NORME INTERNATIONALE

INTERNATIONAL STANDARD

CEI
IEC
61000-4-13

Première édition
First edition
2002-03

PUBLICATION FONDAMENTALE EN CEM
BASIC EMC PUBLICATION

Compatibilité électromagnétique (CEM) –

Partie 4-13:
Techniques d'essai et de mesure –
Essais d'immunité basse fréquence aux harmoniques et inter-harmoniques incluant les signaux transmis sur le réseau électrique alternatif

Electromagnetic compatibility (EMC) –

Part 4-13:
Testing and measurement techniques –
Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity tests

Numéro de référence
Reference number
CEI/IEC 61000-4-13:2002

Numérotation des publications

Depuis le 1er janvier 1997, les publications de la CEI sont numérotées à partir de 60000. Ainsi, la CEI 34-1 devient la CEI 60034-1.

Editions consolidées

Les versions consolidées de certaines publications de la CEI incorporant les amendements sont disponibles. Par exemple, les numéros d'édition 1.0, 1.1 et 1.2 indiquent respectivement la publication de base, la publication de base incorporant l'amendement 1, et la publication de base incorporant les amendements 1 et 2.

Informations supplémentaires sur les publications de la CEI

Le contenu technique des publications de la CEI est constamment revu par la CEI afin qu'il reflète l'état actuel de la technique. Des renseignements relatifs à cette publication, y compris sa validité, sont disponibles dans le Catalogue des publications de la CEI (voir ci-dessous) en plus des nouvelles éditions, amendements et corrigenda. Des informations sur les sujets à l'étude et l'avancement des travaux entrepris par le comité d'études qui a élaboré cette publication, ainsi que la liste des publications parues, sont également disponibles par l'intermédiaire de:

- **Site web de la CEI (www.iec.ch)**
- **Catalogue des publications de la CEI**

  Le catalogue en ligne sur le site web de la CEI (www.iec.ch/catlg-f.htm) vous permet de faire des recherches en utilisant de nombreux critères, comprenant des recherches textuelles, par comité d'études ou date de publication. Des informations en ligne sont également disponibles sur les nouvelles publications, les publications remplacées ou retirées, ainsi que sur les corrigenda.
- **IEC Just Published**

  Ce résumé des dernières publications parues (www.iec.ch/JP.htm) est aussi disponible par courrier électronique. Veuillez prendre contact avec le Service client (voir ci-dessous) pour plus d'informations.
- **Service clients**

  Si vous avez des questions au sujet de cette publication ou avez besoin de renseignements supplémentaires, prenez contact avec le Service clients:

  Email: custserv@iec.ch
  Tél: +41 22 919 02 11
  Fax: +41 22 919 03 00

Publication numbering

As from 1 January 1997 all IEC publications are issued with a designation in the 60000 series. For example, IEC 34-1 is now referred to as IEC 60034-1.

Consolidated editions

The IEC is now publishing consolidated versions of its publications. For example, edition numbers 1.0, 1.1 and 1.2 refer, respectively, to the base publication, the base publication incorporating amendment 1 and the base publication incorporating amendments 1 and 2.

Further information on IEC publications

The technical content of IEC publications is kept under constant review by the IEC, thus ensuring that the content reflects current technology. Information relating to this publication, including its validity, is available in the IEC Catalogue of publications (see below) in addition to new editions, amendments and corrigenda. Information on the subjects under consideration and work in progress undertaken by the technical committee which has prepared this publication, as well as the list of publications issued, is also available from the following:

- **IEC Web Site (www.iec.ch)**
- **Catalogue of IEC publications**

  The on-line catalogue on the IEC web site (www.iec.ch/catlg-e.htm) enables you to search by a variety of criteria including text searches, technical committees and date of publication. On-line information is also available on recently issued publications, withdrawn and replaced publications, as well as corrigenda.
- **IEC Just Published**

  This summary of recently issued publications (www.iec.ch/JP.htm) is also available by email. Please contact the Customer Service Centre (see below) for further information.
- **Customer Service Centre**

  If you have any questions regarding this publication or need further assistance, please contact the Customer Service Centre:

  Email: custserv@iec.ch
  Tel: +41 22 919 02 11
  Fax: +41 22 919 03 00

NORME INTERNATIONALE

INTERNATIONAL STANDARD

CEI
IEC
61000-4-13

Première édition
First edition
2002-03

PUBLICATION FONDAMENTALE EN CEM
BASIC EMC PUBLICATION

Compatibilité électromagnétique (CEM) –

Partie 4-13:
Techniques d'essai et de mesure – Essais d'immunité basse fréquence aux harmoniques et inter-harmoniques incluant les signaux transmis sur le réseau électrique alternatif

Electromagnetic compatibility (EMC) –

Part 4-13:
Testing and measurement techniques – Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity tests

International Electrotechnical Commission, 3, rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland
Telephone: +41 22 919 02 11 Telefax: +41 22 919 03 00 E-mail: inmail@iec.ch Web: www.iec.ch

Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

CODE PRIX
PRICE CODE U

Pour prix, voir catalogue en vigueur
For price, see current catalogue

CONTENTS

FOREWORD ... 5
INTRODUCTION ... 9

1 Scope and object ... 11
2 Normative references ... 11
3 Definitions ... 13
4 General ... 15
4.1 Description of the phenomenon ... 15
4.2 Sources ... 15
5 Test levels ... 17
5.1 Harmonics test levels ... 17
5.2 Test levels for interharmonics and mains signalling ... 21
6 Test instrumentation ... 23
6.1 Test generator ... 23
6.2 Verification of the characteristics of the generator ... 27
7 Test set up ... 27
8 Test procedures ... 29
8.1 Test procedure ... 29
8.2 Application of the test ... 29
9 Evaluation of test results ... 41
10 Test report ... 41

Annex A (informative) Impedance network between voltage source and EUT ... 49
Annex B (informative) Resonance point ... 51
Annex C (informative) Electromagnetic environment classes ... 53

Bibliography ... 55

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-13 : Testing and measurement techniques – Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity tests

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.
2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.
3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.
4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.
5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.
6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 61000-4-13 has been prepared by subcommittee 77A: Low frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

This standard 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
77A/368/FDIS	77A/377/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.

Annexes A, B, and C, are for information only.

The committee has decided that the contents of this publication will remain unchanged until 2008. 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

Measurement techniques

Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines

Mitigation methods and devices

Part 6: Generic Standards

Part 9: Miscellaneous

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

This part is an EMC basic standard which gives immunity requirements and test procedures related to harmonics and interharmonics including mains signalling at a.c. power port.

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-13: Testing and measurement techniques – Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity tests

1 Scope and object

This part of IEC 61000 defines the immunity test methods and range of recommended basic test levels for electrical and electronic equipment with rated current up to 16 A per phase at disturbance frequencies up to and including 2 kHz (for 50 Hz mains) and 2,4 kHz (for 60 Hz mains) for harmonics and interharmonics on low voltage power networks.

It does not apply to electrical and electronic equipment connected to 16 2/3 Hz , or to 400 Hz a.c. networks. Tests for these networks will be covered by future standards.

The object of this standard is to establish a common reference for evaluating the functional immunity of electrical and electronic equipment when subjected to harmonics and interharmonics and mains signalling frequencies. The test method documented in this part of IEC 61000 describes a consistent method to assess the immunity of an equipment or system against a defined phenomenon. As described in IEC guide 107, this is a basic EMC publication for use by product committees of the IEC. As also stated in Guide 107, the IEC product committees are responsible for determining whether this immunity test standard should be applied or not, and if applied, they are responsible for determining the appropriate test levels and performance criteria. TC 77 and its sub-committees are prepared to co-operate with product committees in the evaluation of the value of particular immunity tests for their products.

The verification of the reliability of electrical components (for example capacitors, filters, etc.) is not in the scope of the present standard. Long term thermal effects (greater than 15 min) are not considered in this standard.

The levels proposed are more adapted for residential, commercial and light industry environments. For heavy industrial environments the product committees are responsible for the definition of a class X with the necessary levels. They have also the possibility of defining more complex waveforms for their own need. Nevertheless, the simple waveforms proposed have been mainly observed on several networks (flat curve more often for single phase system) and also on industrial networks (overswing curve more for three phase systems).

2 Normative references

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

IEC 60050(161), *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

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

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

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

3 Definitions

For the purposes of this part of IEC 61000, the following definitions and terms apply as well as the definitions of IEC 60050(161):

3.1
immunity
ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance

[IEV 161-01-20]

3.2
harmonic (component)
component of order greater than 1 of the Fourier series of a periodic quantity

[IEV 161-02-18]

3.3
fundamental (component)
component of order 1 of the Fourier series of a periodic quantity

[IEV 161-02-17]

3.4
flat curve waveshape
waveform that follows a time related function in which each half-wave consists of three parts:

Part 1: starts from zero and follows a pure sine function up to the specified value;

Part 2: is a constant value;

Part 3: follows a pure sine function down to zero

3.5
overswing waveshape
waveform which consists of discrete values of the fundamental harmonic, the 3rd and the 5th harmonics with the specified phase shift

3.6
f_1
fundamental frequency

3.7
mains signalling frequencies
signal frequencies between harmonics for control and communication

3.8
EUT

equipment under test

4 General

4.1 Description of the phenomenon

4.1.1 Harmonics

Harmonics are sinusoidal voltages and currents with frequencies that are integer multiples of the frequency at which the supply system operates.

Harmonic disturbances are generally caused by equipment with non-linear voltage - current characteristics or by periodic and line-synchronised switching of loads. Such equipment may be regarded as sources of harmonic currents.

The harmonic currents from the different sources produce harmonic voltage drops across the impedance of the network.

As a result of cable capacitance, line inductance and the connection of power factor correction capacitors, parallel or series resonance may occur in the network and cause a harmonic voltage amplification even at a remote point from the distorting load. The waveforms proposed are the result of the summation of different harmonic orders of one or several harmonic sources.

4.1.2 Interharmonics

Between the harmonics of the power frequency voltage and current, further frequencies can be observed which are not an integer multiple of the fundamental. They can appear as discrete frequencies or as a wide-band spectrum. Summation of different interharmonic sources is not likely and is not taken into account in this standard.

4.1.3 Mains signalling (ripple control)

Signal frequencies ranging from 110 Hz to 3 kHz used in networks or parts of them in order to transfer information from a sending point to one or more receiving points.

For the scope of this standard, the frequency range is limited to 2 kHz/50 Hz (2,4 kHz/60 Hz).

4.2 Sources

4.2.1 Harmonics

Harmonic currents are generated to a small extent by generation, transmission and distribution equipment and to a greater extent by industrial and residential loads. Sometimes, there are only a few sources generating significant harmonic currents in a network; the individual harmonic level of the majority of the other devices is low, nevertheless these may make a relatively high contribution to the harmonic voltage distortion, at least for low order harmonics due to their summation.

Significant harmonic currents in a network can be generated by non-linear loads, for example:

- controlled and uncontrolled rectifiers, especially with capacitive smoothing (for example used in television, indirect and direct static frequency converters, and self-ballasted lamps), because these harmonics are in approximately the same phase from different sources and there is only poor compensation in the network;
- phase controlled equipment, some types of computers and UPS equipment.

Sources may produce harmonics at a constant or varying level, depending on the method of operation.

4.2.2 Interharmonics

Sources of interharmonics can be found in low-voltage networks as well as in medium-voltage and high voltage networks. The interharmonics produced in the medium-voltage/high voltage networks flow in the low-voltage networks they supply and vice versa.

The main sources are indirect and direct static frequency converters, welding machines and arc furnaces.

4.2.3 Mains signalling (ripple control)

Sources of mains signalling frequencies covered by this standard are transmitters operating mostly in the 110 Hz to 2 kHz (2,4 kHz) frequency range in order for the public supplier to control equipment in the supply network (public lighting, tariffs for meters, etc.). The transmitter energy is coupled into the system on HV, MV, or LV level. The transmitters operate with interrupted signals, and normally for a short time only. The frequencies used lie normally in between the harmonics.

5 Test levels

The test level is the harmonic voltage specified as a percentage of the fundamental voltage. The voltages given in this standard have the nominal power supply network voltage (U_1 fundamental) as a basis.

It is essential that the r.m.s. voltage of the resultant waveforms remain at the nominal value during the application of these tests by adjusting the voltage values of fundamental and harmonics according to the percentages indicated in the corresponding tables (for example 230 V r.m.s., 120 V r.m.s.).

5.1 Harmonics test levels

The preferential range of test levels for individual harmonics are given in tables 1 to 3.

Harmonic voltages at a test level of 3 % and higher, up to the 9th harmonic, shall be applied using a phase shift of both 0° and 180° with respect to the positive zero-crossing of the fundamental. Harmonic voltages at a test level of less than 3 % shall be applied using no phase-shift with respect to the positive zero-crossing of the fundamental.

For compatibility levels see IEC 61000-2-2 using factor *k*. Immunity levels have to be higher (for example times 1,5 additionally).

The application of the test to a multiphase EUT is given in 8.2.5.

Table 1 – Odd harmonics non-multiple of 3 harmonics

h	Class 1	Class 2	Class 3	Class X
	Test levels % U_1	Test levels % U_1	Test levels % U_1	Test levels % U_1
5	4,5	9	12	Open
7	4,5	7,5	10	Open
11	4,5	5	7	Open
13	4	4,5	7	Open
17	3	3	6	Open
19	2	2	6	Open
23	2	2	6	Open
25	2	2	6	Open
29	1,5	1,5	5	Open
31	1,5	1,5	3	Open
35	1,5	1,5	3	Open
37	1,5	1,5	3	Open

NOTE 1 Classes 1, 2, and 3 are defined in annex C.

NOTE 2 The levels given for class X are open. These levels shall be defined by the product committees. However, for equipment supplied by low voltage public supply systems, the values shall not be lower than those of class 2.

Table 2 – Odd harmonics multiple of 3 harmonics

h	Class 1	Class 2	Class 3	Class X
	Test levels % U_1	Test levels % U_1	Test levels % U_1	Test levels % U_1
3	4,5	8	9	Open
9	2	2,5	4	Open
15	No test	No test	3	Open
21	No test	No test	2	Open
27	No test	No test	2	Open
33	No test	No test	2	Open
39	No test	No test	2	Open

NOTE 1 Classes 1, 2, and 3 are defined in annex C.

NOTE 2 The levels given for class X are open. These levels shall be defined by the product committees. However, for equipment supplied by low voltage public supply systems the values shall not be lower than those of class 2.

Table 3 – Even harmonics

h	Class 1	Class 2	Class 3	Class X
	Test levels % U_1	Test levels % U_1	Test levels % U_1	Test levels % U_1
2	3	3	5	Open
4	1,5	1,5	2	Open
6	No test	No test	1,5	Open
8	No test	No test	1,5	Open
10	No test	No test	1,5	Open
12-40	No test	No test	1,5	Open

NOTE 1 Classes 1, 2, and 3 are defined in annex C.

NOTE 2 The levels given for class X are open. These levels shall be defined by the product committees. However, for equipment supplied by low voltage public supply systems the values shall not be lower than those of class 2.

5.2 Test levels for interharmonics and mains signalling

The preferential ranges of test levels are given in tables 4a and 4b.

Table 4 – Frequencies between harmonic frequencies

Table 4a – Frequencies between harmonic frequencies (for 50 Hz mains)

Frequency range	Class 1	Class 2	Class 3	Class X
Hz	Test levels % U_1	Test levels % U_1	Test levels % U_1	Test levels % U_1
16 – 100	no test	2,5	4	Open
100 – 500	no test	5	9	Open
500 – 750	no test	3,5	5	Open
750 – 1 000	no test	2	3	Open
1 000 – 2 000	no test	1,5	2	Open

NOTE 1 Classes 1, 2, and 3 are defined in annex C.

NOTE 2 The levels for class X are open. These levels shall be defined by the product committees.

Table 4b – Frequencies between harmonic frequencies (for 60 Hz mains)

Frequency range	Class 1	Class 2	Class 3	Class X
Hz	Test levels % U_1	Test levels % U_1	Test levels % U_1	Test levels % U_1
20 – 120	no test	2,5	4	Open
120 – 600	no test	5	7,5	Open
600 – 900	no test	3,5	5	Open
900 – 1200	no test	2	3	Open
1200 – 2400	no test	1,5	2	Open

NOTE 1 Classes1, 2, and 3 are defined in annex C.

NOTE 2 The levels given for class X are open. These levels shall be defined by the product committees.

Immunity test levels for interharmonics above 100 Hz are covered by the mains signalling levels and optionally by the Meister curve levels defined in 8.2.4. Mains signalling levels are in the range of 2 % to 6 % of U_1. Discrete interharmonic frequencies have a level of about 0,5 % of the fundamental frequency voltage U_1 (in absence of resonance). In class 3 for industrial networks, these levels can be considerably higher.

6 Test instrumentation

6.1 Test generator

The test generator shall have the ability to generate a signal with a 50 Hz or 60 Hz fundamental frequency and to superimpose the required frequencies (harmonics and frequencies between the harmonics).

The test generator shall have sufficient filtering such that the harmonic and interharmonic disturbances do not influence any auxiliary equipment which may be used to perform the test.

The test levels according to tables 1 to 4 shall be applied at the terminals of the EUT connected as in normal conditions (single or three phase) and operating as specified in the relevant product standard.

The test generator shall have the following specifications:

Table 5 – Characteristics of the test generator

Output current per phase at rated voltage	Necessary to fulfil the requirements at the operating EUT (see note 1)
Fundamental voltage:	
- Magnitude U_1	Nominal mains voltage ± 2 % single phase
	Nominal mains voltage ± 2 % three phase
- Frequency	50 Hz ± 0,5 % or 60 Hz ± 0,5 %
- Angle between phases	120° ± 1,5° (star connection)
Preselectable individual harmonics:	See note 2
- Order	2 to 40
- Magnitude U_h	
• Range	0 % to 14 % U_1
• Accuracy	The larger of ± 5,0 % U_h or 0,1 % U_1
- Phase angle φ_h	
• h = 2 to 9	0°; 180° (see also note 6)
• Accuracy of zero phase crossing displacement with respect to fundamental	± 2° of the fundamental
Combination of harmonics:	See note 3
Frequencies between the harmonics:	See note 2
- Magnitude	
• Range	0 % to 10 % U_1
• Accuracy	The larger of ± 5,0 % U_h or 0,1 % U_1
- Frequency	
• Range	0,33 × f_1 to 40 × f_1
• Steps for adjusting	
f = (0,33 to 2) × f_1	= 0,1 × f_1
f = (2 to 20) × f_1	= 0,2 × f_1
f > 20 × f_1	= 0,5 × f_1
• Maximum error of adjusted value	± 0,5 % f
Output impedance	See note 4
External impedance network	See note 5

NOTE 1 The generator equipment shall provide an output which is sufficient to test the EUT or to a maximum rated input current of 16 A r.m.s. per phase. Other values may be given by the product standard or product specification.

NOTE 2 The generator shall provide control inputs for selection of magnitude, frequency, phase-angle, and sequence type of the superimposed voltage.

NOTE 3 The generator equipment shall provide the option to superimpose more than one voltage in each phase.

NOTE 4 No output impedance is defined since the internal voltage source has to be controlled so that the voltage drop across the internal impedance is compensated and the set values are met at the terminals of the EUT. The connections shall be as short as possible.

NOTE 5 An external series impedance network may be used, but only to find possible resonance excited by harmonics. The IEC 60725 impedance network is suggested. Annex A is included in this standard for guidance.

NOTE 6 φ_h is the phase difference between the positive zero crossing of the fundamental voltage and the positive zero crossing of the harmonics voltage expressed in degrees of the harmonics frequency.

6.2 Verification of the characteristics of the generator

The generator output characteristics shall be verified at the terminals of the source prior to the test. For this purpose, the terminal voltage shall be monitored by a harmonic analyser according to IEC 61000-4-7, accuracy class A, and the superimposed values shall be stored and/or printed. An oscilloscope may be used in addition for a rough overview.

The maximum harmonic voltage distortion of the generator shall be in accordance with IEC 61000-3-2 (when no harmonic/inter-harmonic is selected). The maximum distortion limits while delivering power to the EUT are given in table 6.

Table 6 – Maximum harmonic voltage distortion

Harmonic number	% of U_1
3	0,9
5	0,4
7	0,3
9	0,2
2 to 10 (even harmonics)	0,2
11-40	0,1

The peak value of the test voltage shall be within 1,40 and 1,42 times its rms value and shall be reached within 87° to 93° after the zero crossing. The maximum output voltage change between no load and rated current of an EUT shall be ±2 % of the nominal voltage.

The characteristics of the generator specified in 6.1 lead to generators with low internal impedance. To simplify the procedure, the verification of the characteristics of the generator in accordance with 6.2 shall be performed in the absence of an external impedance network.

7 Test set up

In addition to the test generator, the following test equipment may be needed for the immunity test:

- analyser for harmonics and interharmonics according to IEC 61000-4-7 for the verification of the test voltage at the terminals of the EUT;
- control unit to provide the sequence of the selected superimposed voltages during a test;
- printer or plotter for the documentation of the test voltage sequence;
- oscilloscope for monitoring the supply voltage on the EUT.

Some of these items may be combined in one unit.

Examples of test arrangements are given:

- in figure 2 for a single phase EUT;
- in figure 3 for a three phase EUT.

8 Test procedures

8.1 Test procedure

8.1.1 Climatic conditions

Unless otherwise specified by the committee responsible for the generic or product standard, the climatic conditions in the laboratory shall be within any limits specified for the operation of the EUT and the test equipment by their respective manufacturers.

Tests shall not be performed if the relative humidity is so high as to cause condensation on the EUT or the test equipment.

NOTE Where it is considered that there is sufficient evidence to demonstrate that the effects of the phenomenon covered by this standard are influenced by climatic conditions, this should be brought to the attention of the committee responsible for this standard.

8.1.2 Test plan

Before starting the test of a given equipment, a test plan shall be prepared.

It is recommended that the test plan comprises of the following items:

- the description of the EUT;
- information on possible connections (plugs, terminals, etc.) corresponding cables and peripherals;
- input power port of equipment to be tested;
- representative operational modes of the EUT for the test;
- type of tests/test levels;
- performance criteria under test conditions as specified by the standard or manufacturer;
- description of the test set up.

If the auxiliary equipment is not available for the EUT, it may be simulated.

For each test, any degradation of performance must be recorded. The monitoring equipment should be capable of displaying the status of the operational mode of the EUT during and after the tests. After each group of tests a relevant check will be performed.

8.2 Application of the test

Figures 1a and 1b have been added to give guidance on how to optimise test time with a high confidence of test performance. The test levels in the «harmonic combinations» test and the «sweep in frequencies» test exceed the test levels of the «individual harmonics» test.

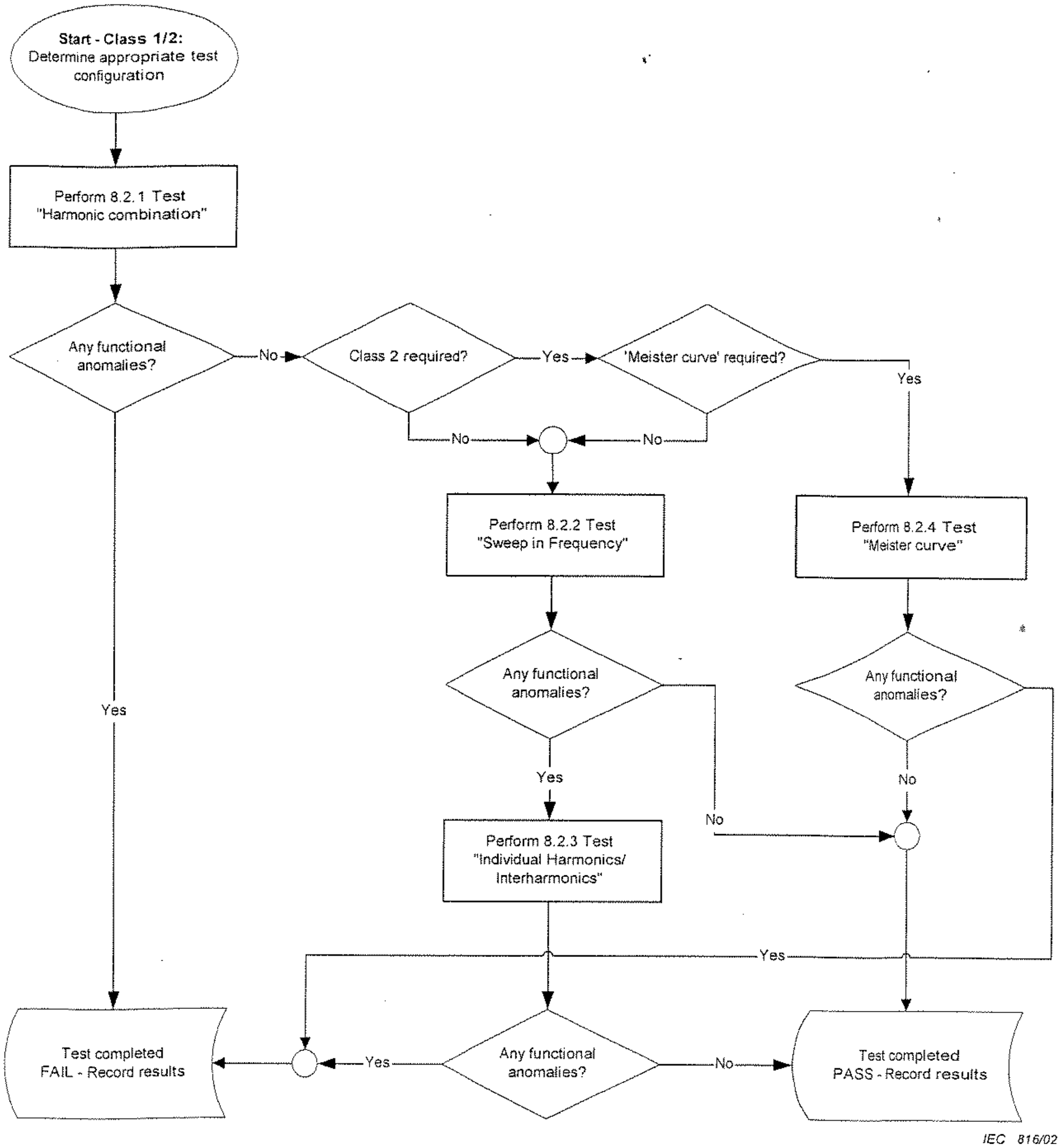


Figure 1a – Test flowchart class 1 and class 2

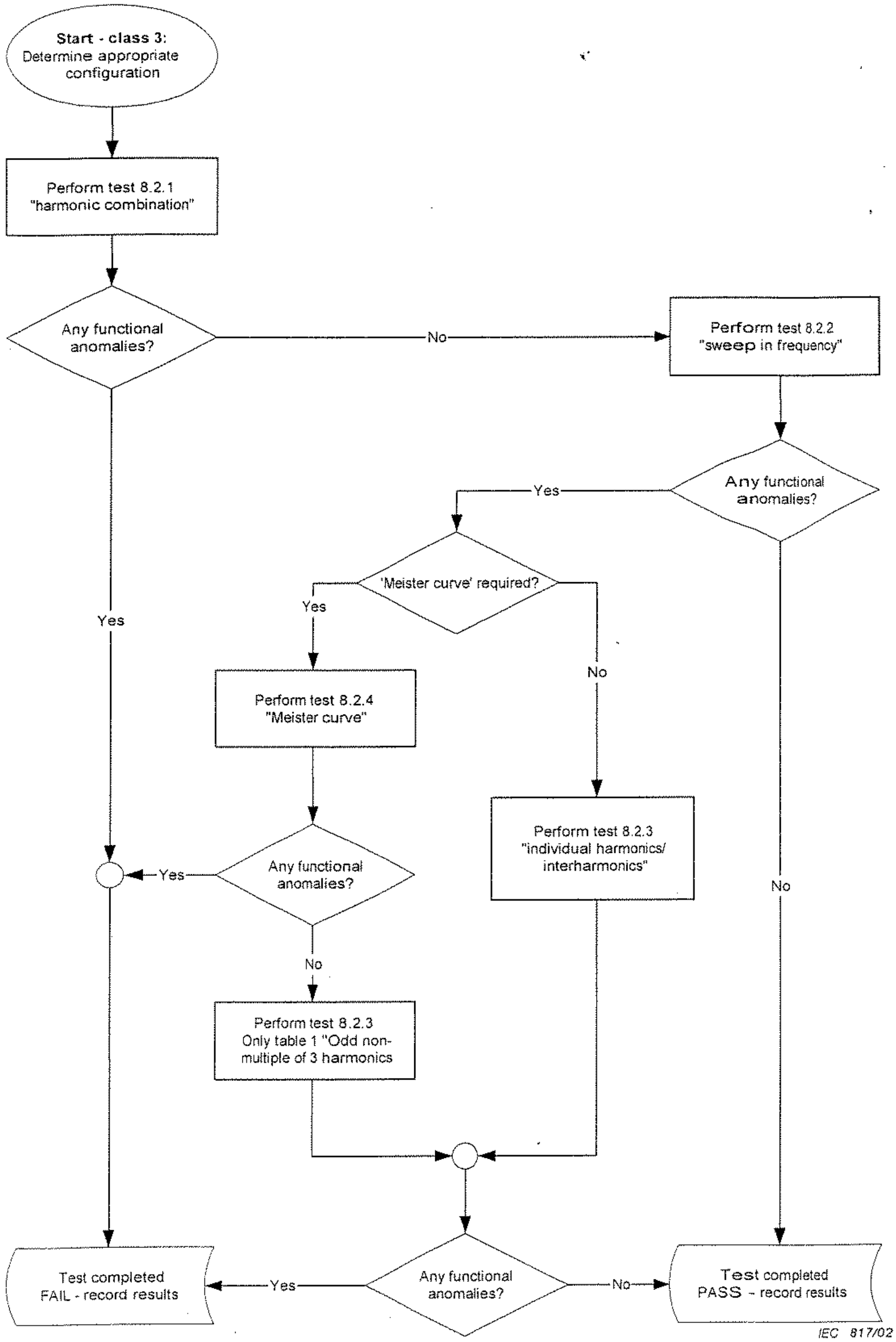


Figure 1b – Test flowchart class 3

Figure 1 – Test flowcharts

8.2.1 Harmonic combination test flat curve and over swing

The two harmonic combination tests to be carried out are flat curve and over swing. The EUT shall be tested for each harmonic combination, according to tables 7 and 8 for 2 minutes. The time-domain waveforms are shown in figures 6 and 7 for the flat curve and over swing tests respectively.

Flat curve: the voltage follows a time related function in which each half-wave consists of three parts. See figure 6.

- Part 1 starts from zero, it follows a pure sine function up to 90 % of the peak value for class 2 and up to 80 % for class 3.
- Part 2 is a constant voltage.
- Part 3 is equivalent to Part 1 (following a pure sine function).

Over swing: Over swing is generated by adding a discrete value of the 3rd harmonic and also of the 5th harmonic both with a corresponding phase relationship.

Table 7 – Time related function, "flat curve"

Function (parts 1 and 3)	Voltage (parts 1 and 3)	Function (part 2)	Voltage (part 2)	Class
$0 \le \lvert\sin(\omega t)\rvert \le 0{,}95$	$u = U_1 \times \sqrt{2} \times \sin(\omega t)$	$0{,}95 \le \lvert\sin(\omega t)\rvert \le 1$	$u = \pm 0{,}95 \times U_1 \times \sqrt{2}$	1
$0 \le \lvert\sin(\omega t)\rvert \le 0{,}9$	$u = U_1 \times \sqrt{2} \times \sin(\omega t)$	$0{,}9 \le \lvert\sin(\omega t)\rvert \le 1$	$u = \pm 0{,}9 \times U_1 \times \sqrt{2}$	2
$0 \le \lvert\sin(\omega t)\rvert \le 0{,}8$	$u = U_1 \times \sqrt{2} \times \sin(\omega t)$	$0{,}8 \le \lvert\sin(\omega t)\rvert \le 1$	$u = \pm 0{,}8 \times U_1 \times \sqrt{2}$	3
$0 \le \lvert\sin(\omega t)\rvert \le X$	$u = U_1 \times \sqrt{2} \times \sin(\omega t)$	$X \le \lvert\sin(\omega t)\rvert \le 1$	$u = \pm X \times U_1 \times \sqrt{2}$	X

NOTE 1 Classes 1, 2, and 3 are defined in annex C.

NOTE 2 The levels given for class X are open. These levels shall be defined by the product committees. However, for equipment for use in public supply systems the values shall not be lower than those of class 2.

NOTE 3 Maximum deviation : $\Delta u = \pm(0{,}01 \times U_1 \times \sqrt{2} + 0{,}005 \times u)$.

The rms value of the resultant waveform shall be maintained at nominal voltage during the application of this test.

Table 8 – Harmonic combination, "over swing"

h	3	5	Class
% of U_1	4 % / 180°	3 % / 0°	1
% of U_1	6 % / 180°	4 % / 0°	2
% of U_1	8 % / 180°	5 % / 0°	3
% of U_1	X / 180°	X / 0°	X

NOTE 1 Classes 1, 2, and 3 are defined in annex C.

NOTE 2 The levels given for class X are open. These levels shall be defined by the product committees. However, for equipment for use in public supply systems, the values shall not be lower than those of class 2.

8.2.2 Test method "Sweep in frequencies"

The equipment set-up for sweep frequency tests are shown in figures 2 and 3. The amplitude of the sweep frequencies depends on the frequency range (see table 9 and figure 5). The sweep (analogue) or step rate (digital) should be such that the time taken per decade is no less than 5 min, as shown in figure 5. The frequency sweep will dwell at frequencies where performance anomalies are detected as well as at all resonant frequencies. At each dwell point, the test time should be at least 120 s. A resonance frequency shall be selected with an oscilloscope or another comparable method for example a spectrum analyser.

For the purpose of this standard, a resonance frequency shall have the following characteristics:

If the harmonic or interharmonic current at a constant harmonic voltage amplitude has reached a maximum value at a frequency f, and the current decreases by at least 3 dB in the frequency range f_{res} *to* $1.5 \times f_{res}$ *, the frequency f shall be denoted as a resonant frequency* f_{res} *. If the maximum value of the current is attained and a change of the amplitude has resulted in the frequency range* f_{res} *to* $1,5 \times f_{res}$*, then a search for the resonant frequency must be repeated with a lower but constant amplitude. Determination of resonant frequencies shall be made at the completion of the sweep in frequencies test.*

The selection of resonant frequencies is further detailed in Annex B.

Table 9 – Sweep in frequency test levels

Frequency range	Frequency step	Class 1	Class 2	Class 3	Class X
f	Δf	Test levels % U_1	Test levels % U_1	Test levels % U_1	Test levels % U_1
$0,33 \times f_1$ to $2 \times f_1$	$0,1 \times f_1$	2	3	4,5	Open
$2 \times f_1$ to $10 \times f_1$	$0,2 \times f_1$	5	9	14	Open
$10 \times f_1$ to $20 \times f_1$	$0,2 \times f_1$	4	4,5	9	Open
$20 \times f_1$ to $30 \times f_1$	$0,5 \times f_1$	2	2	6	Open
$30 \times f_1$ to $40 \times f_1$	$0,5 \times f_1$	2	2	4	Open

NOTE 1 Classes 1, 2, and 3 are defined in annex C.

NOTE 2 The levels given for class X are open. These levels shall be defined by the product committees. However, for equipment for use in public supply systems the values shall not be lower than those of class 2.

8.2.3 Individual harmonics and interharmonics with a specified test level sequence

In the frequency range $2 \times f_1$ to $40 \times f_1$, single sinusoidal voltages with magnitude according to tables 1 to 3 shall be superimposed on the fundamental voltage U_1. Each frequency shall be applied for 5 s with a one second interval to the next one (see figure 4) whereas the r.m.s. value of the resultant voltage shall be kept constant during the duration of the whole test.

For the interharmonics test, in the frequency ranges shown in tables 4a and 4b, the frequency step sizes are dictated in table 10. Each step point shall be applied for 5 s with a one second interval to the next one whereas the r.m.s. value of the resultant waveform shall be kept constant during the duration of the whole test.

Table 10 – Frequency step sizes for interharmonics and Meister curve

Frequency range	Frequency step
f	Δf
$0,33 \times f_1$ to $2 \times f_1$	$0,1 \times f_1$
$2 \times f_1$ to $10 \times f_1$	$0,2 \times f_1$
$10 \times f_1$ to $20 \times f_1$	$0,2 \times f_1$
$20 \times f_1$ to $40 \times f_1$	$0,5 \times f_1$

8.2.4 Application of the Meister curve

If the EUT is used in countries where mains signalling and/or ripple control is applied, the «Meister curve» test has to be performed.

During this test, the frequency may be swept (analogue) or stepped (digital) at a rate of no less than 5 min per decade (see figure 5).

In both cases, the amplitude of the applied interharmonic levels has to follow the values given in table 11.

Table 11 – Meister curve test levels

Frequency range	Frequency step	Class 1	Class 2	Class 3	Class X
f	Δf	Test levels % U_1	Test levels % U_1	Test levels % U_1	Test levels % U_1
$0,33 \times f_1$ to $2 \times f_1$	$0,1 \times f_1$	No test	3	4	Open
$2 \times f_1$ to $10 \times f_1$	$0,2 \times f_1$	No test	9	10	Open
$10 \times f_1$ to $20 \times f_1$	$0,2 \times f_1$	No test	4 500/f	4 500/f	Open
$20 \times f_1$ to $40 \times f_1$	$0,5 \times f_1$	No test	4 500/f	4 500/f	Open

If the Meister curve is applied in class 3, the «Frequencies between harmonic frequencies» test (interharmonics, table 4) is replaced by this test.

In class 2, the «Sweep in frequency» test (table 4) is replaced by this test (see figure 1a flowchart).

8.2.5 Application of the test in a multi-phase EUT

See figure 3.

The harmonic or interharmonic distortion shall be applied simultaneously to all line-neutral phases, and the harmonics in each line-neutral voltage shall have the same phase relation to the fundamental of the corresponding wave form. This means, that apart from a 120° shift, the multiple wave forms are equal as it is most often observed in low voltage networks.

A consequence of this approach is that the test generator should have a neutral on its output, and cannot have a multiple phase output transformer which will not transfer the homopolar triple harmonics.

For multi-phase equipment without neutral connection, this does not apply, and testing with tripled harmonics is not required.

9 Evaluation of test results

The test results shall be classified in terms of the loss of function or degradation of performance of the equipment under test, relative to a performance level defined by its manufacturer or the requestor of the test, or agreed upon between the manufacturer and the purchaser of the product. The recommended classification is as follows:

a) normal performance within limits specified by the manufacturer, requestor or purchaser;

b) temporary loss of function or degradation of performance which ceases after the disturbance ceases, and from which the equipment under test recovers its normal performance, without operator intervention;

c) temporary loss of function or degradation of performance, the correction of which requires operator intervention;

d) loss of function or degradation of performance which is not recoverable, owing to damage to hardware or software, or loss of data.

The manufacturer's specification may define effects on the EUT which may be considered insignificant, and therefore acceptable.

This classification may be used as a guide in formulating performance criteria, by committees responsible for generic, product and product-family standards, or as a framework for the agreement on performance criteria between the manufacturer and the purchaser, for example where no suitable generic, product or product-family standard exists.

10 Test report

The test report shall contain all the information necessary to reproduce the test. In particular, the following shall be recorded:

- the items specified in the test plan required by clause 8 of this standard;
- identification of the EUT and any associated equipment, for example brand name, product type, serial number;
- identification of the test equipment, for example brand name, product type, serial number;
- any special environmental conditions in which the test was performed, for example shielded enclosure;
- any specific conditions necessary to enable the test to be performed;
- performance level defined by the manufacturer, requestor or purchaser;
- performance criterion specified in the generic, product or product-family standard;
- any effects on the EUT observed during or after the application of the test disturbance, and the duration for which these effects persist;
- the rationale for the pass / fail decision (based on the performance criterion specified in the generic, product or product-family standard, or agreed upon between the manufacturer and the purchaser);
- any specific conditions of use, for example cable length or type, shielding or grounding, or EUT operating conditions, which are required to achieve compliance.

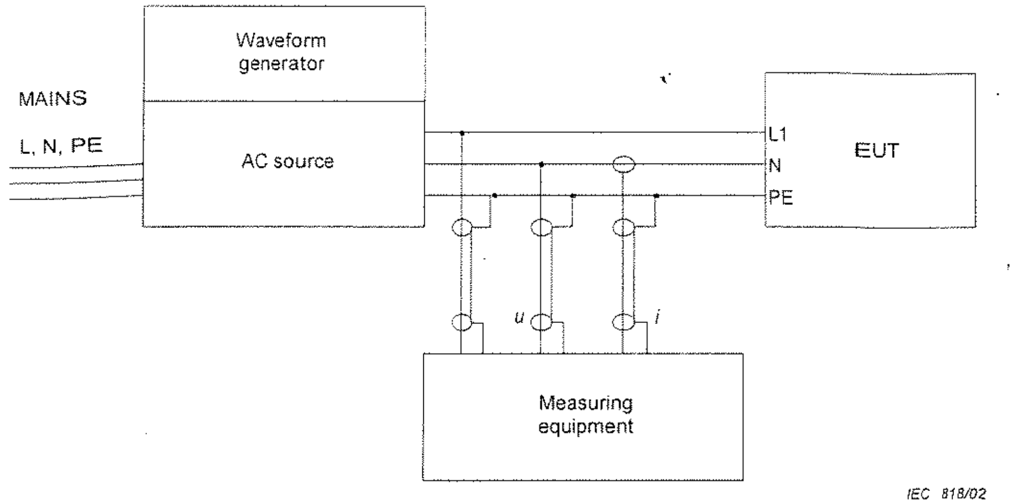


Figure 2 – An example of a test set-up for single phase

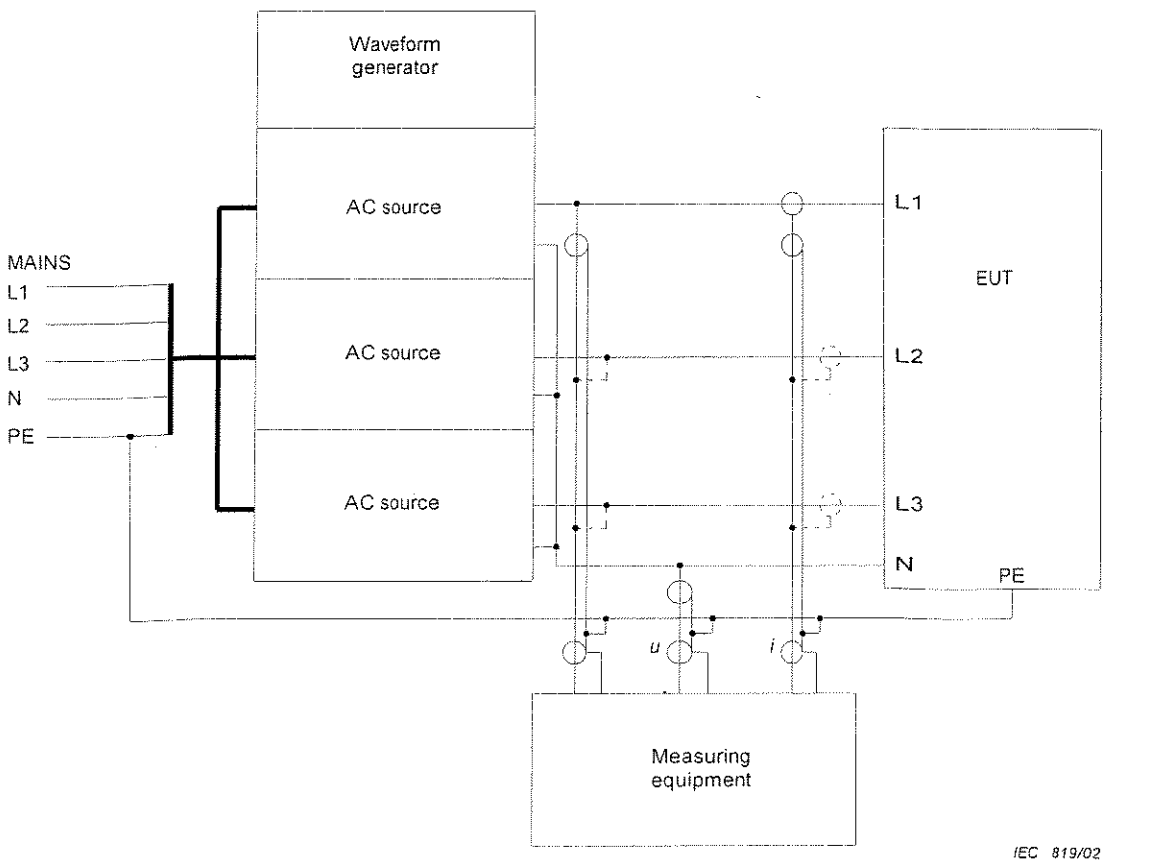
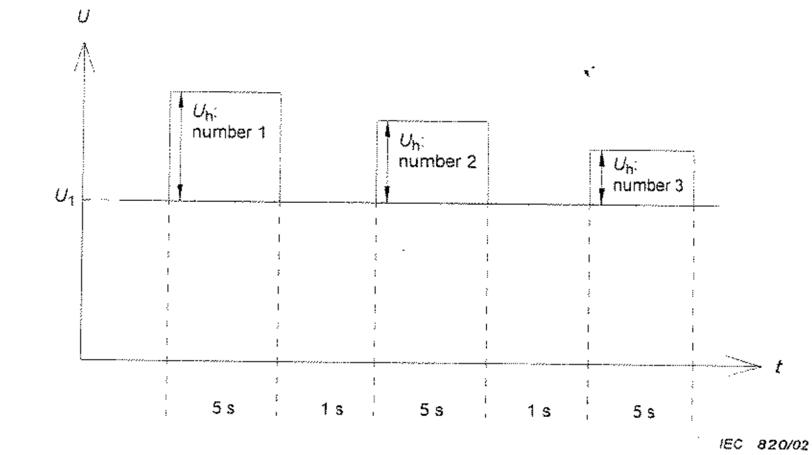
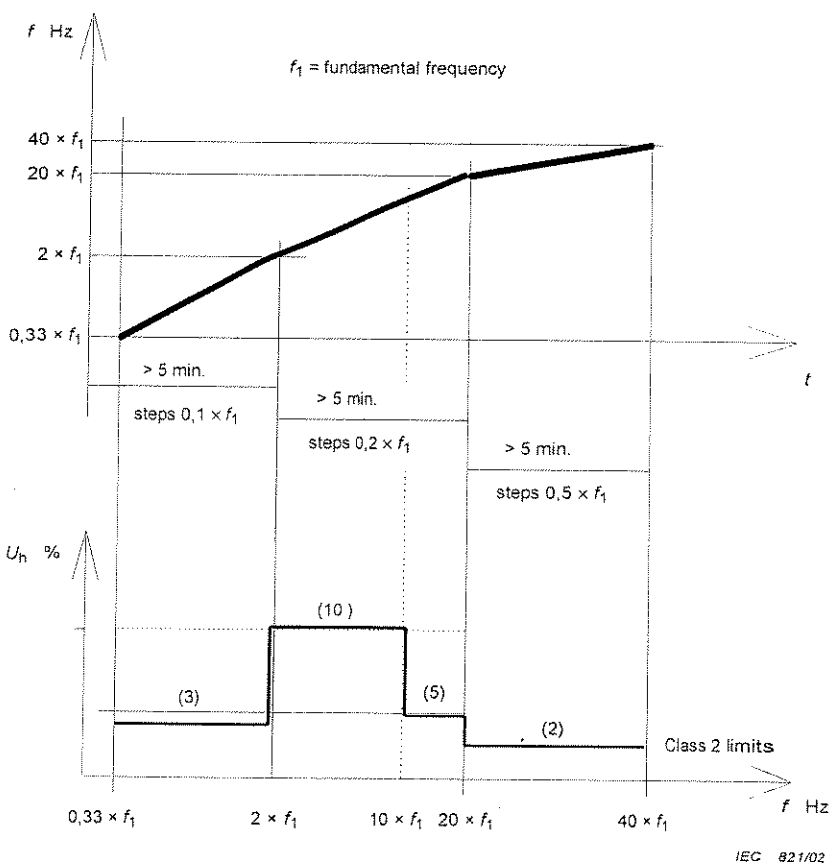


Figure 3 – An example of a test set-up for three phases



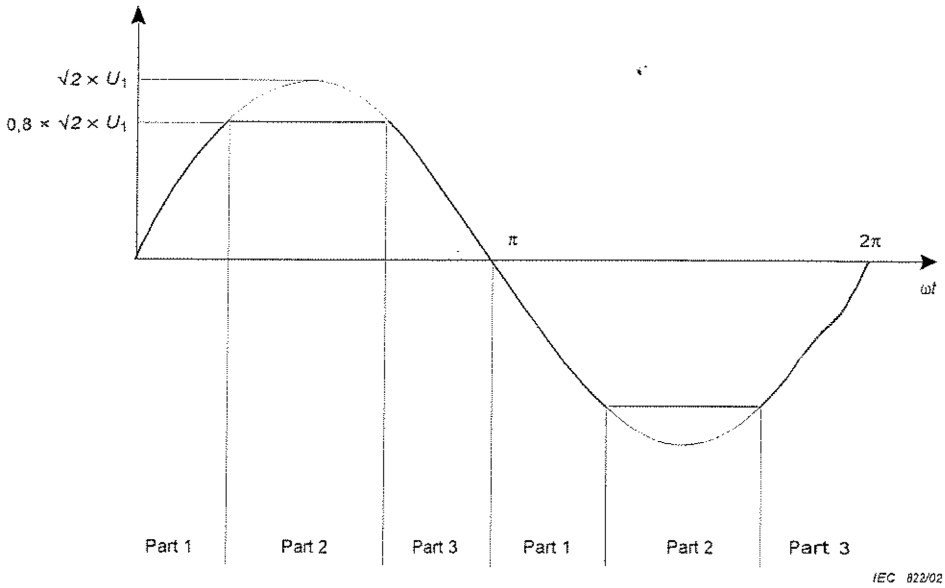
NOTE The r.m.s. voltage remains constant during all harmonics tests.

Figure 4 – Test sequences for individual harmonics



NOTE U_h = value of superimposed harmonics in %.

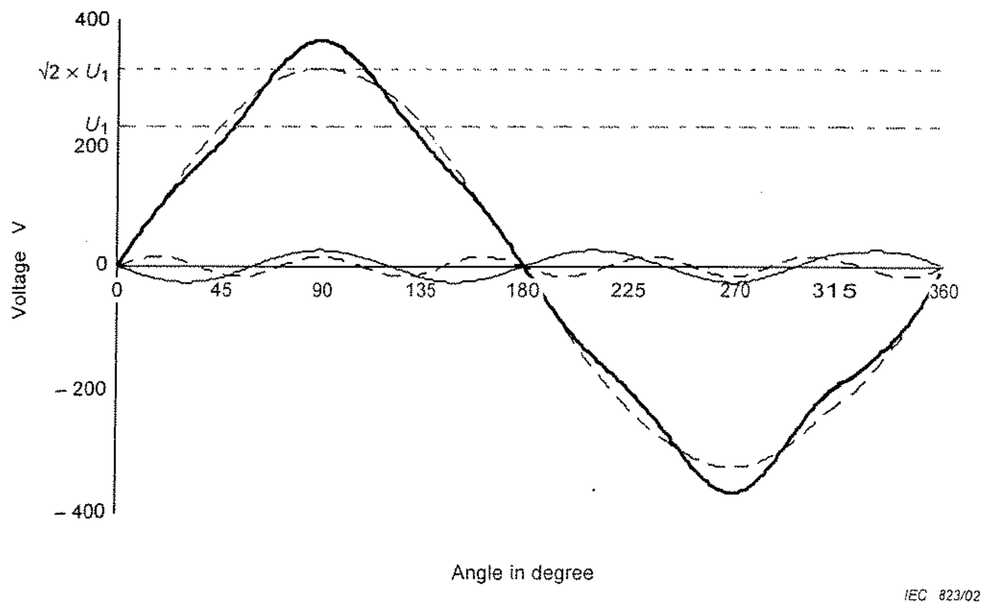
Figure 5 – An example of the sweep in frequency test (for example class 2 equipment from table 9)



Example for class 3:

U_1 = 255,7 V (fundamental voltage)
0,8 × √2 × U_1 = 289,3 V (max. voltage of flat curve)
√2 × U_1 = 361,6 V (U_1 peek voltage)
$U_{r.m.s.}$ = 230 V (resultant rms voltage)

Figure 6 – Flat curve waveshape



Example for class 3:

$U_{r.m.s.}$ = 230 V (resultant voltage)
U_1 = 229 V (fundamental voltage)
h = 3: 8 % of U_1 / 180°
h = 5: 5 % of U_1 / 0°

Figure 7 – Over swing waveshape

Annex A
(informative)

Impedance network between voltage source and EUT

Most test generators have an extremely low, near zero, impedance which does not present a problem for testing. However, if it can be determined by a product committee that an impedance network is desired to find possible resonance between line and the EUT that could be excited by harmonics, the IEC 60725 impedance network is suggested.

As a result of LC resonant circuits formed by network line impedance and capacitor(s) inside an EUT, resonant phenomena excited by harmonic voltage sources can appear. These resonant phenomena can affect the proper operation of an EUT.

This leads to the necessity to place an impedance between the voltage fundamental and harmonics source and the EUT. Mains disturbance effects are likely to occur for high-level lower frequency harmonics when they excite these resonant circuits.

The IEC 60725 impedance network (phase Z = 0,24 + j 0,15 Ω, neutral Z = 0,16 + j 0,10 Ω at 50 Hz) is specified to be inserted in the test set-up between the source and EUT to detect possible damaging resonant phenomena excited by harmonics.

The representative impedance for 60 Hz networks is suggested as follows:

- for 120 / 208 V (phase Z = 0,10 + j 0,04 Ω, neutral Z = 0,10 + j 0,03 Ω)
- for 347 / 600 V (phase Z = 0,29 + j 0,07 Ω, neutral Z = 0,30 + j 0,04 Ω)

Product committees are free to realise additional tests with other impedance values considered to be of significant interest with regard to interactions with the EUT.

Annex B
(informative)

Resonance point

The definition of a resonant frequency, in 8.2.2, was selected because an increasing current with an increase in the frequency is not enough to determine the start of the resonant frequency, for example a capacitor alone causes an increasing current while increasing the frequency, even without a resonance. A decreasing current demonstrates that there is a resonance.

In practice, resonance appear especially at higher frequencies.

Example:

A transformer is loaded by a capacitor. The capacitor causes a rising transformer current by increasing the frequency. If the leakage inductance of the transformer and the capacitor cause a resonance, a peak in the amplitude of current can occur. If the frequency is further increased, the transformer current decreases.

The harmonic and interharmonic currents can cause additional dissipation in the transformer. This interaction can cause a degradation of the performance of an EUT. The heating effects due to this increased dissipation are not considered in this standard.

Annex C
(informative)

Electromagnetic environment classes

The following classes of electromagnetic environment have been summarised from IEC 61000-2-4.

Class 1

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

NOTE1 Class 1 environments normally contain equipment which requires protection by such apparatus as uninterruptible power supplies (UPS) or filters.

NOTE 2 If UPS with high distortion level is used, class 2 may be recommended.

Class 2

This class applies to points of common coupling (PCC's for consumer systems) and in-plant points of common coupling (IPC's) in the industrial environment in general. The compatibility levels in this class are identical to those of public networks; therefore components designed for application in public networks may be used in this class of industrial environment.

Class 3

This class applies only to IPC's 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.

NOTE 1 The supply to highly disturbing loads, such as arc-furnaces and large converters which are generally supplied from a segregated bus-bar, frequently has disturbance levels in excess of class 3 (harsh environment). In such special situations, the compatibility levels should be agreed upon.

NOTE 2 The class applicable for new plants and extensions of existing plants should relate to the type of equipment and process under consideration.

Bibliography

IEC 60068-1: *Environmental testing – Part 1: General and guidance*

IEC 60725: *Considerations on reference impedances for use in determining the disturbance characteristics of household appliances and similar electrical equipment*

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