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Titre :

**Compatibilité Electromagnétique (CEM) -  
Partie 2-2 : Environnement - Niveaux de  
compatibilité pour les perturbations conduites  
basse fréquence et la transmission de signaux  
sur les réseaux publics d'alimentation à basse  
tension.**

Title :

**Electromagnetic Compatibility (EMC) - Part 2-2 :  
Environment - Compatibility levels for low-  
frequency conducted disturbances and  
signalling in public low-voltage power supply  
systems.**

Note d'introduction

Introductory note

<b>ATTENTION</b>  <b>CDV soumis en parallèle au vote (CEI) et à l'enquête (CENELEC)</b>	<b>ATTENTION</b>  <b>Parallel IEC CDV/CENELEC Enquiry</b>
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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## ELECTROMAGNETIC COMPATIBILITY (EMC)

**Part 2-2: Environment – Compatibility levels for low-frequency  
conducted disturbances and signalling in public low-voltage  
power supply systems – Basic EMC publication**

## FOREWORD

- 1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 61000-2-2 has been prepared by subcommittee 77A: Low frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

It has the status of a basic EMC publication in accordance with IEC guide 107.

The text of this standard is based on the following documents:

FDIS	Report on voting
XX/XX/FDIS	XX/XX/RVD

Full information on the voting for the approval of this standard 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 3.

The committee has decided that the contents of this publication will remain unchanged until \_\_\_\_\_. 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 the product committees)

### **Part 4: Testing and measurement 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 sections which are to be published either as international standards or as technical reports.

These standards and reports will be published in chronological order and numbered accordingly.

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.

## **ELECTROMAGNETIC COMPATIBILITY (EMC)**

### **Part 2-2 : Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems.**

#### **BASIC EMC PUBLICATION**

## **1 Scope**

This standard is concerned with conducted disturbances in the frequency range from 0 to 9 kHz, with an extension up to 148.5 kHz specifically for mains signalling systems. It gives compatibility levels for public low voltage a.c. distribution systems having a nominal voltage up to 420 V, single-phase or 690 V, three-phase and a nominal frequency of 50 Hz or 60 Hz.

The compatibility levels specified in this standard apply at the point of common coupling. At the power input terminals of equipment receiving its supply from the above systems the severity levels of the disturbances can, for the most part, be taken to be the same as the levels at the point of common coupling. In some situations this is not so, particularly in the case of a long line dedicated to the supply of a particular installation, or in the case of a disturbance generated or amplified within the installation of which the equipment forms a part.

Compatibility levels are specified for electromagnetic disturbances of the types which can be expected in public low voltage power supply systems, for guidance in:

- a) the limits to be set for disturbance emission into public power supply systems (including the planning levels defined in 3.1.5).
- b) the immunity limits to be set by product committees and others for the equipment exposed to the conducted disturbances present in public power supply systems.

The disturbance phenomena considered are:

- voltage fluctuations and flicker;
- harmonics up to order 50;
- inter-harmonics up to the 50<sup>th</sup> harmonic;
- voltage distortions at higher frequencies (above 50<sup>th</sup> harmonic);
- voltage dips and short supply interruptions;
- voltage unbalance;
- transient overvoltages;
- power frequency variation;
- d.c. components;
- mains signalling.

Most of these phenomena are described in IEC 61000-2-1.

## 2 Normative references

The following normative documents contain provisions which, through references in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60050-161 : 1990, *International Electrotechnical Vocabulary (IEV) - Part 161: Electromagnetic compatibility*

IEC 60050-161-am1 : 1997, *Amendment No. 1*

IEC 60050-161-am2 : 1998, *Amendment No. 2*

IEC 60050-101 : 1998, *International Electrotechnical Vocabulary (IEV) - Part 101: Mathematics*

IEC 61000-3-3 : 1994, *Electromagnetic compatibility (EMC) - Part 3: Limits - Section 3: Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current  $\leq 16$  A*

IEC 61000-4-7 : 1991, *Electromagnetic compatibility (EMC) - Part 4: Testing and measurement techniques - Section 7: General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto*

IEC 61000-4-15 : 1997, *Electromagnetic compatibility (EMC) - Part 4: Testing and measurement techniques - Section 15: Flickermeter -Functional and design specifications.*

IEC 60664-1 : 2000, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

## 3 Definitions

### 3.1 General definitions

#### 3.1.1

##### **(electromagnetic) disturbance**

Any electromagnetic phenomenon which, by being present in the electromagnetic environment, can cause electrical equipment to depart from its intended performance [IEV 161-01-05 modified]

#### 3.1.2

##### **disturbance level**

The amount or magnitude of an electromagnetic disturbance, measured and evaluated in a specified way [IEV 161-03-01 modified]

### 3.1.3

#### **electromagnetic compatibility**

##### **EMC (abbreviation)**

The ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

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 levels of the devices equipment and systems at any location are not exceeded by the disturbance level at that location resulting from the cumulative emissions 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 is sufficiently low. See 61000-2-1 clause 4.

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 effects which devices, equipment and systems undergo from each other or from electromagnetic phenomena.

[IEV 161-01-07 modified]

### 3.1.4

#### **(electromagnetic) compatibility level**

The specified electromagnetic disturbance level used as a reference level in a specified environment for co-ordination in the setting of emission and immunity limits.

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.

[IEV 161-03-10 modified]

### 3.1.5

#### **planning level**

A level of a particular disturbance in a particular environment, adopted as a reference value for the limits to be set for the emissions from large loads and installations, in order to co-ordinate 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 information, see Annex A.

### 3.1.6

#### **point of common coupling**

##### **PCC (abbreviation)**

The 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]

## **3.2 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 numerical application of the Fourier Transform as defined in IEV 101-13-09. See ANNEX B.

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 IEC and other standards. Some of those other definitions, although not used in this standard, are discussed in the informative annex, ANNEX B.

### 3.2.1

#### **fundamental frequency**

A 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 purpose of this standard, the fundamental frequency is the same as the power supply frequency [IEV 101-14-53 modified]

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

### 3.2.2

#### **fundamental component**

The component whose frequency is the fundamental frequency.

### 3.2.3

#### **harmonic frequency**

A frequency which is an integer multiple of the fundamental frequency. The ratio of the harmonic frequency to the fundamental frequency is the *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 an 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 an 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 *subharmonic frequency* may be used.

### 3.2.6

#### **interharmonic component**

A 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 (50 Hz systems) or 12 fundamental periods (60 Hz systems), i.e. approximately 200 ms. The difference in frequency between 2 consecutive interharmonic components is, therefore, approximately 5 Hz.



**3.2.7****total harmonic distortion  
(THD abbreviation)**

The 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.

$$\text{THD} = \sqrt{\sum_{h=2}^{h=H} \left( \frac{U_h}{U_1} \right)^2}$$

where

Q represents either current or voltage

$Q_1$  = r.m.s. value of the fundamental component

h = harmonic order

$Q_h$  = r.m.s. value of the harmonic component of order h

H = 50 generally, but 25 when the risk of resonance at higher orders is low.

NOTE - THD takes account of harmonics only. For the case where interharmonics are to be included, see B.1.2.1, *distortion content*, Annex B.

**3.2.8****voltage unbalance (imbalance)**

A condition in a polyphase system in which the r.m.s. values of the line voltages (fundamental component), or the phase angles between consecutive 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 - In this standard voltage unbalance is considered in relation to three-phase systems.

NOTE 2 - The following approximation gives sufficiently accurate results for the levels of unbalance normally encountered (ratio of negative to positive sequence components):

$$\text{Voltage unbalance} = \sqrt{\frac{6 \cdot (U_{12}^2 + U_{23}^2 + U_{31}^2)}{(U_{12} + U_{23} + U_{31})}} - 2$$

Where  $U_{12}$ ,  $U_{23}$  and  $U_{31}$  are the three line-to-line voltages.

**4 Compatibility levels**

The following sections set down compatibility levels 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. Within the individual compatibility levels below, the most unfavourable combination of disturbance levels should be defined on a product specific basis.

**4.1 Voltage Fluctuations and Flicker**

Voltage fluctuations on the low voltage networks are produced by fluctuating loads, operation of transformer tap changers and other operational adjustments of the supply system or equipment connected to it.

In normal circumstances the value of rapid voltage changes is limited to 3% of nominal supply voltage. However step voltage changes exceeding 3% can occur infrequently on the public supply network.

Furthermore, following exceptional load changes or switching operations, voltage excursions outside the normal operational tolerances (e.g.  $\pm 10\%$  of declared supply voltage) are possible for a few tens of seconds until on-load tap-changers on the high voltage-medium voltage transformers have operated.

Voltage fluctuations in low voltage networks can cause flicker. Flicker severity is measured in accordance with IEC 61000-4-15 and assessed in accordance with IEC 61000-3-3. Flicker severity is calculated with respect to both short and long term effects.

The short term severity level, denoted by  $P_{st}$ , is determined for a 10-minute period. Figure 1 shows the threshold curve of permissible flicker for standard lamps, arising from rectangular voltage changes at different repetition rates. This curve corresponds to  $P_{st} = 1$ .

The severity of flicker resulting from non-rectangular voltage fluctuations may be found either by measurement with a flickermeter or by the application of correction factors, as indicated in IEC standard 61000-3-3.

The long-term severity level, denoted by  $P_{lt}$ , is calculated for a two-hour period. It is derived as follows from the values of  $P_{st}$  for 12 consecutive 10-minute periods.

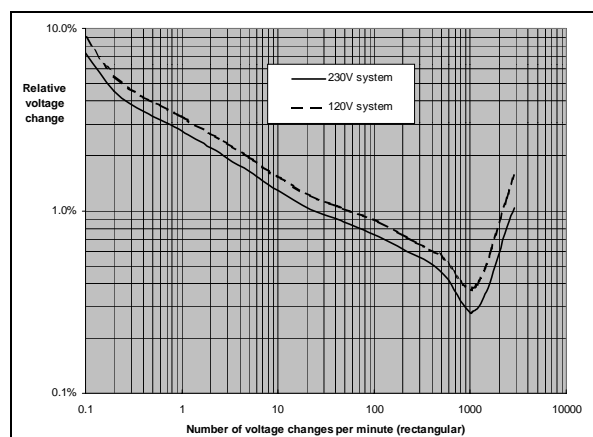
$$P_{lt} = 3 \sqrt{\frac{1}{12} \cdot \sum_{i=1}^{12} P_{st-i}^3}$$

Where  $P_{sti}$  ( $i = 1, 2, \dots, 12$ ) are 12 consecutive values of  $P_{st}$  (See IEC 61000-4-15).

Compatibility levels are as follows:

Short-term:  $P_{st} = 1$

Long-term:  $P_{lt} = 0,8$ .



**Figure 1 – Flicker: Curve of equal severity ( $P_{st} = 1$ ) for rectangular voltage changes on LV power supply systems.**

## 4.2 Harmonics

In specifying compatibility levels for harmonics, two facts must be considered. One is that the number of harmonic sources is increasing. The other is that the proportion of purely resistive loads (heating loads), which function as damping elements, is decreasing in relation to the overall load. Therefore increasing harmonic levels are to be expected in power supply systems until the sources of harmonic emissions are brought under effective limits.

The compatibility levels in this standard shall be understood to relate to quasi-stationary or steady-state harmonics, and are given as reference values for both long term effects and very short term effects.

- The long term effects relate mainly to thermal effects on cables, transformers, motors, capacitors, etc. They arise from harmonic levels that are sustained for ten minutes or more.
- Very short term effects relate mainly to disturbing effects on electronic devices that may be susceptible to harmonic levels sustained for three seconds or less. Transients are not included.

With reference to long term effects the compatibility levels for individual harmonic components of the voltage are given in Table 1. The corresponding compatibility level for the total harmonic distortion is THD = 8%.

**Table 1 – Compatibility levels for individual harmonic voltages in low voltage networks.  
(r.m.s. values as percent of r.m.s. value of the fundamental component)**

Odd harmonics Non-multiple of 3		Odd harmonics Multiple of 3		Even harmonics	
Harmonic Order h	Harmonic Voltage %	Harmonic Order h	Harmonic Voltage %	Harmonic Order h	Harmonic Voltage %
5	6	3	5	2	2
7	5	9	1,5	4	1
11	3,5	15	0,4	6	0,5
13	3	21	0,3	8	0,5
17 ≤ h ≤ 49	2,27 x (17/h) – 0,27	21 < h ≤ 45	0,2	10 ≤ h ≤ 50	0,25 x (10/h) + 0,25

NOTE - The levels given for odd harmonics that are multiples of three apply to zero sequence harmonics. Also, on a three-phase network without a neutral conductor or without load connected between line and ground, the values of the 3<sup>rd</sup> and 9<sup>th</sup> harmonics may be much lower than the compatibility levels, depending on the unbalance of the system.

With reference to very short term effects, the compatibility levels for individual harmonic components of the voltage are the values given in Table 1, multiplied by a factor k, where k is as follows:

$$k = 1,3 + 0,7 (h-5)/45$$

The corresponding compatibility level for the total harmonic distortion is THD = 11%.

NOTE – Commutation notches, in so far as they contribute to harmonic levels in the supply voltage, are covered by the compatibility levels given above. In relation to their other effects, however, including their influence on the commutation of other converters and their effects on other equipment involving the higher order harmonic components, a time-domain description is required – see the relevant product standard.

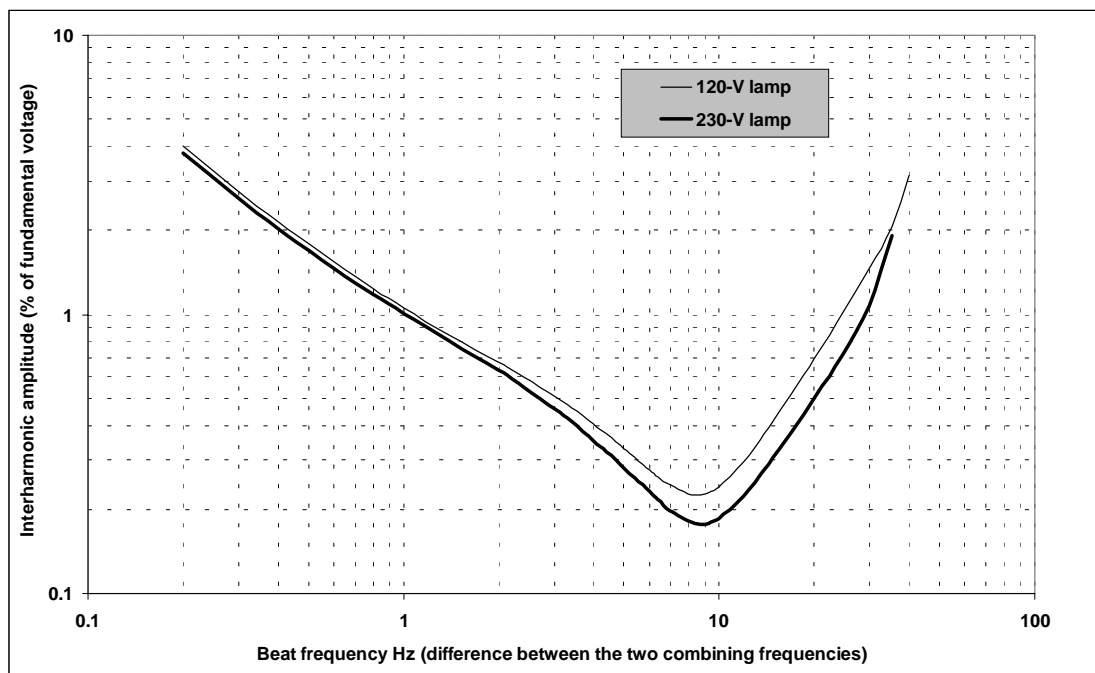
### 4.3 Interharmonics

Knowledge of the electromagnetic disturbance involved in interharmonic voltages is still developing. See Annex B for further discussion.

In this standard compatibility levels are given only for the case of an interharmonic voltage occurring at a frequency close to the fundamental frequency (50 Hz or 60 Hz), resulting in amplitude modulation of the supply voltage.

In these conditions certain loads that are sensitive to the square of the voltage, especially lighting devices, exhibit a beat effect, resulting in flicker. (See 4.1). The beat frequency is the difference between the frequencies of the two coincident voltages – i.e. between the interharmonic and fundamental frequencies.

The compatibility level for the interharmonic voltage in the above case, expressed as the ratio of its amplitude to that of the fundamental, is shown in Figure 2 as a function of the beat frequency. As in 4.1, it is based on a flicker level of  $P_{st} = 1$  for lamps operated at 120 V and 230 V.



**Figure 2 – Compatibility level for interharmonic voltages relating to flicker (beat effect)**

NOTE 1 – A similar situation is possible when there is an appreciable level of voltage at a harmonic frequency (particularly of order 3 or 5) coincident with an interharmonic voltage at a nearby frequency. In this case the effect should also be assessed in accordance with Figure 2, with the amplitude given by the product of the relative amplitudes of the harmonic and interharmonic voltages giving rise to the beat frequency. The result is rarely significant.

NOTE 2 – Below interharmonic order 0,2 compatibility levels are determined by similar flicker requirements. For this purpose the flicker severity should be calculated in accordance with annex A of IEC 61000-3-7 using the shape factor given for periodic and sinusoidal voltage fluctuations. The conservative value of the shape factor is 0,8 for  $0,04 < m \leq 0,2$ , and 0,4 for  $m \leq 0,04$ .

#### 4.4 Voltage Dips and Short Supply Interruptions

For a discussion of these phenomena, see Annex B and (the future) IEC 61000-2-8.

#### 4.5 Voltage Unbalance

In this standard voltage unbalance is considered only in relation to the negative phase sequence component, this being the component relevant to possible interference with equipment connected to public low voltage distribution systems. In this standard voltage unbalance is considered in relation to long term effects, i.e. for durations of 10 minutes or longer.

The voltage unbalance caused by a single-phase load connected line-to-line is in practice equal to the ratio of the load power to the network three-phase short circuit power.

The compatibility level for unbalance is a negative sequence component of 2% of the positive sequence component. In some areas, especially where it is the practice to connect large single-phase loads, values up to 3% may occur.

#### 4.6 Transient Overvoltages

For a discussion of these phenomena, see Annex B.

Having regard to the differences, in respect of amplitude and energy content, between transient overvoltages of different origins (mainly lightning and switching surges), a compatibility level is not specified. For insulation co-ordination, see IEC 60664-1.

#### 4.7 Temporary Power Frequency Variation

In public power supply systems the frequency is maintained as close as possible to the nominal frequency, but the extent to which that is possible depends mainly on the aggregate size of the systems which are interconnected synchronously. For the most part, the range is within 1 Hz of the nominal frequency. Island systems, not synchronously connected to large systems, can undergo somewhat greater variation. Where synchronous interconnection is implemented on a continental scale, the variation is usually very much less.

The compatibility level for the temporary variation of frequency from the nominal frequency is  $\pm 1$  Hz

The steady-state deviation of frequency from the nominal frequency is much less.

NOTE – For some equipment the rate of change of frequency is significant.

#### 4.8 D.C. Component

The voltage of public power supply systems covered by this standard does not normally have a d.c. component at a significant level. That can arise, however, when certain non-symmetrically controlled loads are connected. (Uncontrollable events such as geomagnetic storms are discounted)

The critical point is the level of d.c. current. The value of the d.c. voltage depends upon not only d.c. current but also 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. See Annex B.

## 4.9 Mains Signalling

Although public networks are intended primarily for the supply of electric energy to customers, the suppliers also use them for the transmission of signals for network management purposes such as the control of some categories of load. (These networks are not used for the transmission of signals between private users)

Technically, mains signalling is a source of interharmonic voltages – see 4.3 and Annex B. In this case, however, the signal voltage is intentionally impressed on a selected part of the supply system. The voltage and frequency of the emitted signal are pre-determined, and the signal is transmitted at particular times.

For co-ordination of the immunity of equipment connected to networks on which mains signals exist, the voltage levels of these signals need to be taken into account.

The design of mains signalling systems should meet three objectives:

- to assure compatibility between neighbouring installations,
- to avoid interference with the mains signalling system and its elements by equipment on or connected to the network.
- to prevent the mains signalling system from disturbing equipment on or connected to the network.

Four types of mains signalling systems are described in clause 10 of IEC 61000-2-1.

### 4.9.1 Ripple control systems (110 Hz to 3000 Hz)

Ripple control signals are transmitted as a sequence of pulses, each pulse having a duration in the range 0,1 to 7s, and the duration of the entire sequence ranging from 6 to 180s. More usually, the pulse duration is about 0,5s, and the sequence duration is about 30s.

Generally, these systems operate in the frequency range of 110 Hz to 3000 Hz. The value of the injected sine wave signal is in the region 2% to 5% of the nominal supply voltage, depending on local practice, but resonance can cause levels to rise to 9%. In some countries the so-called Meister curve, given in figure 3, is officially recognised.

On more recently installed systems the signals usually are in the range of 110 Hz to 500 Hz. Where the Meister curve is not applied, the amplitudes of signals within this frequency range should not exceed the levels given in Table 1 for odd harmonics (non-multiple of 3).

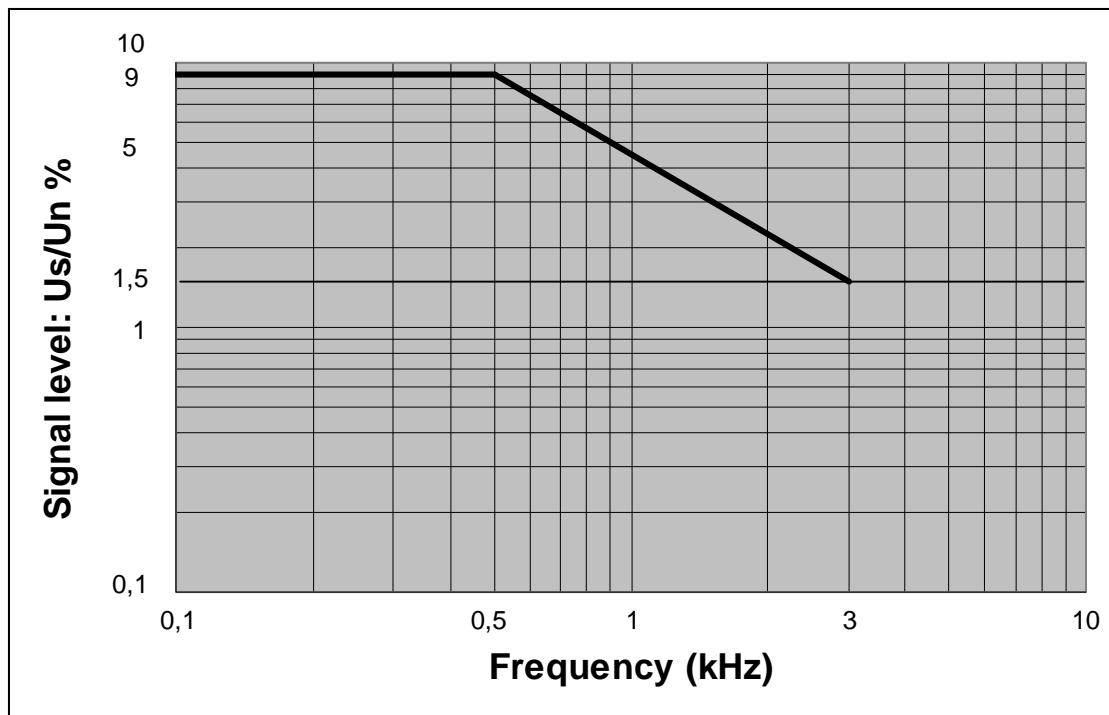


Figure 3 – Meister curve for ripple control systems in public networks (100 Hz to 3000 Hz)

#### 4.9.2 Medium-frequency power-line carrier systems (3 kHz to 20 kHz)

(under consideration).

#### 4.9.3 Radio-frequency power-line carrier systems (20 kHz to 148,5 kHz)

(under consideration).

#### 4.9.4 Mains-mark systems

Because of the different characteristics of the various systems, no general guidance can be given and it is for manufacturers to ensure compatibility between their systems and the supply network.

## **ANNEX A** (informative)

### **The function of compatibility levels and planning levels in EMC**

Electromagnetic compatibility (EMC) is concerned with the possible degradation of the performance of electrical and electronic equipment due to the disturbances present in the electromagnetic environment in which the equipment operates. For compatibility, there are two essential requirements:

- the emission of disturbances into the electromagnetic environment must be maintained below a level that would cause an unacceptable degradation of the performance of equipment operating in that environment.
- all equipment operating in the electromagnetic environment must have sufficient immunity from all disturbances at the levels at which they exist in the environment.

Limits for emission and immunity cannot be set independently of each other. Clearly, the more effectively emissions are controlled, the less restrictive are the immunity demands that have to be placed on equipment. Similarly, if equipment is highly immune, there is less need for stringent limits on the emission of disturbances.

There is a requirement, therefore, for close co-ordination between the limits adopted for emission and immunity. That is the principal function of the compatibility levels specified in this standard.

The disturbance phenomena covered are those that are conducted on the low voltage networks of public ac power supply systems. In effect, the supply system, which is intended to be the channel through which electrical energy is conveyed from the generating stations to the utilising equipment, also, unintentionally, is made the channel through which electromagnetic disturbances are conveyed from their sources to the equipment affected by them.

Three considerations have been borne in mind in setting the compatibility level for each phenomenon:

- the compatibility level is the level of the disturbance which can be expected in the environment, allowing for a small probability (< 5%) of its being exceeded. For some disturbance phenomena severity levels are rising, and therefore a long-term perspective is required.
- it is a disturbance level which can be maintained by implementing practicable limits on emissions.
- it is the level of disturbance from which, with a suitable margin, equipment operating in the relevant environment must have immunity.

#### **A.1 Relation between Compatibility Level and Immunity Levels**

For each disturbance phenomenon, the compatibility level must be recognised as the level of severity which can exist in the relevant environment. All equipment intended for operation in that environment requires to have immunity at least at that level of disturbance. Normally a margin will be provided between the compatibility and immunity levels, appropriate to the equipment concerned.



Moreover, the compatibility levels have been set for the individual disturbance phenomena, and, in the case of harmonics and interharmonics, for individual frequencies. It must be recognised, however, that it is normal for several disturbance phenomena to co-exist in the environment, and that it is possible that the performance of some equipment can be degraded by a particular combination of disturbances, although each is at a level less than the compatibility level.

For example, in the case of harmonics and interharmonics, certain combinations of frequency, magnitude, and phasing can substantially alter the magnitude of the voltage peak and/or the point of zero crossing. Further complications can be added by the presence of other disturbances.

Because the number of permutations is infinite, it is not possible to set compatibility levels for combinations of disturbances.

Therefore if, within the compatibility levels, there is some combination of disturbances which could degrade the performance of a particular product, that combination needs to be identified for the product concerned, so that its immunity requirements can be considered accordingly.

## **A.2 Relation between Compatibility Level and Emission Limits**

It must first be noted that some disturbances have their sources in atmospheric phenomena, especially lightning, or in the normal and unavoidable response of a well-designed supply system to electrical faults or to the switching of load or of particular devices. The principal disturbances in this category are transient overvoltages, voltage dips and short supply interruptions. Emission limits cannot be assigned for these phenomena, since the emission sources are largely uncontrollable. In their case the compatibility level is intended to reflect the level of severity which can be expected in practice.

Many disturbances, however, have their sources in the equipment by which the public electricity supply is utilised, or, to a small extent, in equipment forming part of the supply system itself. The disturbance arises when such equipment draws a current which is not a regular or constant function of the voltage supplied, but contains abrupt variations or fails to follow the complete cycle of the voltage waveform. These irregular currents flow through the impedances of the supply networks and create corresponding irregularities in the voltage.

Although reduction of some of the network impedances is sometimes considered in order to mitigate the effects of a specific source of disturbance, the general case is that they are fixed, largely on the basis of voltage regulation and other considerations not concerned with disturbance mitigation.

The voltage irregularities are, in turn, conducted to other equipment, for some of which they constitute disturbances. The severity levels at which they reach the other equipment depend on the types of equipment which form the sources of the emissions, the number and location of such sources operating at any given time, and on how the emissions from these diverse sources combine together to yield particular levels of disturbance at particular locations. These levels should not exceed the compatibility level.

Therefore, emission limits have a more complex relation with the compatibility level than immunity levels. Not only are the sources of emission highly diverse, but also, especially in the case of low-frequency disturbances, any source to which a limit is to be applied is only one of many sources combining together to produce the environmental disturbance level represented by the compatibility level.

Moreover, many emission limits are expressed in terms of current, although the compatibility levels are expressed in terms of voltage for most types of disturbances. (This makes it necessary to consider network impedances)

Nevertheless, the objective of setting emission limits is to ensure that actual disturbance levels will not exceed the compatibility level, apart from the low-probability events that are accepted in EMC.

This means that emission limits for equipment of any particular type cannot be established independently, but must, for each disturbance phenomenon, be co-ordinated with the limits set for all other sources of the same disturbance. The co-ordination must be such that when all sources are complying with their individual limits, and are acting together to the degree that can be expected in the relevant environment, the resulting disturbance level is less than the compatibility level.

The sources of emission are extremely diverse, but it is useful to divide them into two broad categories:

- **Large equipment and installations.** At one time these were almost the only significant sources of low-frequency emissions such as harmonics and voltage fluctuations. The important point relating to them is that they are always brought to the attention of the electricity supplier, who therefore has the opportunity, together with the operator or owner of the disturbing equipment, to devise an operating regime intended to maintain emissions within acceptable limits, and a method of supply which can ensure that emissions within those limits are unlikely to disturb other equipment connected to the supply network. This solution is specific to the location involved.
- **Small equipment.** To an ever increasing extent equipment of relatively low power, widely used in domestic, commercial and the smaller industrial premises, is the source of high levels of low frequency disturbances. This equipment is purchased on the open market and is generally installed and operated without reference to the electricity supplier. The emissions from any single piece of equipment are small in absolute terms, but the total number connected is very large and may account for 50% of system demand. Moreover, for much of this equipment the emissions are large relative to the rated power. Therefore this type of equipment has become a large and increasing source of low frequency disturbances. The only feasible method of controlling these emissions is to ensure that the equipment is designed and manufactured in compliance with appropriate emission limits.

Thus, in order to maintain the compatibility level as a true indication of the maximum probable level of disturbance in the electromagnetic environment, it is necessary to co-ordinate in a coherent manner the emission limits adopted for this wide range of products, including both the larger installations which are brought to the notice of the electricity supplier and the smaller equipment which the user installs at his own discretion.

NOTE - Installations which are considered specifically by the electricity supplier may contain large numbers of low power professional equipment. In that case, however, emissions are considered in relation to the installation as a whole, without imposing limits on the individual items.

### A.3 Planning Levels

For large loads and installations those responsible for the power supply system have a particular role. In determining the appropriate emission limits for such installations they use the concept of planning level, as defined in 3.1.5.

Planning levels are relevant primarily to medium voltage and higher voltage networks. However, low frequency conducted disturbances are conducted in both directions between low voltage and the higher voltage networks. The co-ordination of emission limits must take account of all voltage levels.

The use of planning levels is described in Technical Reports 61000-3-6 and 61000-3-7. The important points are:

- The planning level is a value adopted by the body responsible for planning and operating the power supply system in a particular area, and is used in setting emission limits for large loads and installations which are to be connected to the system in that area. It is used as an aid in distributing the emission limitation burden as equitably as possible.
- The planning level cannot be higher than the compatibility level. Generally, it is lower by a margin which depends on factors such as the disturbance phenomenon involved, the structure and electrical characteristics of the supply network (provided it is adequately designed and maintained), the background levels of disturbance, the possibility of resonance, and load profiles. It is, therefore, locally specific.
- Although the planning level is related mainly to large equipment and installations, account must be taken also of the many other sources of disturbance, notably numerous low-power equipment connected at low voltage. The margin available to accommodate emissions from large installations depends on how effectively limits are applied to the low power equipment. Any difficulty in this regard is an indication that a stricter approach to emissions from low power equipment is required. The over-riding objective is to ensure that the predicted level of disturbance does not exceed the compatibility level.

The various EMC levels and limits are shown in Figure A.1. Although not exact mathematically, it illustrates the relationships between the values.

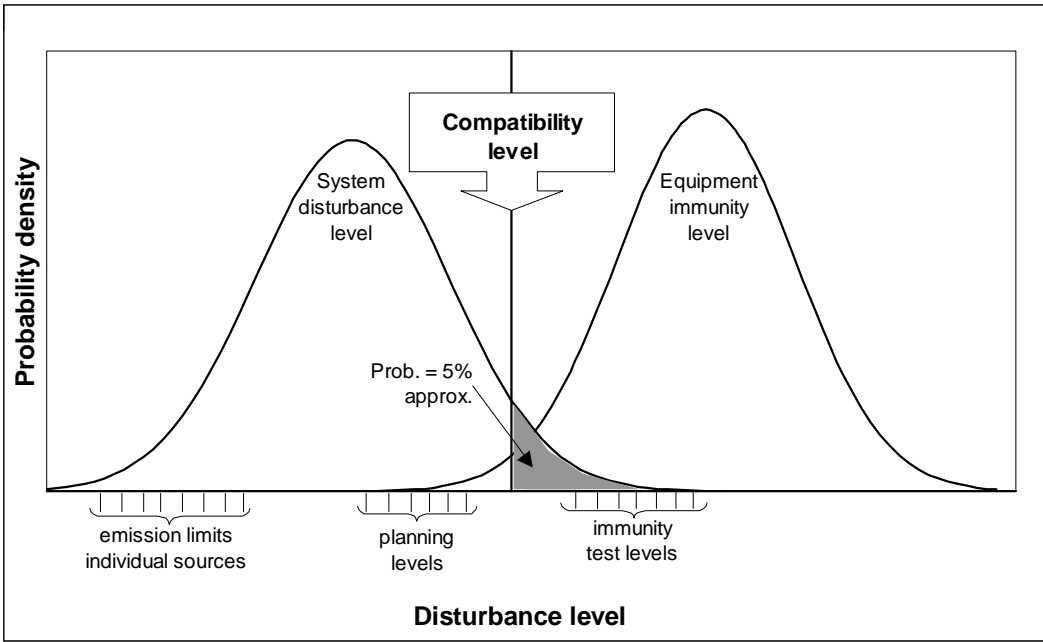


Figure A.1 – Relation between compatibility, immunity, planning and emission levels

## ANNEX B (informative)

### Discussion of some disturbance phenomena

#### B.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 (IEV 101-1-49). 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 numerical 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 of the DFT,  $f_b$ .

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. Thus the actual signal is approximated 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 ( $M = 2^l$ ). (In other words, it requires 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 B.1.1), 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 the amplitudes of true lines.

Accordingly, the measurement techniques defined in IEC 61000-4-7 (future edition) and the definition of the fundamental frequency in 3.2.1 are 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.

### **B.1.1 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).

### **B.1.2 Definitions of additional terms**

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

#### **B.1.2.1 distortion content**

Quantity remaining when the fundamental component is subtracted from an alternating quantity, all being treated as functions of time.

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

where

Q is the total r.m.s. value, representing either current or voltage

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

Harmonic content includes both harmonic and interharmonic components. See also IEC 101-14-54 and IEC 551-20-06.

**B.1.2.2****total distortion factor****TDF (abbreviation)**

The ratio of the r.m.s. value of the distortion content of an alternating quantity to the r.m.s. value of the fundamental component of the quantity. [IEV 551-20-08 MOD]

$$THDc = \frac{Hc}{Q_1} = \frac{\sqrt{Q^2 - Q_1^2}}{Q_1}$$

with the same notation as in B.1.2.1.

## **B.2 Interharmonics and voltage components at frequencies above that of the 50<sup>th</sup> harmonic**

### **B.2.1 Sources of unwanted currents and voltages**

The public a.c. distribution systems are intended to deliver voltages at the power frequencies, 50 or 60 Hz. The presence of voltages at other frequencies is, as far as possible, to be avoided. However, modern developments in electricity utilisation are tending to increase the superposition on the supply voltage of voltages at unwanted frequencies. An increasingly important source of the unintended frequencies is the electronic power conditioning modules which are increasingly being incorporated in electricity utilisation devices.

The following are typical sources:

1. Most electronic components require a d.c. supply. In the absence of or as an alternative to batteries or other d.c. supply, the common practice is to provide an electronic module that extracts the required energy from the a.c. supply and delivers it to the components by way of a d.c. voltage. The switched mode power supply is the most common device used for this purpose. The result, however, is that power is drawn from the a.c. system in a highly non-linear manner, resulting in currents at many harmonic and interharmonic frequencies, extending even to frequencies beyond that of the 50<sup>th</sup> harmonic. As these currents flow through the impedances of the supply system, they give rise to voltages at the corresponding frequencies, and these, in turn, are superimposed on the supply voltage delivered to users. At the higher frequencies, the emitter can often be modelled as a voltage source.
2. In some cases the end-use of the electricity requires an a.c. voltage at a frequency other than the supply frequency, as in variable or adjustable speed drive systems. Again, this is accomplished by electronic devices that extract the required energy from the incoming supply and deliver it to the downstream components by way of a voltage at the required frequency. Viewed from the supply system, these devices are sources of current at many frequencies in addition to the supply frequency. While harmonic frequencies are generally prevalent, some types of converters produce interharmonics in addition.

Voltage source inverters, with pulse width modulated converters on the network side, produce harmonics of the modulation frequency, which has no synchronism with the network frequency. (These are mainly at higher frequencies: switching frequency and its harmonics). High power equipment, typically above 1 MW and connected to a medium or high voltage power network, uses cycloconverters or current source inverters, operated at any frequency without synchronism with the network frequency. They can produce interharmonics due to residual coupling between the motor side and the network.

As a general result, sources such as static frequency converters can produce discrete frequencies in the range of 0 Hz to 2500 Hz, or even more. (See IEC 61000-2-4: Annex C)

3. Electrical arc-furnaces can be a source of a large amount of both interharmonics and components at frequencies above that of the 50<sup>th</sup> harmonic. This also is high power equipment, which would not be connected to a public low voltage power network.
4. Arc welding machines generate a continuous wide band frequency spectrum, associated with an intermittent process in which the duration of the individual welding actions varies between a second and several seconds.
5. Induction motors can give rise to an irregular magnetising current due to the slots in the stator and rotor, possibly in association with saturation of the iron. At the normal speed of the motor, this generates interharmonics at frequencies between 10 to 40 times the power frequency, but during the starting period they run through the whole frequency range up to their final value.

Sources such as the above are connected to networks of low, medium and high voltage. Their emissions result in interharmonic and high frequency voltages which are generated in and transmitted between all voltage levels and depend on the network impedances. These voltages can reach 0,5%. Higher values also can be found, especially when a resonant effect occurs. (There is a background level of interharmonics of the order of 0,02% of the nominal supply voltage, measured with a bandwidth of 10 Hz.)

(Mains signalling is also a source of interharmonic voltages, but in this case the emissions are intentional and utilities and users exercise careful control to ensure compatibility – see 4.9)

### **B.2.2 Effects of the unwanted voltages**

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 clause 4.3. Table B.1 indicates the interharmonic voltage levels corresponding to the compatibility level given in Figure 2.



**Table B.1 – Indicative values of interharmonic voltage in low voltage networks corresponding to the compatibility level with respect to the flicker effect.**

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

Some other effects of interharmonics include:

- Unwanted currents flowing in the supply networks generate additional energy losses, with a consequent increase in the gaseous emissions from generating stations.
- Interharmonic voltages can disturb the operation of fluorescent lamps and electronic equipment such as television receivers. In fact, any use of electricity where the crest voltage or the time of zero crossing is important can be disturbed if the combination of unwanted frequencies present alters these attributes of the supply voltage.
- The greater the range of frequencies present and the greater the amplitudes of the voltages at these frequencies, the greater is the risk of unpredictable resonant effects which can amplify the voltage distortion and lead to overloading or disturbance of equipment on the supply networks and in electricity users' installations.
- Another effect is the production of acoustic noise. This is caused by voltages in the range of 1 kHz to 9 kHz and even more, with amplitude from 0,5 % upwards and dependant upon the frequency value and upon the kind of equipment influenced.

### B.2.3 Need for compatibility levels for the unwanted voltages

Given the possible effects of voltages at interharmonic frequencies and frequencies beyond the 50<sup>th</sup> harmonic, it is desirable to establish reference levels for the co-ordination of emission and immunity in the interests of electromagnetic compatibility. However, knowledge of these frequencies on public power networks is not yet sufficient to permit agreement on the compatibility levels to be adopted, except in the above case of flicker arising from beat frequencies. It will be necessary to keep this situation under close review.

On the one hand, it is clear that the generation of voltages at the unwanted frequencies ought not to be allowed to grow without limit. On the other hand, given that these voltages are becoming more prevalent, it is important that equipment to be connected to the public networks has sufficient immunity to continue to operate as intended in their presence.

It seems prudent to consider compatibility levels no higher than those for adjacent harmonics. For example, there can be no reason for accepting a higher voltage at 95 Hz than at 100 Hz on a 50 Hz system, or a higher voltage at 115 Hz than at 120 Hz on a 60 Hz system. Accordingly, it is suggested that the reference level for each interharmonic frequency be equal to the compatibility level given in Table 1 for the next higher even harmonic.

Ripple control receivers are a special case. Their response level can be as low as 0,3% of the nominal supply voltage. Therefore an unintended interharmonic voltage in excess of this value, on a network containing ripple control receivers, can cause disturbance if its frequency is the same as the defined operational frequency of the receivers. Based on this value, the reference level at the defined frequency should be 0,2% of the nominal supply voltage. (The defined frequency is locally specific)

In the case of voltages at frequencies in excess of that of the 50<sup>th</sup> harmonic 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.

For a discrete frequency in the range from the 50<sup>th</sup> harmonic up to 9 kHz, the suggested reference level of  $u$ , expressed as the ratio of the r.m.s. value of the voltage at that frequency to the r.m.s. value of the fundamental component, is as follows:

$$u = 0,2\%$$

For a band of frequencies in the range from the 50<sup>th</sup> harmonic up to 9 kHz, the suggested reference level for any 200 Hz bandwidth centred at frequency  $F$  is as follows:

$$u_b = 0,3\%,$$

where

$$u_b = \frac{1}{V_{1N}} \cdot \sqrt{\frac{1}{200 \text{ Hz}} \cdot \int_{F-100 \text{ Hz}}^{F+100 \text{ Hz}} V_f^2 \cdot df}$$

and

$V_1$  = r.m.s. value of the voltage (fundamental component)

$V_f$  = r.m.s. voltage at frequency  $f$

$F$  = centre frequency of the band (the band is above the 50<sup>th</sup> harmonic)

While there has been some experience in which values in excess of the above levels have been found to cause disturbances, more extensive experimental data in the future may indicate that somewhat higher compatibility levels may be appropriate for voltages at frequencies beyond the 50<sup>th</sup> harmonic.

### **B.3 Voltage dips and Short Supply Interruptions**

Voltage dips and short supply interruptions 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.

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 one tenth of a second 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 voltage 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 1000ms.

The number of voltage dips is significant only when the immunity of a given device is insufficient for the depth-duration occurring, or when the question being considered is whether a given process needs a particular level of immunity.

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. 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.

Short supply interruptions can last up to 180s according to the type of reclosing or transfer system used in overhead networks. Frequently, short supply interruptions are preceded by voltage dips. (See also IEC 61000-2-8).

As regards compatibility levels, the main requirement in the case of voltage dips is to enable immunity levels to be co-ordinated. 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.

Moreover, in the case of short interruptions or the more severe voltage dips, immunity of electrical equipment is not, in the strict sense, an appropriate concept. That is because no electrical device can continue indefinitely 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 to the brief interruption or diminution of power in an intended manner, often with safety and damage limitation as the principal aims.

See also IEC 61000-2-8.

## **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 one microsecond to a few milliseconds. Their levels and durations can sometimes be limited by the use of surge arrestors throughout the system, and not only at the point of common coupling.

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 usually contain the greater energy. Critical equipment needs to be protected by individual 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. This needs to be taken into account if immunity is being considered for particular equipment or installations.

Magnitudes up to 2 kV are generally regarded as typical of transients of atmospheric origin, but values up to 6 kV and even higher have been recorded.

See also IEC 60664-1 in relation to insulation co-ordination.

## **B.5 DC Component**

While a significant level of d.c. component is not normally present in the voltage on public power supply systems, the connection of certain non-symmetrically controlled loads could bring about this phenomenon. Geomagnetic storms have been found occasionally to give rise to large d.c. currents and voltages in some locations, but such uncontrollable events are not taken into account in this standard.

In the event that a d.c. component is present in the supply voltage, a d.c. current can cause unsymmetrical magnetisation in distribution transformers, leading to overheating. Moreover, in flowing through the earth, such a current leads to increased corrosion of metal fixtures underground.

The value of this current is quite variable, since it is determined by the d.c. resistance of the circuit concerned as well as by the voltage of the d.c. component. Therefore the tolerable d.c. voltage can only be determined case by case.

## **ANNEX C** (informative)

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