TECHNICAL REPORT

IEC TR 61000-1-4

First edition
2005-05

Electromagnetic compatibility (EMC) –

Part 1-4:
General – Historical rationale for the limitation of power-frequency conducted harmonic current emissions from equipment, in the frequency range up to 2 kHz

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 1-4: General – Historical rationale for the limitation of power-frequency conducted harmonic current emissions from equipment, in the frequency range up to 2 kHz

FOREWORD

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IEC 61000-1-4, which is a technical report, has been prepared by subcommittee 77A: Low frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

The text of this technical report is based on the following documents:

DTR	Report on voting
77A/477/DTR	77A/481/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

IEC 61000 is published in separate parts according to the following structure:

Part 1: General

General considerations (introduction, fundamental principles)

Definitions, terminology

Part 2: Environment

Description of the environment

Classification of the environment

Compatibility levels

Part 3: Limits

Emission limits

Immunity limits
(in so far as they do not fall under the responsibility of product committees)

Part 4: Testing and measurement techniques

Measurement techniques

Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines

Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

Each part is further subdivided into several parts published either as International Standards or as technical specifications or technical reports, some of which have already been published as sections. Others will be published with the part number followed by a dash and a second number identifying the subdivision (example: IEC 61000-6-1).

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 1-4: General – Historical rationale for the limitation of power-frequency conducted harmonic current emissions from equipment, in the frequency range up to 2 kHz

1 Scope

This part of IEC 61000, which is an IEC technical report, reviews the sources and effects of power frequency conducted harmonic current emissions in the frequency range up to 2 kHz on the public electricity supply, and gives an account of the reasoning and calculations leading to the *existing* emission limits for equipment in the editions of IEC 61000-3-2, up to and including the second edition (2000) and its first amendment (2001), and in the first edition of IEC 61000-3-12 (2004).

The concepts in this technical report apply to all low voltage AC systems, but the numerical values apply specifically to the European 230 V/400 V 50 Hz system.

NOTE A rationale for the limits in future complete revisions of IEC 61000-3-2 or IEC 61000-3-12 or both will be included in a new technical report.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61000-2-2:2002[1)], *Electromagnetic compatibility (EMC) – Part 2-2: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems*

IEC 61000-3-2:2000[2)], *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)*[3)]
Amendment 1 (2001)

IEC 61000-3-3:1994, *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage fluctuations and flicker in public low-voltage supply systems for equipment with rated current ≤ 16 A*[4)]
Amendment 1 (2001)

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1) This technical report also refers to the first edition of IEC 61000-2-2 (1990), *Electromagnetic compatability (EMC) – Part 2: Environment – Section 2: Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems*, since superseded by the second edition of that publication.

2) This technical report also refers to the first edition of IEC 61000-3-2 (1995), *Electromagnetic compatability (EMC) – Part 3: Limits – Section 2: Limits for harmonic current emissions (equipment input current ≤ 16 A per phase),* and its Amendment 1 (1995), since superseded by the second edition and its amendments of that publication.

3) A consolidated edition 2.2 exists, which includes IEC 61000-3-2:2000 and its Amendments 1 (2001) and 2 (2004).

4) A consolidated edition 1.1 exists, which includes IEC 61000-3-3:1994 and its Amendment 1 (2001), *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection*

IEC 61000-3-4, *Electromagnetic compatibility (EMC – Part 3-4: Limits – Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 16 A*

IEC 61000-3-6, *Electromagnetic compatibility (EMC) – Part 3: Limits – Section 6: Assessment of emission limits for distorting loads in MV and HV power systems*

IEC 61000-3-11, *Electromagnetic compatibility (EMC) – Part 3-11: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems – Equipment with rated current ≤ 75 A and subjet to conditional connection*

IEC 61000-3-12, *Electromagnetic compatibility (EMC) – Part 3-12: Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current > 16 A and ≤ 75 A per phase*

IEC 61000-4-13, *Electromagnetic compatibility (EMC) – Part 4-13: Testing and measurement techniques – Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity tests*

3 Definitions

Definitions of terms used in this technical report can be found in other publications in the IEC 61000 series.

4 General appraisal

The electricity supply industry intends to supply electric power with a sinusoidal voltage waveform, and customers' equipment is designed to operate correctly on such a supply. However, because the internal impedance of the supply system is not zero, a non-linear load connected by one customer produces distortion of the voltage waveform that may adversely affect another customer's equipment, as well as equipment in the supply system itself. There is no type of load or supply system equipment that is totally immune to distortion of the voltage waveform, although 'natural' immunity levels (those achieved by customary designs without special attention to improving immunity) vary greatly. Based largely on experience of the amounts of voltage distortion that give rise to evidence of malfunction of, or damage to, equipment, compatibility levels of voltage distortion for the low-voltage (LV) public supply system have been determined and are given in IEC 61000-2-2. The correspondences between these levels and other values are shown schematically in Figure 1. See Annex A of IEC 61000-2-2 from which that figure is taken. Compatibility levels are set as an acceptable compromise between immunity to harmonics and reduction of emissions. Methods to check that the immunity of equipment to voltage distortion is adequate are given in IEC 61000-4-13.

NOTE For the purposes of this technical report, the compatibility levels in the first edition of IEC 61000-2-2 apply.

The intention of applying limits on the harmonic current emissions of equipment connected to the public low-voltage (LV) system is to keep the actual levels of voltage distortion on the system below the compatibility levels for a very large proportion of the time, and below lower levels, known as planning levels, for a lesser but still large proportion of the time. (See Figure 1.)

NOTE 1 Emissions into the medium-voltage (MV) and high voltage (HV) systems can be controlled by other methods and procedures. See IEC 61000-3-6.

NOTE 2 In some countries, the electricity supply industry places reliance on IEC 61000-3-2 to control emissions from portable equipment, whether the point of common coupling is at LV, MV or HV.

Emissions from equipment are expressed as currents, because these are largely, but not completely, independent of the source impedance of the supply system, whereas the voltage distortion produced by the equipment is almost proportional to the supply-system impedance and therefore has no definite value. A product that draws a non-linear current from the supply system may alternatively be regarded as drawing a sinusoidal current, while emitting into the supply system harmonic currents of the opposite polarity to those that it actually draws.

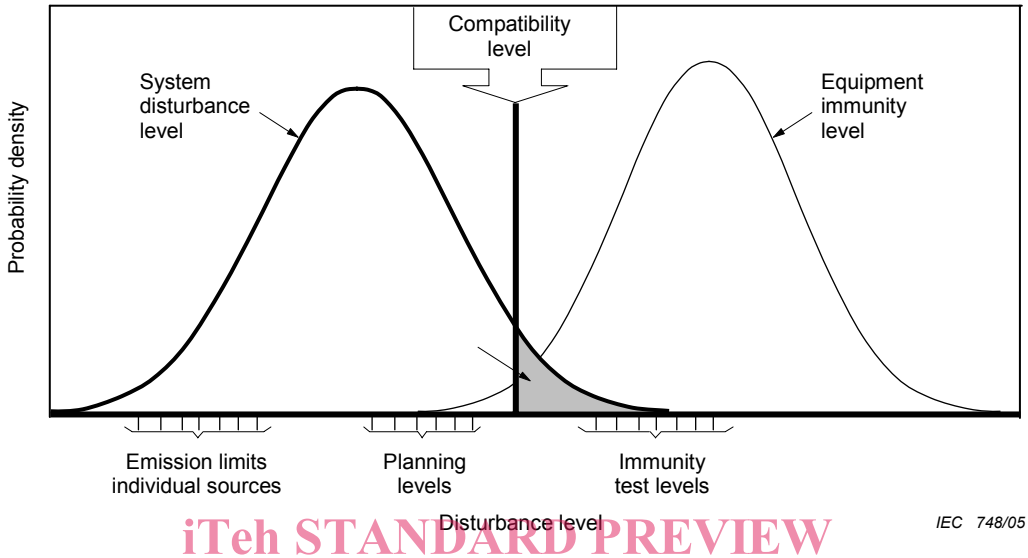

Figure 1 – Diagram showing compatibility level in relation to disturbance and immunity levels

5 Acceptable provisions in standards related to regulatory legislation

The equipment manufacturing industry can accept requirements in a voluntary standard, whose application may be determined by custom or moderated during individual contract negotiations, that would be unacceptable in a standard backed by regulatory enforcement. For example, a standard may contain provisions that, if fully applied, would result in very long test times. Parties to a contract might waive these provisions, wholly or partly (calculation or simulation might be employed, for example) whereas in an enforcement situation, no deviation from the provisions might be allowed.

Both 7.1 of EN 50006 and 5.3.1 of IEC (60)555-2[5)] required the test operator to search for worst-case conditions using the controls of the equipment under test, and in IEC (60)555-2, this was required for each harmonic in turn. Such a test might well take many days, with no assurance that another test operator might not find a different worst-case condition for just one harmonic. Such a provision was also contained in clause C.1 of IEC 61000-3-2:1995 and was not removed until the publication of Amendment 1 to IEC 61000-3-2:2000.

A standard must not include regulatory requirements: it is concerned only with the procedures necessary to determine whether a product within its scope meets its requirements.

5) IEC (60)555-2 was withdrawn in 1995 and replaced by IEC 61000-3-2.

6 History of IEC 61000-3-2 and its predecessors

6.1 Before 1960

The most numerous non-linear loads were television receivers with half-wave rectifiers. Because most of these had mains connectors of reversible polarity, the d.c. components approximately cancelled. The number of receivers installed was insufficient to create any significant system problems due to harmonic current emissions, but there is evidence that there was enough random unbalance of polarity of connection in some countries for the resultant d.c. component to cause corrosion problems in underground cables.

6.2 1960 to 1975

Phase-controlled dimmers for household lighting began to be marketed. These created high-frequency conducted emissions, thus initially drawing the attention of radio-spectrum protection authorities. Measures to limit these emissions could be made mandatory, but it was also noted that the dimmers produced harmonic currents and there was no practicable way of reducing the ratios of harmonic to fundamental current.

A system survey in Europe determined the 90th percentile value for supply impedance for residential customers (who were mostly fed by overhead LV distribution) as $(0{,}4 + jh0{,}25)$ ohms, where h is the harmonic order, and this value was included in IEC 60725. In addition it was determined that without some control of emissions from dimmers, the voltage distortion might grow to exceed acceptable levels (later to be called 'compatibility levels').

NOTE There is no direct relationship between compatibility levels and emission limits generally. Further information on this subject can be found in Annex A.

The first standard on this subject (according to its own text it is not based on any previous standard) was the European standard EN 50006 of 1975, implemented as various national standards including BS 5406:1976. This standard took burst-firing techniques into account and also covered voltage fluctuations, now the subject of IEC 61000-3-3 and IEC 61000-3-11. Limitation of harmonic current emissions was achieved by:

- prohibiting the use of phase control for heating loads over 200 W;
- applying limits for odd-harmonic emissions;
- applying limits for even-harmonic emissions to both symmetrical and asymmetrical control techniques.

The limits were expressed as voltage-harmonic percentages, produced with a supply system whose impedance (for single-phase loads) was $(0{,}4 + jh0{,}25)$ ohms. However, the test procedure actually required measurement of the harmonic currents, from which the voltage distortions were calculated. The standard does not include any explanation of the derivation of the limits, which are preserved as the Class A limits in IEC 61000-3-2, up to the 2000 edition. In fact, the numerical values were undoubtedly established piecemeal by negotiation between supply industry and equipment manufacturer experts. The retention of a strict mathematical rule for determining the values would not have been a priority for either group.

There was, however, a study that led to an approximate algorithm for determining the cumulative contribution of many dimmers set at different firing angles to a net voltage distortion level at the terminals of the LV transformer feeding the final distribution. (See also Annex A.)

6.3 1975 to 1982

During this period, a more comprehensive standard, IEC (60)555-2:1982, was developed. Still *effectively* restricted to 220(380) V-240(415) V 50 Hz European systems, it was adopted by CENELEC as EN (60)555-2 in 1987. It introduced three sets of limits; the original current limits unchanged from EN 50006, limits 1,5 times greater for products used only for short periods, such as portable tools, and special limits for television receivers, although an exemption for receivers whose input power was less than 165 W caused the limits to apply only to a small proportion of the receivers manufactured. The limits were expressed directly as currents, even for television receivers.

NOTE All IEC standards were renumbered in the 60000 series from 1998-01-01. To indicate the references of standards withdrawn before, or not reprinted after, that date, the '6xxx' prefix is here enclosed in parentheses. Hence 'IEC (60)555-2'.

Although this standard included an Annex that claimed to explain the derivation of the original current limits, in fact, it did not do so, merely citing the voltage distortion limits that were included in EN 50006 without explanation.

6.4 1982 to 1995

This period saw three profound changes; the great expansion of the use of switch-mode power supplies, both in business and in the home, the intimation that mandatory regulation of the electromagnetic compatibility (EMC) characteristics of electronic products would be introduced in Europe, and the further intimation that the European public electricity supply would be subject to 'product quality' requirements.

The early standards, EN 50006 and IEC (60)555-2, did not apply to professional equipment, but there is no relevant definition in either standard, although EN 50006 cites 'office machinery' as an example. Thus it was unclear whether the standards applied to desktop computers. This was clarified in Europe by a decision that such computers were 'household appliances', so that the original current limits applied. (But CISPR 14/EN 55014 was not applied for high-frequency emissions.) However the great expansion of single phase consumer electronics using direct on line switch mode dc power units, such as television receivers and desktop computers, led to significant peak flattening of the supply voltage waveforms due to near coincidence of the large current pulses drawn by these products. Although direct-on-line switch mode d.c. power units provided technology advantages (higher efficiency, lighter weight, smaller size), the near coincidence of the large current pulses being drawn can result in significant distortion of the supply voltage waveform. (Products with transformer-fed non-switching supplies have proportionally lower emissions because the series impedance of the transformer results in a larger conduction angle of the rectifiers.)

As a result, the development of the successor to IEC (60)555-2 was extremely controversial. It has been suggested that while the electricity supply industry continued to work in depth on the development of IEC 61000-3-2, the involvement of the equipment manufacturing industry was less structured. This may be true, but should be seen in the context that 'equipment manufacture' is a very diverse industry sector, whose sub-sectors have very different priorities in considering harmonic current emissions, while the supply industry has very little diversity in priorities, mainly deriving from differing infra-structure configurations in different countries.

IEC 61000-3-2:1995 introduced many new features. Most notably, it applies to '[***all***] electrical and electronic equipment having an input current up to and including 16 A per phase and intended to be connected to public low-voltage distribution systems.' (However, 'professional equipment', as defined in the standard, enjoys exemption from some requirements.)

The standard thus includes requirements and limits that apply to several different types of product, grouped into four classes. It *effectively* applies only to European systems, as for previous standards.