional electrician fall into Category 2: usable both in the first and second environment i.e. in all installation sites. This is possible because the number of variable speed drives is low relative to household equipment and hence the influence of the drives on the electromagnetic environment is small compared to the influence of the much larger number of household appliances. The C2 requirements are sufficient to guarantee the proper operation of all devices within the physical environment where the devices are installed. The requirement for installation by a professional electrician means that the installation manuals and recommendations are followed in terms of distances, cabling, grounding, cable glands etc. The total installation will be C2 compliant and not cause any issues only if all the instructions of the manufacturer are followed to the letter. Devices which are certified as being compliant obviously make it easier to create an installation which is compliant as whole – there is no need for further additional components (filters, special cables etc.) to be installed, making a C2 environment the most cost-effective one. Suitable construction of the distribution system will also help – separate transformers for normal and for sensitive equipment, for example.

Category C3 is for VSDs used in industrial applications, with some degree of control over the local environment, category C4 is for modules that are built into larger systems.



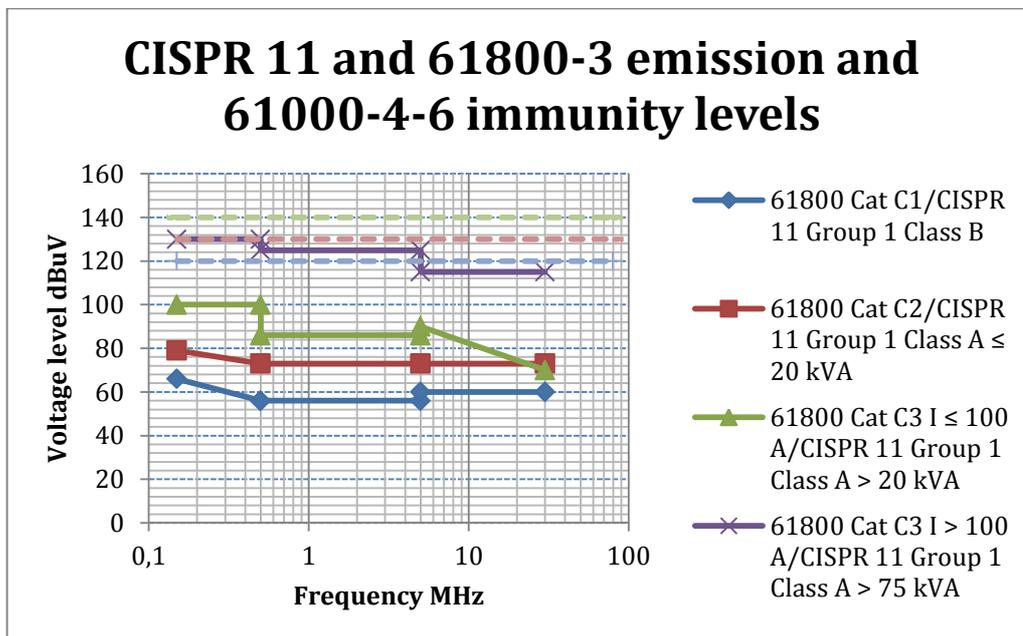


Figure 3: Allowed levels of emission and required levels of immunity.

Comparing the levels required by the two standards shows that IEC 61800 allows a higher level in a commercial environment than does CISPR 11 – in fact, the same level that CISPR 11 allows in industrial environments. The basic reason for this lies in the so called impact factor, i.e. the number of drives is small compared to other pieces of apparatus and hence the influence on the total radio frequency environment is relatively small, even if the values allowed are higher.

According to the EMC Directive, however, if problems in the final installation occur, it is up to the manufacturer of the disturbing equipment to solve the problem.

The other part of the EMC equation is the immunity of the products against interference. These levels are also set in various standards: for a commercial environment IEC 61000-4-6 specifies a 1 V (120 db uV) level for the frequency range 150 kHz – 80 MHz, i.e. a relatively large margin is required – see the picture above.

The following classes/environments are defined:

Class 1: Low-level electromagnetic radiation environment. Typical level where radio/television stations are located at a distance of more than 1 km and typical level for low-power transceivers.

Class 2: Moderate electromagnetic radiation environment.

Low-power portable transceivers (typically less than 1 W rating) are in use, but with restrictions on use in close proximity to the equipment. A typical commercial environment.

Class 3: Severe electromagnetic radiation environment.

Portable transceivers (2 W and more) are in use relatively close to the equipment but at a distance not less than 1 m. High-powered broadcast transmitters are in close proximity to the equipment and ISM equipment may be located close by. A typical industrial environment.

The required margin in the worst case commercial environment (i.e. immunity requirement is Class 1 and the emission level is C2) is 40 dB. This implies that a very large number of drives is required to reach that level (a difference of 40 dB implies that at least 10000 sources would be required).

In most buildings the drives' contribution to the total EMC level is small, most of the emissions come from other sources, such as lighting (all modern high-efficiency lighting is a source of emissions), PC power supplies, copying machines, TV sets etc. Power electronics are becoming ubiquitous in or modern society and the correct functioning is guaranteed by compliance with the relevant standards. Creating filters to comply with the C1 requirements is expensive and increases the product cost and size – and price, for a very marginal gain. Special attention must also be paid to the installation, as both radiated and conducted emission limits are low. In most cases C1 levels for conducted disturbances can be achieved – the limits for radiated emissions can be very challenging to reach.

