BRITISH STANDARD

BS EN 61000-2-4:2002

Electromagnetic compatibility (EMC) —

Part 2-4: Environment — Compatibility levels in industrial plants for low-frequency conducted disturbances

The European Standard EN 61000-2-4:2002 has the status of a British Standard

ICS 33.100.10; 33.100.20

British Standards

National foreword

This British Standard is the official English language version of EN 61000-2-4:2002. It is identical with IEC 61000-2-4:2002. It supersedes BS EN 61000-2-4:1995 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee GEL/210, EMC - policy committee, to Subcommittee GEL/210/8, EMC - low frequency disturbances, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Cross-references

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English version

Electromagnetic compatibility (EMC)
Part 2-4: Environment -
Compatibility levels in industrial plants
for low-frequency conducted disturbances
(IEC 61000-2-4:2002)

CompatibilitÈ ÈlectromagnÈtique (CEM)
Partie 2-4: Environnement -
Niveaux de compatibilitÈ
dans les installations industrielles
pour les perturbations conduites
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Elektromagnetische Vertr‰glichkeit (EMV)
Teil 2-4: Umgebungsbedingungen -
Vertr‰glichkeitspegel f¸r niederfrequente
leitungsgef¸hrte Stˆrgrˆflen
in Industrieanlagen
(IEC 61000-2-4:2002)

This European Standard was approved by CENELEC on 2002-09-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

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CENELEC

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Foreword

The text of document 77A/378/FDIS, future edition 2 of IEC 61000-2-4, prepared by SC 77A, Low frequency phenomena, of IEC TC 77, Electromagnetic compatibility, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61000-2-4 on 2002-09-01.

This European Standard supersedes EN 61000-2-4:1994.

The following dates were fixed:

ñ latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2003-06-01
ñ latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2005-09-01

Annexes designated "normative" are part of the body of the standard.
Annexes designated "informative" are given for information only.
In this standard, annex ZA is normative and annexes A, B and C are informative.
Annex ZA has been added by CENELEC.

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Endorsement notice

The text of the International Standard IEC 61000-2-4:2002 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60038	NOTE	Harmonized as HD 472 S1:1989 (modified).
IEC 61000-4-7	NOTE	Harmonized as EN 61000-4-7:1993 (not modified).
IEC 61000-4-15	NOTE	Harmonized as EN 61000-4-15:1998 (not modified).

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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 the 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, 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: 61000-3-11).

Detailed information on the various types of disturbances that can be expected on public power supply systems can be found in IEC 61000-2-1 and IEC 61000-2-12.

3.1.3
electromagnetic compatibility
EMC
ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

[IEV 161-01-07]

NOTE 1 Electromagnetic compatibility is a condition of the electromagnetic environment such that, for every phenomenon, the disturbance emission level is sufficiently low and immunity levels are sufficiently high so that all devices, equipment and systems operate as intended.

NOTE 2 Electromagnetic compatibility is achieved only if emission and immunity levels are controlled such that the immunity level of devices, equipment and systems, at any location, are not exceeded by the disturbance level at that location, resulting from the cumulative emission of all sources and other factors such as circuit impedances. Conventionally, compatibility is said to exist if the probability of the departure from intended performance or of the adverse effect is sufficiently low. See Clause 4 of IEC 61000-2-1.

NOTE 3 Where the context requires it, compatibility may be understood to refer to a single disturbance or class of disturbances.

NOTE 4 Electromagnetic compatibility is a term used also to describe the field of study of the adverse electromagnetic effect which devices, equipment and systems undergo from each other or from electromagnetic phenomena.

3.1.4
(electromagnetic) compatibility level
specified electromagnetic disturbance level used as a reference level in a specified environment for coordination in the setting of emission and immunity limits

[IEV 161-03-10, modified]

NOTE By convention, the compatibility level is chosen so that there is only a small probability that it will be exceeded by the actual disturbance level.

3.1.5
planning level
level of a particular disturbance in a particular environment, adopted as a reference value for the limits to be set for the emission of large loads and installations, in order to coordinate those limits with all the limits adopted for equipment intended to be connected to the power supply system

NOTE The planning level is locally specific and is adopted by those responsible for planning and operating the power supply network in the relevant area. (For further explanation, see Annex A of IEC 61000-2-2.)

3.1.6
point of common coupling
PCC
point on a public power supply network, electrically nearest to a particular load, at which other loads are, or could be, connected

[IEV 161-07-15, modified]

3.1.7
in-plant point of coupling
IPC
point on a network inside a system or an installation, electrically nearest to a particular load, at which other loads are, or could be, connected

NOTE The IPC is usually the point for which electromagnetic compatibility is to be considered.

3.2 Phenomena-related definitions

The definitions below that relate to harmonics are based on the analysis of system voltages or currents by the Discrete Fourier Transform method (DFT). This is the practical application of the Fourier Transform as defined in IEV 101-13-09. See Annex A.

NOTE The Fourier Transform of a function of time, whether periodic or non-periodic, is a function in the frequency domain and is referred to as the frequency spectrum of the time function, or simply spectrum. If the time function is periodic the spectrum is constituted of discrete lines (or components). If the time function is not periodic, the spectrum is a continuous function indicating components at all frequencies.

Other definitions related to harmonics or interharmonics are given in IEV and other standards. Some of those other definitions, although not used in this standard, are discussed in Annex A.

3.2.1
fundamental frequency
frequency, in the spectrum obtained from a Fourier transform of a time function, to which all the frequencies of the spectrum are referred. For the purposes of this standard, the fundamental frequency is the same as the power supply frequency

[IEV 101-14-50, modified]

NOTE 1 In the case of a periodic function, the fundamental frequency is generally equal to the frequency of the function itself. (See A.1.)

NOTE 2 In case of any remaining risk of ambiguity, the power supply frequency should be referred to the polarity and speed of rotation of the synchronous generator(s) feeding the system.

NOTE 3 This definition may be applied to any industrial power supply network, without regard to the load it supplies (a single load or a combination of loads, rotating machines or other loads), and even if the generator feeding the network is a semiconductor converter.

3.2.2
fundamental component (or fundamental)
component whose frequency is the fundamental frequency

3.2.3
harmonic frequency
frequency which is an integer multiple of the fundamental frequency. The ratio of the harmonic frequency to the fundamental frequency is named harmonic order. (Recommended notation "h")

3.2.4
harmonic component
any of the components having a harmonic frequency. Its value is normally expressed as an r.m.s. value

For brevity, such a component may be referred to simply as a harmonic

3.2.5
interharmonic frequency
any frequency which is not an integer multiple of the fundamental frequency

NOTE 1 By extension from harmonic order, the interharmonic order is the ratio of interharmonic frequency to the fundamental frequency. This ratio is not an integer. (Recommended notation "m")

NOTE 2 In the case where $m < 1$, the term sub-harmonic frequency may also be used.

3.2.6
interharmonic component
component having an interharmonic frequency. Its value is normally expressed as an r.m.s. value.

For brevity, such a component may be referred to simply as an interharmonic

NOTE For the purpose of this standard, and as stated in IEC 61000-4-7, the time window has a width of 10 fundamental periods (for 50 Hz systems) or 12 fundamental periods (for 60 Hz systems), i.e. approximately 200 ms. The difference in frequency between two consecutive interharmonic components is, therefore, approximately 5 Hz.

3.2.7
total harmonic distortion
THD
ratio of the r.m.s. value of the sum of all the harmonic components up to a specified order (recommended notation "*H*") to the r.m.s. value of the fundamental component

$$THD = \sqrt{\sum_{h=2}^{h=H} \left(\frac{Q_h}{Q_1} \right)^2}$$

where:

Q represents either current or voltage;

Q_1 is the r.m.s. value of the fundamental component;

h is the harmonic order;

Q_h is the r.m.s. value of the harmonic component of order h;

H is 50 for the purpose of the compatibility levels in this standard.

NOTE *THD* takes account of harmonics only. For the case where interharmonics are to be included, see A.3.1.

3.2.8
voltage unbalance (imbalance)
condition in a polyphase system in which the r.m.s. values of the line-to line voltages (fundamental component), or the phase angle between consecutive line-to line voltages, are not all equal. The degree of the inequality is usually expressed as the ratios of the negative and zero sequence components to the positive sequence component

[IEV 161-08-09, modified]

NOTE 1 Generally voltage unbalance, in relation to three-phase systems, is considered through its negative phase sequence only. However, in some circumstances, the zero sequence component should also be considered.

NOTE 2 Several approximations give reasonably accurate results for the levels of unbalance normally encountered (ratio of negative to positive sequence components):

$$\text{e.g. voltage unbalance} = \sqrt{6 \times \frac{U_{12}^2 + U_{23}^2 + U_{31}^2}{(U_{12} + U_{23} + U_{31})^2} - 2}$$

where U_{12}, U_{23}, U_{31} are the three fundamental line-to-line voltages.

3.2.9
voltage deviation
increase or decrease of the r.m.s. supply voltage normally due to the variation of the load on the supply network or a part of it, or a rapid voltage change repeated, or not, due to a rapid change of load (see the first paragraph of 4.2 of IEC 61000-2-2); the part of transients with no remaining effects is excluded

NOTE Some voltage deviations may be fast changes due to adaptation of the voltage network to the load conditions (example: voltage taps changes of transformers, permanent effect of capacitor bank switching). Voltage fluctuation, which may cause flicker is a different phenomenon (series of voltage changes or cyclical voltage changes). Voltage variations and voltage fluctuations are the major types of voltage changes.

3.2.10
voltage dip (voltage sag)
sudden reduction of the voltage at a particular point on an electricity supply system below a dip threshold voltage, followed by its recovery after a brief interval

NOTE 1 Typically a dip is associated with the occurrence and termination of a short circuit or other extreme current increase on the system or installations connected to it.

NOTE 2 Generally the threshold corresponds to the minimum value of the tolerance band.

3.2.11
transient overvoltage
oscillatory or non-oscillatory overvoltage, highly damped and up to a few ms in duration. Compatibility level is related to the peak value line to earth

NOTE The origin of transient overvoltages is generally atmospheric or in operations in the network (switching, fuses). Its rise time may be from less than 1 μs to a few ms.

4 Electromagnetic environment classes

Several classes of electromagnetic environment can be defined, but for simplicity only three are considered and defined in this standard, as follows.

Class 1 This class applies to protected supplies and has compatibility levels lower than those on public networks. It relates to the use of equipment very sensitive to disturbances in the power supply, for instance electrical instrumentation in laboratories, some automation and protection equipment, some computers, etc.

Class 2 This class applies generally to PCCs and to IPCs in the environments of industrial and other non-public power supplies. The compatibility levels of this class are generally identical to those of public networks. Therefore, components designed for supply from public networks may be used in this class of industrial environment.

Class 3 This class applies only to IPCs in industrial environments. It has higher compatibility levels than those of class 2 for some disturbance phenomena. For instance, this class should be considered when any of the following conditions are met:

- a major part of the load is fed through converters;
- welding machines are present;
- large motors are frequently started;
- loads vary rapidly.

The class applicable for new plants and extensions of existing plants cannot be determined *a priori* and should relate to the type of equipment and process under consideration.

NOTE 1 Class 1 environments normally contain equipment which requires protection by such apparatus as uninterruptible power systems (UPS), filters or surge suppressers.

NOTE 2 In some cases, highly sensitive equipment may require compatibility levels lower than the ones relevant to class 1 environments. The compatibility levels are then to be agreed upon case by case (controlled environment).

NOTE 3 The supply to highly disturbing loads, such as arc-furnaces and large converters which are generally supplied from a segregated busbar, frequently has disturbance levels in excess of class 3 (harsh environment). In such special situations, the compatibility levels should be agreed upon.

NOTE 4 Taking account of diversity of industrial environments, different classes can be relevant for different phenomena in any given network.

5 Compatibility levels

5.1 General comment

The compatibility levels are set down for the various disturbances on an individual basis only. However, the electromagnetic environment usually contains several disturbances simultaneously, and the performance of some equipment can be degraded by particular combinations of disturbances. See Clause A.2 of IEC 61000-2-2.

Levels are provided in Table 1 to Table 5. See also guidance for interharmonics in Annex C.

IPCs should be categorized according to their compatibility levels. To enable the selection of specific equipment or devices such as rotating machines, power-capacitor banks, filters, it may be necessary to obtain a specific description of the voltage deviations that may be present at the equipment terminals. The technical committees responsible for the relevant product standards will specify the information to facilitate the proper selection of components. They should also take into account the compatibility levels in this standard when specifying the supply operating conditions of the equipment.

Compatibility levels are given at the IPCs, but this does not imply that disturbances at these levels will satisfy the emission requirements at the PCC. This fact is to be carefully considered when selecting the equipment.

NOTE 1 Equipment operating within class 1 is generally low-voltage equipment.

NOTE 2 To illustrate disturbance levels caused by power converters in various industrial environments, a few examples of calculated results are given in Annex B.

NOTE 3 The compatibility levels of class 3 cover the possible disturbances in industrial environments. For a specific installation it is expected that only some types of disturbances occur with the level pertaining to class 3. Since equipment or devices have different sensitivities to the various types of disturbances, a specific equipment or device may be used conditionally with a class 3 supply depending on the actual disturbance levels.

NOTE 4 Disturbance levels, which have both time and location variations, cannot be controlled at all locations and at all times. Therefore, evaluation should be made for the entire industrial system being considered, rather than at a specific location within that system.

5.2 Voltage deviations

See Table 1. For class 3, voltage deviations resulting in supply voltages in the range 0,85 U_C to 0,9 U_C are expected for a duration not longer than 60 s. For longer durations the range 0,9 U_C to 1,1 U_C applies.

NOTE 1 Voltage fluctuation leading to flicker is generally of concern only to lighting equipment. This should be connected to a class 2 supply. The compatibility levels of IEC 61000-2-2 apply.

NOTE 2 In certain circumstances, some equipment might be sensitive to rapid voltage changes.

5.3 Voltage dips and short interruptions

For class 1 IPCs, a protection provided by UPSs is considered and dips are not expected.

For a discussion of the other aspects of these phenomena see Clause B.3.

5.8 Voltage components at higher frequencies (above 50th harmonic)

Distortion of the voltage wave form can be such as to be equivalent to the superposition of voltages at frequencies, some of which are greatly in excess of that of the 50th harmonic. In the case of such higher frequency voltages it is generally not significant whether they are harmonics or interharmonics. They can occur both at discrete frequencies and in relatively broad bands of frequencies.

Until more experience makes publication of compatibility levels possible, Annex C.3 provides levels for guidance.

5.9 Transient overvoltages

The relative amplitude of transients is generally a function of their duration, of their frequency and of the voltage level of the network. For a discussion of these phenomena, see Clause B.4.

5.10 DC component

The voltage of industrial power supply systems covered by this standard does not normally have a d.c. component at a significant level. That can arise, however, due to slight defects of symmetry of controlled loads which are directly connected without a dedicated transformer.

The critical point is the level of d.c. current. The value of the d.c. voltage depends not only upon d.c. current but also upon other factors, especially the resistance of the network at the point to be considered. Therefore, a compatibility level for the d.c. voltage is not specified.

A d.c. component can cause unsymmetrical magnetization in transformers, leading to overheating and emission of harmonic voltages. Moreover, if flowing through the earth, such a d.c. current leads to increased corrosion of metal fixtures under ground.

6 Compatibility levels

Compatibility levels for voltage tolerance, voltage unbalance and power-frequency variations are given in Table 1 below.

Compatibility levels for harmonics are indicated in Tables 2 to 4.

Compatibility levels for total harmonic distortion are presented in Table 5.

Interharmonic compatibility levels are represented in Figure 1.

Table 1 – Compatibility levels for voltage tolerance, voltage unbalance and power-frequency variations

Disturbance		Class 1	Class 2	Class 3
Voltage tolerance, relative to nominal voltage U_N:	$\Delta U/U_N$	±8 %	±10 % [a]	+10 % to −15 % [b]
Voltage unbalance	U_{neg}/U_{pos}	2 %	2 %	3 %
Power-frequency deviations [c]	Δf	±1 Hz	±1 Hz	±1 Hz

[a] Value not defined in IEC 61000-2-2.
[b] See 5.2
[c] ±2 Hz in case of isolated networks.

Table 2 – Compatibility levels for harmonics – Harmonic voltage components Odd harmonics non-multiple of three

Order h	Class 1 U_h %	Class 2 U_h %	Class 3 U_h %
5	3	6	8
7	3	5	7
11	3	3,5	5
13	3	3	4,5
17	2	2	4
$17 < h \leq 49$	$2{,}27 \times (17/h) - 0{,}27$	$2{,}27 \times (17/h) - 0{,}27$	$4{,}5 \times (17/h) - 0{,}5$

NOTE In some cases where part of an industrial network is dedicated to large non-linear loads, the class 3 compatibility levels for that part of the network may be 1,2 times the above values. In such cases precautions should be taken regarding immunity of equipment connected. However, at the PCC (public network) the compatibility levels from IEC 61000-2-2 and IEC 61000-2-12 take precedence.

Table 3 – Compatibility levels for harmonics – Harmonic voltage components
Odd harmonics multiple of three

Order h	Class 1 U_h %	Class 2 U_h %	Class 3 U_h %
3	3	5	6
9	1,5	1,5	2,5
15	0,3	0,4	2
21	0,2	0,3	1,75
$21 < h \leq 45$	0,2	0,2	1

NOTE 1 These levels apply to zero sequence harmonics.

NOTE 2 In some cases where part of an industrial network is dedicated to large non-linear loads, the class 3 compatibility levels for that part of the network may be 1,2 times the above values. In such cases precautions should be taken regarding immunity of equipment connected. However, at the PCC (public network) the compatibility levels from IEC 61000-2-2 and IEC 61000-2-12 take precedence.

Table 4 – Compatibility levels – Harmonic voltage components even order

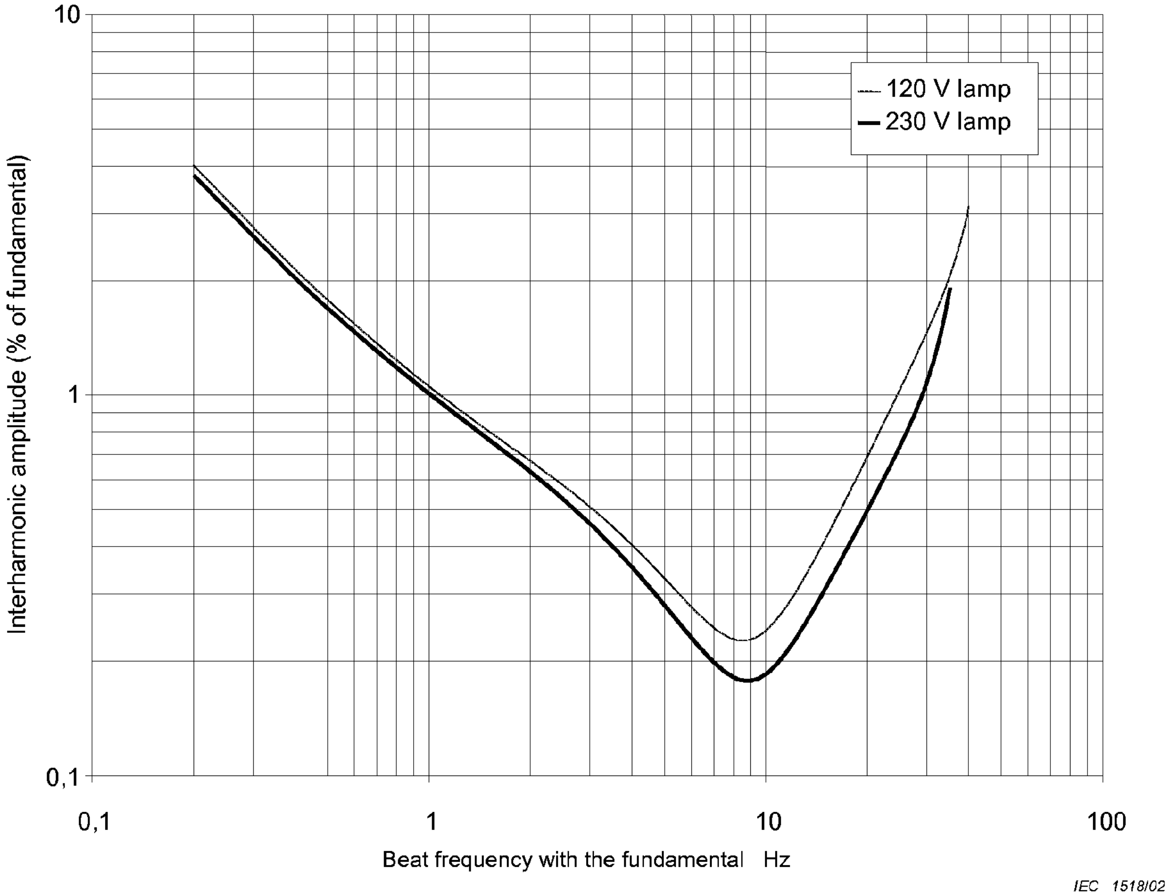
Order h	Class 1 U_h %	Class 2 U_h %	Class 3 U_h %
2	2	2	3
4	1	1	1,5
6	0,5	0,5	1
8	0,5	0,5	1
10	0,5	0,5	1
$10 < h \leq 50$	$0,25 \times (10/h) + 0,25$	$0,25 \times (10/h) + 0,25$	1

NOTE In some cases where part of an industrial network is dedicated to large non-linear loads, the class 3 compatibility levels for that part of the network may be 1,2 times the above values. In such cases precautions should be taken regarding immunity of equipment connected. However, at the PCC (public network) the compatibility levels from IEC 61000-2-2 and IEC 61000-2-12 take precedence.

Table 5 – Compatibility levels for total harmonic distortion

	Class 1	Class 2	Class 3
Total harmonic distortion (THD)	5 %	8 %	10 %

NOTE In some cases where part of an industrial network is dedicated to large non-linear loads, the class 3 compatibility levels for that part of the network may be 1,2 times the above values. In such cases precautions should be taken regarding immunity of equipment connected. However, at the PCC (public network) the compatibility levels from IEC 61000-2-2 and IEC 61000-2-12 take precedence.



Compatibility levels for interharmonics near the fundamental frequency – 230 V and 120 V systems – corresponding to perception of flicker are given by Figure 1 as a function of the beat frequency, which makes the result independent from the system frequency.

Figure 1 – Interharmonic compatibility levels
(Flickermeter response for P_{st} = 1 related to 60-W incandescent lamps)

Annex A
(informative)

Explanations and examples for interharmonics

A.1 Resolution of non-sinusoidal voltages and currents

The distortion of the supply voltage from its intended sinusoidal wave shape is equivalent to the superposition on the intended voltage of one or more sinusoidal voltages at unwanted frequencies. (The discussion below is valid for both voltage and current – therefore the word *quantity* is used.)

Fourier series analysis (IEV 101-13-08) enables any non-sinusoidal but periodic quantity to be resolved into truly sinusoidal components at a series of frequencies, and in addition, a d.c. component. The lowest frequency of the series is called the fundamental frequency f_f (IEV 101-14-50). The other frequencies in the series are integer multiples of the fundamental frequency and are called harmonic frequencies. The corresponding components of the periodic quantity are referred to as the fundamental and harmonic components, respectively.

The Fourier transform (IEV 101-13-09) may be applied to any function, periodic or non-periodic. The result of the transform is a spectrum in the frequency domain, which in the case of a non-periodic time function is continuous and has no fundamental component. The particular case of application to a periodic function shows a lines spectrum in the frequency domain, where the lines of the spectrum are the fundamental and harmonics of the corresponding Fourier series.

The Discrete Fourier Transform (DFT) is the practical application of the Fourier Transform. In practice the signal is analysed over a limited period of time (a *window* with duration T_w) using a limited number (M) of samples of the actual signal. The result of the DFT depends on the choice of these parameters, T_w and M. The inverse of T_w is the basic frequency f_b of the DFT.

The DFT is applied to the actual signal inside the window. The signal is not processed outside the window but is assumed to be an identical repetition of the signal inside the window. This results in an approximation of the actual signal by a virtual signal which is truly periodic and whose period is the time window.

The FFT (Fast Fourier Transform) is a special algorithm allowing short computation time. It requires the number of samples (M) to be an integer multiple of 2 ($M = 2^i$). (In other words, it does require the sampling frequency to be a locked integer power of 2 of the fundamental). However, modern digital signal processors have such capability that the extra complexity in a DFT (tables of sine and cosine functions) can be more economic and flexible than the frequency locked FFTs.

In order that the result of the DFT, applied to a function considered as periodic (see A.2), is the same as the result of a Fourier series analysis, the fundamental frequency f_f is made an integer multiple of the basic frequency (this requires the sampling frequency to be an exact integer multiple of the basic frequency [$f_s = M \times f_b$]). The synchronous sampling is essential. Loss of synchronism can change the spectrum result, making extra lines appear and changing amplitudes of true lines.

Accordingly, the measurement techniques defined in the second edition of IEC 61000-4-7[2] and the definition of the fundamental frequency in 3.2.1 is consistent for application to all electrotechnical and power electronics items. Other cases need further consideration.

As an illustration, the superposition of a sinusoidal ripple control signal at 175 Hz on a sinusoidal 50 Hz supply voltage may be considered. This results in a periodic voltage having a period of 40 ms and a frequency of 25 Hz. A classical Fourier series analysis of this voltage yields a fundamental component of 25 Hz with zero amplitude and two components with non-zero amplitude, a 2nd harmonic (50 Hz) with amplitude equal to that of the supply voltage and a 7th harmonic (175 Hz) with an amplitude equal to that of the ripple control signal. The definitions in 3.2 avoid the confusion implicit in this approach, and produce a result in line with the common practice of the DFT (as described in IEC 61000-4-7), showing a fundamental at 50 Hz and an interharmonic of order 3,5.

NOTE 1 When analysing the voltage of a power supply system, the component at the fundamental frequency is the component of the highest amplitude. This is not necessarily the first line in the spectrum obtained when applying a DFT to the time function.

NOTE 2 When analysing a current, the component at the fundamental frequency is not necessarily the component of the highest amplitude.

A.2 Time varying phenomena

The voltages and currents of a typical electricity supply system are affected by incessant switching and variation of both linear and non-linear loads. However, for analysis purposes, they are considered as stationary within the measurement window (approximately 200 ms), which is an integer multiple of the period of the power supply voltage. Harmonic analysers are designed to give the best compromise that technology can provide (see IEC 61000-4-7).

A.3 Definition of additional terms

The following definitions are complementary to those given in 3.2 and may be of practical use.

A.3.1
total distortion content
quantity remaining when the fundamental component is subtracted from an alternating quantity, all being treated as functions of time

NOTE The r.m.s. value of the total distortion content is:

$$TDC = \sqrt{Q^2 - Q_1^2}$$

Q_1 is the r.m.s. value of the fundamental component;

Q is the total r.m.s. value;

Q can represent either current or voltage.

It includes both harmonic and interharmonic components.

See also the definitions IEV 101-14-54 (IEC 60050-101) and IEV 551-20-11 (IEC 60050-551-20).

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2 Second edition, to be published.

A.3.2
total distortion ratio
TDR
ratio of the r.m.s. value of the total distortion content of an alternating quantity to the r.m.s. value of the fundamental component of the quantity

[IEV 551-20-14, modified]

$$TDR = \frac{TDC}{Q_1} = \frac{\sqrt{Q^2 - Q_1^2}}{Q_1}$$

where

Q_1 is the r.m.s. value of the fundamental component;

Q is the total r.m.s. value;

Q can represent either current or voltage.

Annex B
(informative)

Examples of expected disturbance levels in typical industrial networks

This annex gives the results of the calculation of the disturbance levels at the IPCs in some typical industrial networks. The cases studied are as follows:

– rolling mills (Table B.1; Figure B.1);
– paper industry (Table B.1; Figure B.2);
– manufacturing industry (Table B.2; Figure B.3).

B.1 Voltage disturbance levels in industrial networks due to large converters

It can be seen that some IPCs, namely those feeding large converters, can have disturbance levels considerably higher than those specified for public networks.

It is especially the levels of higher order harmonics (the 11th order is given as example), the total harmonic distortion coefficient (THD) or the voltage changes that exceed the corresponding levels for public networks.

The reported results are not total disturbance levels since the contribution caused by disturbances present in the public supply is not considered.

Table B.1 – Type of network

	Rolling mills			Paper industry		
	IPC 1	IPC 2	PCC	IPC 1	IPC 2	PCC
Harmonic voltages						
Average values						
U_5 (%)	3 to 6,5	2 to 3,9	1 to 2,2	1 to 1,7	1 to 2,3	0,5 to 1,1
U_{11} (%)	3 to 6,8	1,5 to 2,9	1 to 2	0,5 to 1,1	0,7 to 1,4	0,4 to 0,7
THD (%)	7 to 14,3	3,5 to 7,3	2 to 4,7	1,5 to 2,9	2 to 4	1 to 1,9
Harmonic voltages						
Peak values						
U_5 (%)	6 to 11,4	2,5 to 5,1	2 to 3,5	1 to1,9	1,5 to 2,7	0,6 to 1,3
U_{11} (%)	6 to 11,5	2 to 4,2	2 to 3,3	0,5 to 1,2	0,8 to 1,6	0,4 to 0,8
THD (%)	12 to 24,7	5 to 9,9	4 to 7,3	1,5 to 3,3	2 to 4,6	1 to 2,3
Voltage changes ΔU (%)	2 to 4,7	0,5 to 1,2	0,5 to 1,2	<0,1	<0,3	<0,1
Time interval between two voltage changes ΔT (s)	5 to 100	5 to 100	5 to 100	>600	>600	>600

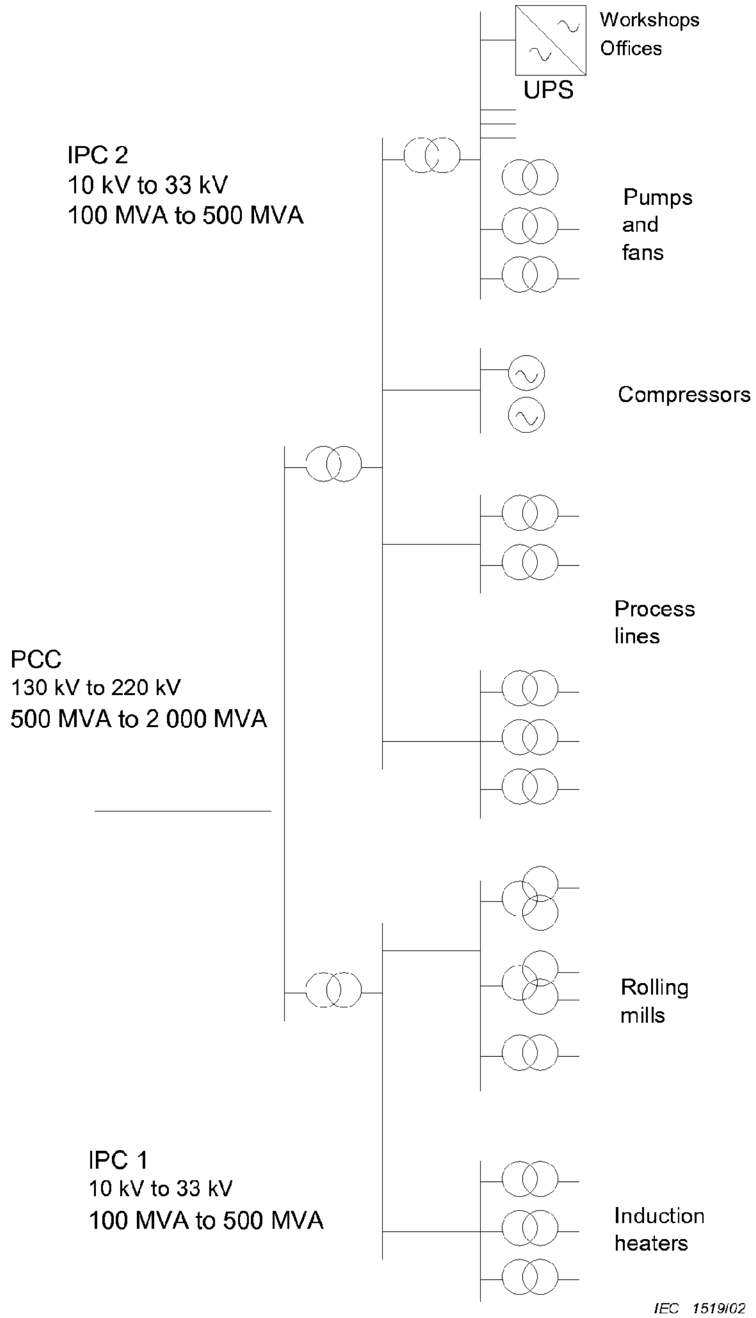

Figure B.1 – Example of power distribution in industry with rolling mills

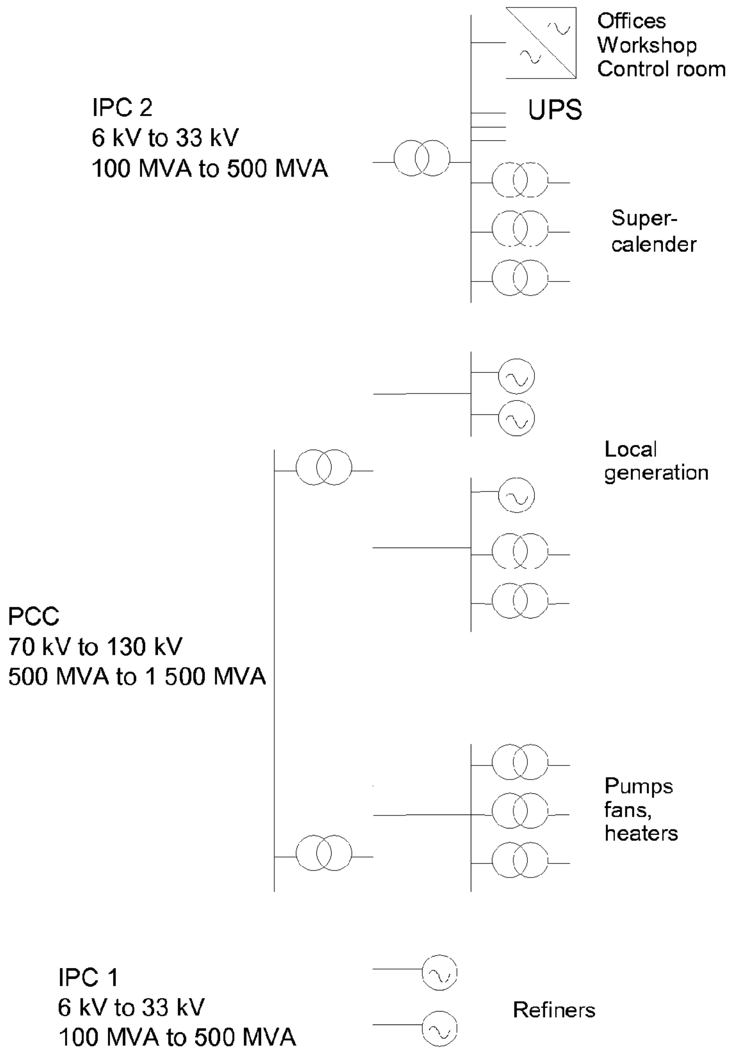

Figure B.2 – Example of power distribution in the paper industry

B.2 Voltage disturbance levels in industrial networks at high load

The range of the given values depends on the assumed range of variation of the system parameters and of the coincidence factors.

No power capacitor is present and therefore the possible magnification of the harmonic voltages is neglected.

Table B.2 – Voltage disturbance levels in a typical manufacturing industry

	Impedance 1/MVA [a]	Short-circuit fault level (S_{SC}) MVA	Total load MVA	Converter load MVA	THD %	Voltage changes %
130 kV line	1/2 000	2 000				
Transformer TA	1/320	275,8				
MT cable	1/6 000					
IPC		266,6	2,3	1,25	1,08	0,6
Transformer T1	1/8,9					
LV1 line		8,6	0,3	0,05	1,34	2,4
Transformer T5	1/1,25					
Converter C1		1,09		0,05	10,6	
Transformer T3	1/12					
LV2 line		11,5	0,6	0,3	5,0	3,0
350 kVA motors		2,275	0,3			
60 µH reactor	1/8,5					
Converter C2		5,25		0,3	13,2	
Transformer T4	1/22,2					
LV3 line		20,5	0,9	0,9	10,1	3,1
400 V cable	1/582					
Converters C3 ..... C10		20		0,9	10,4	

[a] The impedances are in p.u. on a 1 MVA basis.

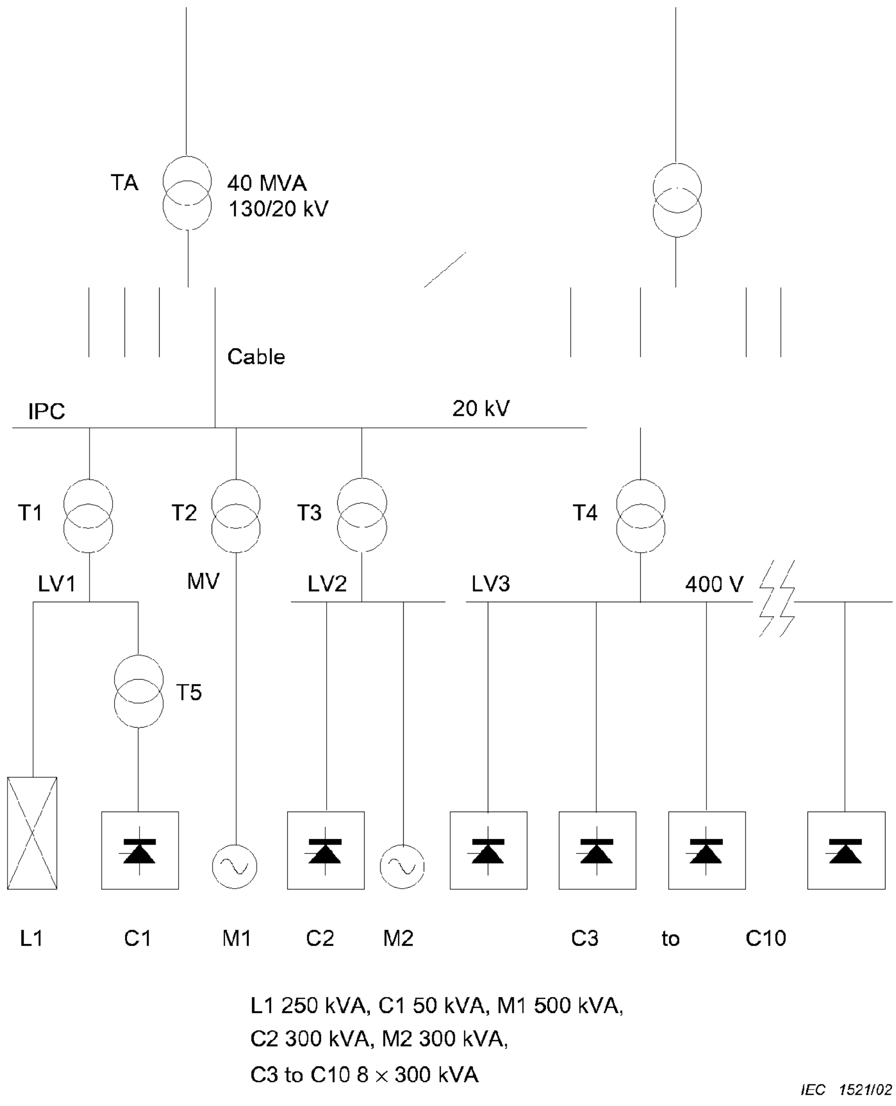

Figure B.3 – Example of power distribution
in a generic manufacturing industry

B.3 Voltages dips and short interruption

B.3.1 Description

Voltage dips and short interruptions at the PCC have the main influence on these phenomena inside the installation. They are unpredictable, largely random events arising mainly from electrical faults on the power supply system or large installations. They are best described in statistical terms. See IEC 61000-2-8.

A voltage dip is a two-dimensional disturbance phenomenon, since the level of the disturbance increases with both the depth and duration of the dip.

The depth of the voltage dip depends on the proximity of the observation point to the point on the network at which the short circuit occurs. At that point the voltage collapses to near zero, so that the depth of the dip approaches 100 %. In the case of other causative events, such as a large load fluctuation, the depth is likely to be less.

A voltage dip may last less than 0,1 s if the incident occurs in the transmission system and is eliminated by very fast systems of protection or if a self-clearing fault is involved. If the fault affects a lower level of the network and is cleared by certain protection systems used on those networks, it may last up to a few seconds. Most voltage dips last between half a period and 1 000 ms.

The number of voltage dips is significant only when the immunity of a given device is insufficient for the depth-duration occurring. This number becomes an important data for choosing the appropriate level of immunity of a given process. The number for a particular line includes voltage dips produced by faults on other lines in the same network and voltage dips coming from upstream networks. (See also IEC 61000-2-8.)

In rural areas supplied by overhead lines, the number of voltage dips can reach several hundreds per year, depending in particular on the number of lightning strokes and other meteorological conditions in the area.

On cable networks, the latest information indicates that an individual user of electricity connected at low voltage may be subjected to voltage dips occurring at a rate which extends from around ten per year to about a hundred per year, depending on local conditions. The duration of these voltage dips is usually between half a cycle and 3 s.

Short supply interruptions last up to 180 s according to the type of reclosing or transfer system used in overhead networks. It may be possible to reduce time in special cases. Frequently short supply interruptions are preceded by voltage dips. Distinction between a dip and a short interruption may be difficult. By convention, a retained voltage below a certain level (10 % for example) may be the criterion to make this distinction. However, in a three-phase system this condition is to be applied to each phase, simultaneously, to be considered as a short supply interruption.

B.3.2 Adaptation

The main requirement for compatibility levels is to enable immunity levels to be coordinated. However, the compatibility level would have to be expressed in a two-dimensional manner, to reflect the level of the disturbance. Sufficient data are not yet available to enable this to be done.

Especially in the case of short interruptions, but also for the more severe voltage dips, immunity of electrical equipment is not, in the strict sense, an appropriate concept, since no electrical device can continue to operate as intended in the absence of its energy supply. Immunity from these disturbances is therefore a matter of either the fast restoration of energy from an alternative source or arranging for the equipment and its associated process to adapt in an intended manner to the brief interruption or diminution of power. This is a complex matter, having both technical and economic aspects, and is beyond the scope of this standard (see Bibliography).

Values describing voltage dips and short interruptions for class 3 IPCs may be established with due consideration of the following:

- the disturbance level values at the PCCs of the plant may be adopted, but it should be remembered that these values can vary considerably with the type of supply system, high voltage or medium voltage via overhead lines or cables, single circuit or double circuits for example, and with the location of the site, exposed and prone to lightning for example;
- the presence of in-plant generation can reduce the severity of voltage dips and short-time interruptions;
- the contribution of the industrial plant to the voltage dips or short-time interruptions should be considered; for instance, as a consequence of severe faults, large voltage depressions can be caused by the simultaneous restarting of several induction motors in the plant;
- the short interruption values for class 3 IPCs refer to plants fed by one supply line only.

As a basis, the results of IEC 61000-2-8 may be adopted.

B.4 Transient overvoltages

Several phenomena, including the operation of switches and fuses and the occurrence of lightning strokes in proximity to the supply networks, give rise to transient overvoltages in low-voltage power supply systems and in the installations connected to them. The overvoltages may be either oscillatory or non-oscillatory, are usually highly damped, and have rise times ranging from less than 1 µs to a few milliseconds.

The magnitude, duration, and energy-content of transient overvoltages vary with their origin. Generally, those of atmospheric origin have the higher amplitude, and those due to switching are longer in duration and contain the greater energy. Critical equipment needs to be protected by surge protective devices, and these should generally be selected to cater for the greater energy content of the switching overvoltages.

Switching of capacitor banks is a common cause of transient overvoltages. Typically, their value at the point of incidence is less than twice the nominal voltage. However, wave reflections and voltage magnification can occur as the transient is propagated along a line, amplifying the overvoltage incident on connected equipment.

Figure B.4 shows an example of tolerance envelope for IT equipment which is applicable for single phase 120 V. Other types of equipment may present different tolerance characteristics.

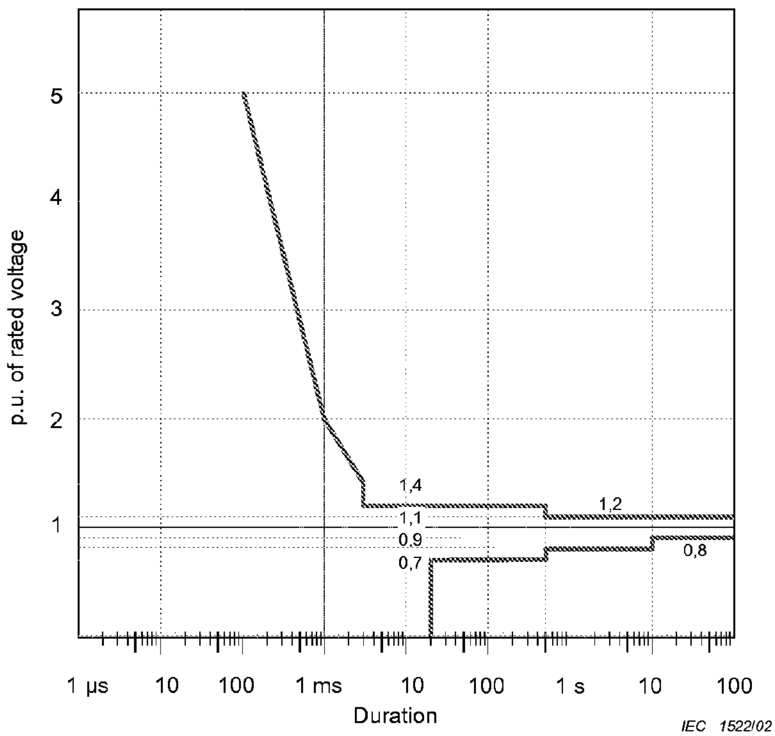

Figure B.4 – ITI (CEBEMA) – Curve of tolerance envelope of ITE

Transients of atmospheric origin have been recorded at magnitudes up to 6 kV on LV networks. This value should be considered for coordination of isolation.

Taking into account that attenuation between the PCC and the practical input of the installation is not sufficiently known and that a 100 % immunity is a very costly fiction (if not impossible), the compatibility level for EMC purposes should be set much lower.

The transient overvoltages of external origin (coming from the public power supply system) may be attenuated according to the location of the IPC within the installation.

Annex C
(informative)

Interharmonic and voltages at higher frequencies

C.1 Sources of interharmonics

C.1.1 Identification

Sources of interharmonics can be found in low-voltage networks as well as in medium-voltage and high-voltage networks. The interharmonics produced by low-voltage sources (welding machines, power converters, induction motors) mainly influence devices in their vicinity; the interharmonics produced in the medium-voltage and/or the high-voltage networks (arc furnaces, power converters, induction motors) flow in the low-voltage networks they supply.

There is also low-level background Gaussian noise, with a continuous regular frequency spectrum, superimposed on the low-voltage curve even in the absence of a local source of interharmonics. Typical voltage levels, on a low-voltage network 230 V, seem to be in the range of 40 mV to 50 mV, when measured with a filter bandwidth of 10 Hz, and 20 mV to 25 mV when measured with a filter bandwidth of 3 Hz.

Four main origins of interharmonics can be distinguished:

- electrical arc-furnaces, arc welding machines or plasma heaters, which have been known for many years as the major power source of interharmonics or sub-harmonics the origin of which is in the process itself, and/or in the position control of the electrodes for which the phenomenon is without any synchronism with the power frequency;
- power converters with active front end may be operated at switching frequencies which generally are interharmonic frequencies; the effect of switching produces interharmonic voltages or currents;
- spurious coupling between circuits where the fundamental frequencies are different; this is the case of electronic frequency converters;
- intentional production of voltages at such interharmonic frequencies for the purpose of signal transmission.

C.1.2 Different types of sources of interharmonics

C.1.2.1 Random sources

Arc welding machines generate a continuous wide band frequency spectrum, associated to an intermittent process with the duration of the individual welding actions varying between 1 s and several seconds. They are mostly connected to the low-voltage network, preferably of low impedance in order to avoid disturbing flicker effects.

Arc furnaces produce continuous but randomly varying interharmonic frequency spectra due to the irregular input current. Their high rating (50 MW to 120 MW) make them always connected to the medium-voltage or high-voltage network. The highest emission level occurs during the starting-phase of a melting process.

C.1.2.2 Sub-harmonics or interharmonics produced by the load of a converter

Electronic frequency converters have a different behaviour according to their structure. Direct converters, such as cycloconverters, consist of an assembly of semiconductor devices and their auxiliary circuits which, by means of their cyclic commutations, convert the input voltage at the fundamental frequency of the power supply network into an output voltage at a fundamental frequency, defined by the control of the converter to be suitable for feeding the load. (The load may be a variable speed motor or a particular network at a fixed frequency, for example, 25 Hz or 16 Hz 2/3.) These cycloconverters have no decoupling function between the two different fundamental frequencies. Therefore currents at multiples of the load frequency are circulating directly in the line side of the converter assembly of each phase. The line current has the form of a current at the power supply network frequency (plus its regular harmonics), modulated in amplitude depending on the load frequency.

NOTE For example, in a cycloconverter for a three-phase balanced load fed at the frequency f_L, the line currents combine in each phase at the point of coupling of the three individual multiphase converters (pulsation index p), each feeding a phase of the three-phase load. The combination of the line currents can be approached when considering the total active power and the total reactive power. In the case of a purely active load and of an ideal converter, the total active power is a constant (without fluctuating power) while the total reactive power is a constant with addition of fluctuating component of low amplitude at a frequency of $2pf_L$. In the case of a purely reactive load and of an ideal converter, the total active power is zero, while the total reactive power is a constant. The line current resulting from these combinations contains a modulation at frequencies of $2pf_L$ and its multiples. Additional other interharmonic currents result from a non-linear command having a rating optimization purpose, and from the unavoidable imperfections of the system.

Indirect frequency converters have an intermediate d.c. link, with an input converter on the line side and an output converter (more often operating as an inverter) on the load side. For both structures, current stiff and voltage stiff, the d.c. link includes a filter decoupling the current or the voltage of the power supply system and of the load. Therefore, the two fundamental frequencies (supply and load) are decoupled. But infinite filtering does not exist, and the remaining coupling path produces currents on the supply network at frequencies present on the d.c. link and due to the load side. These frequencies are sub-harmonic and interharmonic relative to the power supply frequency. However, it should be underlined that this phenomena is most often negligible for voltage source inverters.

Electronic frequency converters inject currents into the network at sub-harmonic and interharmonic frequencies that are mainly in the range from 0 Hz to 150 Hz or 300 Hz. These correspond to the fundamental frequency of the load, which is frequently a variable speed motor. The highest range of frequencies, up to 2 500 Hz, is much smaller in amplitude. The main difficulty is that those sub-harmonics or interharmonics are not at a fixed frequency.

Some semiconductor converters, used to feed particular networks at a fixed frequency, also produce sub-harmonics and/or interharmonics at a fixed frequency.

Harmonic and interharmonic frequencies of such converters with an input fundamental frequency f and an output fundamental frequency F are defined by the following equation:

$$f_{h,m} = [(p_1 \times k_1) \pm 1] \times f \pm [(p_2 \times k_2)] \times F$$

where

p_1 is the pulse number of the input converter;

p_2 is the pulse number of the output converter;

k_1, k_2 are the series of whole integers (0, 1, 2, 3...); and

if $k_2 = 0$, $f_{h,m} = f_h$ (harmonic frequencies).

C.1.2.3 Sub-harmonics or interharmonics produced by internal operation of a converter

Some self-commutated converters have an active front end (using transistors or gate turn-off thyristors) operated at a switching frequency which is not an integer multiple of the network frequency. This switching frequency may be constant or variable according to criteria related to the operation of the converter itself. Each switching changes the current path, thereby showing a non-linearity to the network. This produces interharmonic voltages superimposed to the network voltage when the internal impedance of the switching circuits of the converter is low compared to the internal impedance of the network. This may also produce interharmonic currents injected into the network when the internal impedance of the switching circuits of the converter is high as compared to the internal impedance of the network. The interharmonic frequencies are related to the switching frequency, generally in the range of a few hundred hertz to a few tenths of kilohertz.

C.1.2.4 Other miscellaneous sources

Induction motors may give rise to an irregular magnetizing current due to the slots in the stator and rotor – possibly in association with saturation of the iron – which generates interharmonics in the low-voltage network. At the normal speed of the motor, the disturbing frequencies are practically in the range of orders 10 to 40, but during the starting period they run through the whole frequency range up to their final value.

Voltages at interharmonic pre-defined frequencies are also produced intentionally by ripple control transmitters. The purpose and practice of ripple control transmitters is described in 4.7 of IEC 61000-2-2. Their frequency range is 110 Hz to 3 000 Hz with a maximum relative voltage level U_S/U_N of 9 % up to 500 Hz and decreasing (20 dB per decade) between 500 Hz and 3 000 Hz (1,5 %). Other systems for mains signalling operate in higher frequency ranges (3 kHz to 20 kHz and 20 kHz to 148,5 kHz).

C.1.3 Effects of interharmonics and compatibility

Interharmonics introduce non-periodical or quasi-non-periodical phenomena superimposed on the periodical wave form of voltage network. Therefore the crest voltage is changed at a lower frequency where the difference of the involved frequencies appears as the disturbance. Each use of electricity where the crest voltage is of importance is then disturbed. Examples are lighting equipment, which may flicker, and television receivers, which may be disturbed.

Ripple control receivers are likely to be disturbed by interharmonics. For reception their minimum operating level is as low as 0,3 %, to take into account the different attenuations between the emitter and the receivers in the power supply network. Therefore users of electricity should know whether such ripple control is in operation in their area and what the allocated frequency is. This minimum information is required to ensure compatibility.

The frequency of an interharmonic current may occur and sweep in a wide range of frequencies without discontinuity. The resulting interharmonic voltage is defined by the current and the impedance at the particular frequency. The most spurious effect is the ability to excite anti-resonance frequencies arising from passive filters or power factor compensation capacitor banks connected to the network.

C.1.4 Guidance levels

C.1.4.1 Levels related to flicker effect

The case of a voltage having a frequency which combines with the fundamental frequency and results in a beat frequency has been dealt with in 5.7. Table C.1 indicates the interharmonic voltage levels corresponding to the compatibility level given in Figure 1.

Table C.1 – Indicative values for interharmonic voltages in low-voltage networks with respect to the flicker effect

	50 Hz system			60 Hz system		
Order m	Interharmonic frequency f_m Hz	U_m %		Interharmonic frequency f_m Hz	U_m %	
		120 V system	230 V system		120 V system	230 V system
$0,20 < m \leq 0,60$	$10 < f_m \leq 30$	0,68	0,51	$12,0 < f_m \leq 36,0$	0,95	0,69
$0,60 < m \leq 0,64$	$30 < f_m \leq 32$	0,57	0,43	$36,0 < f_m \leq 38,4$	0,79	0,58
$0,64 < m \leq 0,68$	$32 < f_m \leq 34$	0,46	0,35	$38,4 < f_m \leq 40,8$	0,64	0,48
$0,68 < m \leq 0,72$	$34 < f_m \leq 36$	0,37	0,28	$40,8 < f_m \leq 43,2$	0,50	0,38
$0,72 < m \leq 0,76$	$36 < f_m \leq 38$	0,29	0,23	$43,2 < f_m \leq 45,6$	0,39	0,30
$0,76 < m \leq 0,84$	$38 < f_m \leq 42$	0,23	0,18	$45,6 < f_m \leq 50,4$	0,23	0,18
$0,84 < m \leq 0,88$	$42 < f_m \leq 44$	0,23	0,18	$50,4 < f_m \leq 52,8$	0,22	0,18
$0,88 < m \leq 0,92$	$44 < f_m \leq 46$	0,28	0,24	$52,8 < f_m \leq 55,2$	0,22	0,20
$0,92 < m \leq 0,96$	$46 < f_m \leq 48$	0,40	0,36	$55,2 < f_m \leq 57,6$	0,34	0,30
$0,96 < m < 1,04$	$48 < f_m \leq 52$	0,67	0,64	$57,6 < f_m \leq 62,4$	0,59	0,56
$1,04 < m \leq 1,08$	$52 < f_m \leq 54$	0,40	0,36	$62,4 < f_m \leq 64,8$	0,34	0,30
$1,08 < m \leq 1,12$	$54 < f_m \leq 56$	0,28	0,24	$64,8 < f_m \leq 67,2$	0,22	0,20
$1,12 < m \leq 1,16$	$56 < f_m \leq 58$	0,23	0,18	$67,2 < f_m \leq 69,6$	0,22	0,18
$1,16 < m \leq 1,24$	$58 < f_m \leq 62$	0,23	0,18	$69,6 < f_m \leq 74,4$	0,23	0,18
$1,24 < m \leq 1,28$	$62 < f_m \leq 64$	0,29	0,23	$74,4 < f_m \leq 76,8$	0,39	0,30
$1,28 < m \leq 1,32$	$64 < f_m \leq 66$	0,37	0,28	$76,8 < f_m \leq 79.2$	0,50	0,38
$1,32 < m \leq 1,36$	$66 < f_m \leq 68$	0,46	0,35	$79,2 < f_m \leq 81,6$	0,64	0,48
$1,36 < m \leq 1,40$	$68 < f_m \leq 70$	0,57	0,43	$81,6 < f_m \leq 84,0$	0,79	0,58
$1,40 < m \leq 1,80$	$70 < f_m \leq 90$	0,68	0,51	$84,0 < f_m \leq 108,0$	0,95	0,69

C.1.4.2 General levels

Levels given in Table 4 for the next higher even harmonic may be taken as guidance for each interharmonic frequency.

The levels relevant to class 2 are set in consideration of the presence of ripple control devices. Since ripple control receivers, lighting equipment and television receivers are not generally present in industrial areas, the compatibility levels for class 3 are expected at higher values.

NOTE If such devices are present in the industrial area, they are not directly coupled to the circuit of class 3. For mitigation methods, see Clause C.2.

Where there is a risk of interference with mains signalling, ripple control, or other susceptible equipment, special care should be taken with regard to interharmonics. A class 2 environment should be preferred. For this class, the operational frequency of ripple control receivers is locally specified. The response level of these receivers can be as low as 0,3 % of the nominal supply voltage. A receiver can therefore be disturbed by an unintended interharmonic voltage, at its defined operational frequency, in excess of this value.

The interharmonic compatibility level at the operating frequency of the mains signalling or ripple control system is not defined. At the operating frequency, the emission level should be limited to 0,2 % of the nominal supply voltage, and the immunity of equipment should be defined according to the particular specifications of the corresponding transmitters and network conditions. See 4.7.1 of IEC 61000-2-2.

The use of a class 3 environment requires more investigation such as identification of the coupling path between the class 3 environment and the public supply network, or design of a decoupling system.

High values of interharmonics can be present at class 3 IPCs due especially to some kinds of converters. They can be as high as 2,5 % for frequencies below the 11th order, and up to 1 % for orders above 25. Due to their origin, these values are generally fluctuating and rapidly changing in both amplitude and frequency. For that reason they may cause resonances on capacitor banks and passive filters.

NOTE Everywhere they are used in industrial networks, power factor correction capacitors should be connected through series reactors, particularly those which are intended to be connected to IPCs of class 3.

C.2 Mitigation methods

It is generally a complex matter to decrease emissions of power converters. Where susceptible equipment is expected and cannot be avoided, a possible solution is to introduce an efficient decoupling between the circuits supplying the susceptible equipment and the circuits supplying the power converters by means of filters or even UPSs.

When the purpose of the conversion of power is to produce an adjustable fundamental frequency, a wide spectrum of interharmonic frequencies can be expected. The most complex aspect is due to the interharmonics which sweep the whole spectrum when the output of the converter is operated at a variable frequency.

Interharmonics of this kind are the result of the impossibility of obtaining a perfect decoupling between the input and the output of a converter. The components of the largest amplitude are generally at low or very low frequencies.

Another kind arises from the internal operation mode of the converter. The well-known example of pulse width modulation (PWM) operated converters shows an emission of interharmonics related to the switching frequency controlling the semiconductor devices. This switching frequency may be fixed or adjustable depending on the control technique. Interharmonics of this last kind are at higher frequencies than the previous one. They are generally easier to filter.

However, converters operating with PWM introduce an interharmonics emission at frequencies associated with the switching frequency, which can be filtered if necessary.

C.2.2 Increase immunity

Product standards set immunity limits with reference to compatibility levels. However, when compatibility levels are still under consideration or when the relevant product standard is not available, a solution in case of susceptibility causing malfunction of an equipment, can often be found in appropriate filtering of the supply of the control part of the disturbed equipment. For equipment needing to be synchronized with the power supply system, the appropriate filtering may be limited to the synchronizing circuit by means of a band pass filter tuned at the fundamental frequency. This generally affects circuits of low level of power.

The most efficient solution remains appropriate segregation of the circuits according to their use. In an industrial network, this segregation should be always established between the industrial applications and the offices, and within the industrial applications between the different loads which should be classified appropriately. This kind of segregation facilitates the design of correct decoupling and filtering of the whole installation, with the objective of the best technical and economical compromise.

C.2.3 Protection of ripple control system

Identification of the frequency used by the ripple control system or mains signalling should be made available by the power supply authority.

Two aspects should be considered at the PCC of the installation:

- the maximum emission allowed for the whole installation in order not to disturb the signalling system;
- the minimum impedance, at the particular frequency of the signalling system, that is acceptable for operation of the transmission of the signalling system.

If a particular passive filtering or decoupling system is installed, care should be taken to avoid anti-resonance in case of sweeping interharmonics.

C.3 Voltages at higher frequencies

Distortion of the voltage wave form in the frequency band above the 50th harmonic and less than 9 kHz is also represented by sinusoidal components, which can occur both at discrete frequencies and in relatively broad bands of frequencies. In the case of such higher frequency voltages, it is generally not significant whether they are harmonics or interharmonics.

For a discrete frequency in the range above the 50th harmonic and up to 9 kHz, levels are expressed as the ratio u of the r.m.s. voltage at that frequency to the r.m.s. value of the fundamental component of the voltage.

For a band of frequencies above the 50th harmonic and up to 9 kHz, the levels are related to any 200 Hz bandwidth centred at frequency F, and are expressed as follows:

$$u_b = \frac{1}{V_{1N}} \times \sqrt{\frac{1}{200\ \mathrm{Hz}} \times \int_{F-100\ \mathrm{Hz}}^{F+100\ \mathrm{Hz}} V^2(f) \times df}$$

where

V_{1N} is the rated r.m.s. value of the fundamental component;

$V(f)$ is the r.m.s. voltage at frequency f;

F is the centre frequency of the band (the band is above the 50th harmonic).

From experience, levels up to 80 % or 90 % of the following reference levels have been reported as already met in industrial networks:

u = 0,2 % for class 2 IPCs;

u = 1 % for class 3 IPCs.

u_b = 0,3 % for class 2 IPCs;

u_b = 1,5 % for class 3 IPCs;

and few troubles were reported on networks having values in excess of the above.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60050-101	- [1)]	International Electrotechnical Vocabulary (IEV) Part 101: Mathematics	-	-
IEC 60050-161	- [1)]	Chapter 161: Electromagnetic compatibility	-	-
IEC 60050-551	- [1)]	Part 551: Power electronics	-	-
IEC 61000-2-2	- [1)]	Electromagnetic compatibility (EMC) Part 2-2: Environment - Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems	EN 61000-2-2	2002 [2)]
IEC 61000-2-12	- [3)]	Part 2-12 : Environment - Compatibility levels for low-frequency conducted disturbances and signalling in public medium-voltage power supply systems	-	-

[1)] Undated reference.

[2)] Valid edition at date of issue.

[3)] At draft stage.

Bibliography

IEC 60038: 1983, *IEC standard voltages*
Amendment 1 (1994)
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