IEC TR 61000-1-4

Edition 2.0 2022-06
REDLINE VERSION

TECHNICAL REPORT

colour inside

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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IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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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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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC TR 61000-1-4:2005. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC TR 61000-1-4 has been prepared by subcommittee 77A: EMC – Low frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility. It is a Technical Report.

This second edition cancels and replaces the first edition published in 2005. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) relation between compatibility levels, emission limits and immunity requirements clarified;

b) sharing of emission levels between LV, MV and HV clarified;

c) new historical information added.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
77A/1136/DTR	77A/1141/RVDTR

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

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 61000 series, published under the general title *Electromagnetic compatibility (EMC)*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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- withdrawn,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

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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).

IEC TR 61000-1-4:2005 (first edition) gave a historical rationale for the emission limits for equipment up to 2005. Since there is new historical material available about the developments in the past several years, SC77A is adding this new historical material as a revision of IEC TR 61000-1-4. The revision also clarifies and amends some existing statements that are now known not to report the history until 2005 correctly.

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 a 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 [1][1], 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 fifth edition (2018) with Amendment 1 (2020), and in the second edition of IEC 61000-3-12 (2011) [2].

The history is traced from the first supra-national standard on low-frequency conducted emissions into the public electricity supply, EN 50006:1975 [3] and its evolution through IEC (60)555-2 [4] to IEC 61000-3-2 [1], IEC TR 61000-3-4 [5] and IEC 61000-3-12 [2]. To give a full picture of the history, that of the standard for the measuring instrument IEC 61000-4-7 [6] is mentioned as well.

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

Some concepts in this document 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 documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 (all parts), *Electromagnetic compatibility (EMC)*

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

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1 Numbers in square brackets refer to the Bibliography.

~~2) 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.~~

~~IEC 61000-3-2:2000[3], *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)*[4]~~
~~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*[5]~~
~~Amendment 1 (2001)~~

~~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 Terms and definitions

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

For the purposes of this document, the terms and definitions given in IEC 61000 (all parts) apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

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.

~~[3] 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.~~

~~[4] A consolidated edition 2.2 exists, which includes IEC 61000-3-2:2000 and its Amendments 1 (2001) and 2 (2004).~~

~~[5] 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*~~

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~~ can 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~~ and "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 [7]. The correspondences between these levels and other values are shown schematically in IEC 61000-2-2:2002, Figure A.1. 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 [8].

NOTE 1 ~~For the purposes of this technical report, the compatibility levels in the first edition of IEC 61000-2-2 apply.~~ Logically, compatibility levels would be set somewhat below the lowest acceptable immunity levels, but those data were hard to come by in the past. Recommended immunity levels were first established in IEC 61000-4-13.

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~~2 Emissions into the medium-voltage (MV) and high voltage (HV) systems can be controlled by other methods and procedures. See IEC TR 61000-3-6. [9]

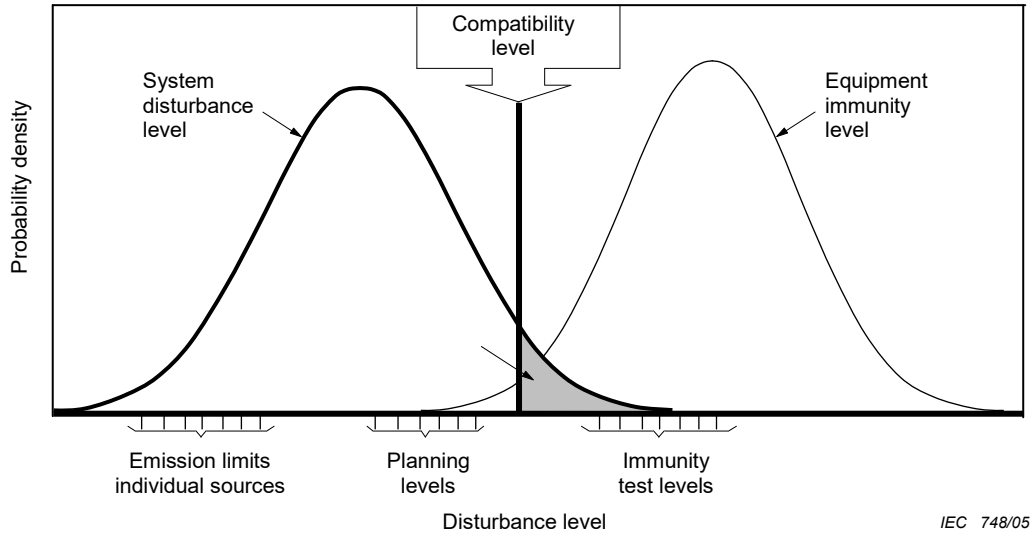
NOTE ~~2~~3 In some countries, the electricity supply industry places reliance on IEC 61000-3-2 [1] to control emissions from portable equipment, whether the point of common coupling is at LV, MV or HV.

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~~ can 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.

Compatibility levels are set, using system disturbance data and standardized immunity levels, so that the probability of the system disturbance level exceeding the lowest immunity test level is acceptably low, and at present is set at 5 %.

NOTE 4 Because the system disturbance level is an aggregate of the emissions of very many loads, the emission limits for equipment are set at quite low disturbance levels.

NOTE 5 For system design, planning values of disturbance levels are adopted unilaterally by distribution system operators; these are not expected to be exceeded but are not subject to standardization.



~~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~~ can 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~~ can 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 EN 50006:1975, 7.1 and IEC (60)555-2:1988, IEC (60)555-2:1988/AMD1:1988 and IEC (60)555-2:1988/AMD2:1988[6], 5.3.1 [4], 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 IEC 61000-3-2:1995 (first edition), Clause C.1 and was not removed until the publication of IEC 61000-3-2:2000/AMD1:2001 (second edition) [1].

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.

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

6.1 History table

The revision histories of IEC 61000-3-2 and IEC 61000-3-12 are given in Annex G (informative).

An up-to-date table of the entire publication history of each IEC publication can be obtained via the IEC webstore at https://webstore.iec.ch.

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

6.2 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 DC 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 DC component to cause corrosion problems in underground cables.

6.3 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~~ (0,4 + j0,25) Ω, and this value was included in IEC TR 60725:1981 [10]. 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.~~

NOTE In IEC (60)555-2:1982, Annex A [4], the supply impedance was regarded as purely resistive and inductive ((0,4 + jh0,25) Ω, where h is the harmonic order number). However, evidence was later presented that showed that the impedance rises above 500 Hz more nearly proportional to the square root of frequency, rather than proportional to frequency. The impedance presented to a particular load at the interface with the network (which is what determines the voltage distortion produced by the current emissions from that load) includes the effect of the impedances of other loads on the feeder. Even a light 10 kW load due to other equipment considerably lowers the impedance at high-order harmonic frequencies. See 6.9.

The first standard on this subject (according to its own text it is not based on any previous standard) was the European standard EN 50006:1975, 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 [11] and IEC 61000-3-11 [12]. 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) Ω. However, the test procedure actually required measurement of the harmonic currents, from which the voltage distortions were calculated.

EN 50006 [3] 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 (second 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 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.)