

# Voltage characteristics of electricity supplied by public distribution networks

The European Standard EN 50160:2007 has the status of a  
British Standard

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## National foreword

This British Standard is the UK implementation of EN 50160:2007. It supersedes BS EN 50160:2000 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/8, Systems aspects for electrical energy supply.

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

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**Voltage characteristics of electricity  
supplied by public distribution networks**

Caractéristiques de la tension  
fournie par les réseaux publics  
de distribution

Merkmale der Spannung  
in öffentlichen  
Elektrizitätsversorgungsnetzen

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**CENELEC**

European Committee for Electrotechnical Standardization  
Comité Européen de Normalisation Electrotechnique  
Europäisches Komitee für Elektrotechnische Normung

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## Foreword

This European Standard was prepared by the Working Group 1, Physical characteristics of electrical energy, of the Technical Committee CENELEC TC 8X, System aspects for electrical energy supply.

The text of the draft was submitted to the formal vote and was approved by CENELEC as EN 50160 on 2007-06-01.

This European Standard supersedes EN 50160:1999 + corrigendum September 2004.

The following dates were fixed:

- latest date by which the EN has to be implemented  
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with the EN have to be withdrawn (dow) 2010-06-01

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## 1 Scope and object

### 1.1 Scope

This European Standard defines, describes and specifies the main characteristics of the voltage at a network user's supply terminals in public low voltage and medium voltage electricity distribution networks under normal operating conditions. This standard describes the limits or values within which the voltage characteristics can be expected to remain over the whole of the public distribution network and does not describe the average situation usually experienced by an individual network user.

NOTE 1 For the definitions of low and medium voltage see 3.7 and 3.8.

The European Standard does not apply under abnormal operating conditions including the following:

- a temporary supply arrangement to keep the network users supplied during condition arising as a result of a fault, maintenance and construction work or to minimize the extent and duration of a loss of supply;
- in case of non-compliance of a network user's installation or equipment with the relevant standards or with the technical requirements for connection, established either by the public authorities or the distribution network operator (DNO) including the limits for the emission of conducted disturbances;

NOTE 2 A network user's installation may include load as well as generation.

- in exceptional situations, in particular,
  - exceptional weather conditions and other natural disasters,
  - third party interference,
  - acts by public authorities,
  - industrial actions (subject to legal requirements),
  - force majeure,
  - power shortages resulting from external events.

The voltage characteristics given in this standard are not intended to be used as electromagnetic compatibility (EMC) levels or user emission limits for conducted disturbances in public distribution networks.

The voltage characteristics given in this standard are not intended to be used to specify requirements in equipment product standards and in installation standards.

NOTE 3 The performance of equipment might be impaired if it is subjected to supply conditions which are not specified in the equipment product standard.

This standard may be superseded in total or in part by the terms of a contract between the individual network user and the DNO.

### 1.2 Object

The object of this European Standard is to define and describe the characteristics of the supply voltage concerning

- frequency,
- magnitude,
- wave form,
- symmetry of the line voltages.

These characteristics are subject to variations during the normal operation of a supply system due to changes of load, disturbances generated by certain equipment and the occurrence of faults which are mainly caused by external events.

The characteristics vary in a manner which is random in time, with reference to any specific supply terminal, and random in location, with reference to any given instant of time. Because of these variations, the levels of the characteristics can be expected to be exceeded on a small number of occasions.

Some of the phenomena affecting the voltage are particularly unpredictable, which make it very difficult to give useful definite values for the corresponding characteristics. The values given in this standard for such phenomena, e.g. voltage dips and voltage interruptions, shall be interpreted accordingly.

## 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 - Chapter 161: Electromagnetic compatibility
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## 3 Definitions

For the purposes of this document, the following terms and definitions apply.

### 3.1

#### **network user**

party being supplied by or supplying to an electricity distribution network

### 3.2

#### **distribution network operator (DNO)**

party responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution network in a given area and, for ensuring the long term ability of the network to meet reasonable demands for the distribution of electricity

### 3.3

#### **supply terminal**

point in a distribution network designated as such and contractually fixed, at which electrical energy is exchanged between contractual partners

NOTE This point can differ from, for example, the electricity metering point or the point of common coupling.

### 3.4

#### **supply voltage**

r.m.s. value of the voltage at a given time at the supply terminal, measured over a given interval

### 3.5

#### **nominal voltage ( $U_n$ )**

voltage by which a distribution network is designated or identified and to which certain operating characteristics are referred

**3.6****declared supply voltage ( $U_c$ )**

the declared supply voltage  $U_c$  is normally the nominal voltage  $U_n$  of the distribution network. If by agreement between the DNO and the network user a voltage different from the nominal voltage is applied to the terminal, then this voltage is the declared supply voltage  $U_c$

**3.7****low voltage (LV)**

for the purpose of this European Standard, voltage whose upper limit of nominal r.m.s. value is 1 kV

**3.8****medium voltage (MV)**

for the purpose of this European Standard, voltage whose nominal r.m.s. value lies above 1 kV and below 35 kV

**3.9****normal operating condition**

for a distribution network, condition of meeting load and generation demands, system switching and clearing faults by automatic system protection in the absence of exceptional conditions due to external influences or major events

**3.10****conducted disturbance**

electromagnetic phenomenon propagated along the line conductors of a distribution network. In some cases an electromagnetic phenomenon is propagated across transformer windings and hence between networks of different voltage levels. These disturbances may degrade the performance of a device, equipment or system or they may cause damage

**3.11****frequency of the supply voltage**

repetition rate of the fundamental wave of the supply voltage measured over a given interval of time

**3.12****voltage variation**

increase or decrease of voltage normally due to load variations

**3.13****rapid voltage change**

single rapid variation of the r.m.s. value of a voltage between two consecutive levels which are sustained for definite but unspecified durations (for more information see EN 61000-3-3)

**3.14****voltage fluctuation**

series of voltage changes or a cyclic variation of the voltage envelope

[IEV 161-08-05]

**3.15****flicker**

impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time

[IEV 161-08-13]

NOTE Voltage fluctuation causes changes of the luminance of lamps which can create the visual phenomenon called flicker. Above a certain threshold flicker becomes annoying. The annoyance grows very rapidly with the amplitude of the fluctuation. At certain repetition rates even very small amplitudes can be annoying.



**3.16****flicker severity**

intensity of flicker annoyance defined by the UIE-IEC flicker measuring method and evaluated by the following quantities:

- **short term severity** ( $P_{st}$ ) measured over a period of ten minutes;
- **long term severity** ( $P_{lt}$ ) calculated from a sequence of 12  $P_{st}$  values over a two hour interval, according to the following expression:

$$P_{lt} = \sqrt[3]{\sum_{i=1}^{12} \frac{P_{sti}^3}{12}}$$

**3.17****supply voltage dip**

sudden reduction of the supply voltage to a value between 90 % and 1 % of the declared voltage  $U_c$  followed by a voltage recovery after a short period of time. Conventionally the duration of a voltage dip is between 10 ms and 1 min. The depth of a voltage dip is defined as the difference between the minimum r.m.s. voltage during the voltage dip and the declared voltage. Voltage changes which do not reduce the supply voltage to less than 90 % of the declared voltage  $U_c$  are not considered to be dips

**3.18****supply interruption**

condition in which the voltage at the supply terminals is lower than 1 % of the declared voltage,  $U_c$ . A supply interruption can be classified as

- **prearranged**, when network users are informed in advance, to allow the execution of scheduled works on the distribution network, or
- **accidental**, caused by permanent or transient faults, mostly related to external events, equipment failures or interference. An accidental interruption is classified as:
  - a long interruption (longer than three minutes);
  - a short interruption (up to three minutes).

NOTE 1 The effect of a prearranged interruption can be minimized by the network users by taking appropriate measures.

NOTE 2 Accidental supply interruptions are unpredictable, largely random events.

**3.19****temporary power frequency overvoltage**

overvoltage, at a given location, of relatively long duration (see CLC/TR 50422, Clause 3 for more information)

NOTE Temporary overvoltages usually originate from switching operations or faults (e.g. sudden load reduction, single phase faults, non-linearities).

**3.20****transient overvoltage**

short duration oscillatory or non-oscillatory overvoltage usually highly damped and with a duration of a few milliseconds or less

[IEV 604-03-13 modified]

NOTE Transient overvoltages are usually caused by lightning, switching or operation of fuses. The rise time of a transient overvoltage can vary from less than a microsecond up to a few milliseconds.

### 3.21 harmonic voltage

sinusoidal voltage with a frequency equal to an integer multiple of the fundamental frequency of the supply voltage. Harmonic voltages can be evaluated

- individually by their relative amplitude ( $U_h$ ) related to the fundamental voltage  $U_1$ , where  $h$  is the order of the harmonic,
- globally, for example by the total harmonic distortion factor THD, calculated using the following expression:

$$THD = \sqrt{\sum_{h=2}^{40} (u_h)^2}$$

NOTE Harmonics of the supply voltage are caused mainly by network users' non-linear loads connected to all voltage levels of the supply network. Harmonic currents flowing through the network impedance give rise to harmonic voltages. Harmonic currents and network impedances and thus the harmonic voltages at the supply terminals vary in time.

### 3.22

#### interharmonic voltage

sinusoidal voltage with a frequency between the harmonics, i.e. the frequency is not an integer multiple of the fundamental

NOTE Interharmonic voltages at closely adjacent frequencies can appear at the same time forming a wide band spectrum.

### 3.23

#### voltage unbalance

condition in a polyphase system in which the r.m.s. values of the line-to-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 European Standard, voltage unbalance is considered in relation to three-phase systems and negative phase sequence only.

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

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

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

### 3.24

#### mains signalling voltage

signal superimposed on the supply voltage for the purpose of transmission of information in the public distribution network and to network users' premises. Three types of signals in the public distribution network can be classified:

- **ripple control signals:** superimposed sinusoidal voltage signals in the range of 110 Hz to 3 000 Hz;
- **power-line-carrier signals:** superimposed sinusoidal voltage signals in the range between 3 kHz to 148,5 kHz;
- **mains marking signals:** superimposed short time alterations (transients) at selected points of the voltage waveform.

## 4 Low-voltage supply characteristics

### 4.1 Power frequency

The nominal frequency of the supply voltage shall be 50 Hz. Under normal operating conditions the mean value of the fundamental frequency measured over 10 s shall be within a range of:

- for systems with synchronous connection to an interconnected system:
 

50 Hz $\pm$ 1 %	(i.e. 49,5 Hz... 50,5 Hz)	during 99,5 % of a year;
50 Hz + 4 % / - 6 %	(i.e. 47 Hz... 52 Hz)	during 100 % of the time;
- for systems with no synchronous connection to an interconnected system (e.g. supply systems on certain islands):
 

50 Hz $\pm$ 2 %	(i.e. 49 Hz... 51 Hz)	during 95 % of a week;
50 Hz $\pm$ 15 %	(i.e. 42,5 Hz... 57,5 Hz)	during 100 % of the time.

### 4.2 Magnitude of the supply voltage

The standard nominal voltage  $U_n$  for public low voltage is  $U_n = 230$  V, either between phase and neutral, or between phases

- for four-wire three phase systems:  
 $U_n = 230$  V between phase and neutral;
- for three-wire three phase systems:  
 $U_n = 230$  V between phases.

NOTE In low voltage systems declared and nominal voltage are equal.

### 4.3 Supply voltage variations

#### 4.3.1 Requirements

The voltage variation should not exceed  $\pm 10$  %.

Situations like those arising from faults or voltage interruptions, the circumstances of which are beyond the reasonable control of the parties, are excluded.

NOTE 1 Overall experience has shown, that sustained voltage deviations of more than  $\pm 10$  % over a longer period of time are extremely unlikely, although they could theoretically be within the given statistical limits of 4.3.2. Therefore, in accordance with relevant product and installation standards and application of IEC 60038 end users' appliances are usually designed to tolerate supply voltages of  $\pm 10$  % around the nominal system voltage, which is sufficient to cover an overwhelming majority of supply conditions. It is expected to be neither technically nor economically viable to generally give appliances the ability to handle supply voltage tolerances broader than  $\pm 10$  %. If, in single cases, evidence is given, that the magnitude of the supply voltage could depart beyond this limit for a longer period of time, additional measures should be taken in cooperation with the local network operator, depending on a risk assessment. The same applies in cases, where specific appliances have an increased sensitivity with respect to voltage variations.

NOTE 2 In cases of electricity supplies in remote areas with long lines or not connected to a large interconnected network, the voltage could be outside the range of  $U_n + 10$  % / - 15 %. Network users should be informed of the conditions.

### 4.3.2 Test method

Under normal operating conditions,

- during each period of one week 95 % of the 10 min mean r.m.s. values of the supply voltage shall be within the range of  $U_n \pm 10 \%$ , and
- all 10 min mean r.m.s. values of the supply voltage shall be within the range of  $U_n + 10 \%$  / - 15 %.

## 4.4 Rapid voltage changes

### 4.4.1 Single rapid voltage change

A rapid voltage change of the supply voltage is mainly caused either by load changes in network users' installations or by switching in the system.

Under normal operating conditions a rapid voltage change generally does not exceed 5 %  $U_n$  but a change of up to 10 %  $U_n$  with a short duration might occur some times per day in some circumstances.

NOTE A negative voltage change resulting in a voltage less than 90 %  $U_n$  is considered a supply voltage dip (see 4.5).

### 4.4.2 Flicker severity

Under normal operating conditions, in any period of one week the long term flicker severity caused by voltage fluctuation should be  $P_{ft} \leq 1$  for 95 % of the time.

NOTE Reaction to flicker is subjective and can vary depending on the perceived cause of the flicker and the period over which it persists. In some cases  $P_{ft} = 1$  gives rise to annoyance, whereas in other cases higher levels of  $P_{ft}$  are found without annoyance.

## 4.5 Supply voltage dips

Voltage dips are generally caused by faults occurring in the network users' installations or in the public distribution network. They are unpredictable, largely random events. The annual frequency varies greatly depending on the type of supply system and on the point of observation. Moreover, the distribution over the year can be very irregular.

Indicative values:

Under normal operating conditions the expected number of voltage dips in a year may be from up to a few tens to up to one thousand. The majority of voltage dips have a duration less than 1 s and a retained voltage greater than 40 %. However, voltage dips with greater depth and duration can occur infrequently. In some areas voltage dips with a retained voltage between 85 % and 90 % of  $U_n$  can occur very frequently as a result of the switching of loads in network users' installations.

## 4.6 Short interruptions of the supply voltage

Indicative values:

Under normal operating conditions the annual occurrence of short interruptions of the supply voltage ranges from up to a few tens to up to several hundreds. The duration of approximately 70 % of the short interruptions may be less than one second.

NOTE In some documents short interruptions are considered as having durations not exceeding one minute. But sometimes control schemes are applied which need operating times of up to three minutes in order to avoid long voltage interruptions.

#### 4.7 Long interruptions of the supply voltage

**Accidental interruptions** are usually caused by external events or actions which cannot be prevented by the DNO. It is not possible to indicate typical values for the annual frequency and durations of long interruptions. This is due to wide differences in system configurations and structure in various countries and also because of the unpredictable effects of the actions of third parties and of the weather.

Indicative values:

Under normal operating conditions the annual frequency of voltage interruptions longer than three minutes may be less than 10 or up to 50 depending on the area.

Indicative values are not given for **prearranged interruptions**, because they are announced in advance.

#### 4.8 Temporary power frequency overvoltages between live conductors and earth

A temporary power frequency overvoltage generally appears during a fault in the public distribution network or in a network user's installation, and disappears when the fault is cleared. Under these conditions, the overvoltage may reach the value of the phase-to-phase voltage (up to max. 440 V in 230/400 V networks) due to a shift of the neutral point of the three-phase voltage system, the actual value depending upon the degree of load unbalance, and the remaining impedance between the faulty conductor and earth.

The duration is limited by the time taken for the MV protection and circuit breaker to clear the fault, typically no more than 5 s.

Under certain circumstances, a fault occurring upstream of a transformer may produce temporary overvoltages on the LV side for the time during which the fault current flows. Such overvoltages do not generally exceed 1,5 kV r.m.s.

#### 4.9 Transient overvoltages between live conductors and earth

Transient overvoltages at the supply terminals generally do not exceed 6 kV peak.

NOTE 1 The rise time can cover a wide range from milliseconds down to much less than a microsecond. However, for physical reasons transients of longer durations usually have much lower amplitudes. Therefore, the coincidence of high amplitudes and a long rise time is extremely unlikely.

NOTE 2 The energy content of a transient overvoltage varies considerably according to the origin. An induced overvoltage due to lightning generally has a higher amplitude but lower energy content than an overvoltage caused by switching, because of the generally longer duration of such switching overvoltages.

NOTE 3 LV Installations and end users' appliances are designed, in accordance with standard EN 60664-1, to withstand transient overvoltages in an overwhelming majority of situations. Where necessary, according to IEC 60364-4-44, surge protective devices should be selected, according to IEC 60364-5-53, to take account of the actual situations. This is assumed to cover the induced over-voltages due to both lightning and switching.

#### 4.10 Supply voltage unbalance

Under normal operating conditions, during each period of one week, 95 % of the 10 min mean r.m.s. values of the negative phase sequence component (fundamental) of the supply voltage shall be within the range 0 % to 2 % of the positive phase sequence component (fundamental). In some areas with partly single phase or two phase connected network users' installations, unbalances up to about 3 % at three-phase supply terminals occur.

NOTE In this European Standard only values for the negative sequence component are given because this component is the relevant one for the possible interference of appliances connected to the system.

#### 4.11 Harmonic voltage

Under normal operating conditions, during each period of one week, 95 % of the 10 min mean r.m.s. values of each individual harmonic voltage shall be less than or equal to the value given in Table 1. Resonances may cause higher voltages for an individual harmonic.

Moreover, the THD of the supply voltage (including all harmonics up to the order 40) shall be less than or equal to 8 %.

NOTE The limitation to order 40 is conventional.

**Table 1 - Values of individual harmonic voltages at the supply terminals for orders up to 25 given in percent of the fundamental voltage  $U_1$**

Odd harmonics				Even harmonics	
Not multiples of 3		Multiples of 3			
Order h	Relative voltage ( $U_n$ )	Order h	Relative voltage ( $U_n$ )	Order h	Relative voltage ( $U_n$ )
5	6,0 %	3	5,0 %	2	2,0 %
7	5,0 %	9	1,5 %	4	1,0 %
11	3,5 %	15	0,5 %	6 ... 24	0,5 %
13	3,0 %	21	0,5 %		
17	2,0 %				
19	1,5 %				
23	1,5 %				
25	1,5 %				

NOTE No values are given for harmonics of order higher than 25, as they are usually small, but largely unpredictable due to resonance effects.

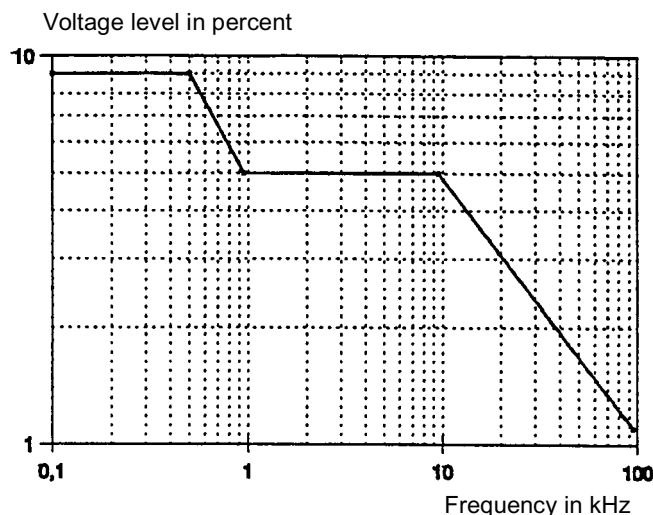
#### 4.12 Interharmonic voltage

The level of interharmonics is increasing due to the development of frequency converters and similar control equipment. Levels are under consideration, pending more experience.

In certain cases interharmonics, even at low levels, give rise to flicker (see 4.4.2), or cause interference in ripple control systems.

#### 4.13 Mains signalling voltage on the supply voltage

In some countries the public distribution networks may be used by the public supplier for the transmission of signals. Over 99 % of a day the 3 s mean of signal voltages shall be less than or equal to the values given in Figure 1.



**Figure 1 - Voltage levels of signal frequencies in percent of  $U_n$  used in public LV distribution networks**

NOTE Power line carrier signalling with frequencies in the range from 95 kHz to 148,5 kHz may be used in network users' installations. Though the use of the public system for the transmission of signals between network users is not allowed, voltages of these frequencies up to 1,4 V r.m.s. in the public LV distribution network have to be taken into account. Because of the possibility of mutual influences of neighbouring signalling installations the network user may need to apply protection or appropriate immunity for his signalling installation against this influence.

## 5 Medium-voltage supply characteristics

Network users with demands exceeding the capacity of the low voltage network are generally supplied at declared voltages above 1 kV. This standard applies to such electricity supplies at declared voltages up to 35 kV.

NOTE Network users may be supplied at such voltages also to satisfy special requirements or to mitigate conducted disturbances emitted by their equipment.

### 5.1 Power frequency

The nominal frequency of the supply voltage shall be 50 Hz. Under normal operating conditions the mean value of the fundamental frequency measured over 10 s shall be within a range of:

- for systems with synchronous connection to an interconnected system:
 

50 Hz $\pm$ 1 %	(i.e. 49,5 Hz... 50,5 Hz)	during 99,5 % of a year;
50 Hz + 4 % / - 6 %	(i.e. 47 Hz... 52 Hz)	during 100 % of the time,
- for systems with no synchronous connection to an interconnected system (e.g. supply systems on certain islands):
 

50 Hz $\pm$ 2 %	(i.e. 49 Hz... 51 Hz)	during 95 % of a week;
50 Hz $\pm$ 15 %	(i.e. 42,5 Hz... 57,5 Hz)	during 100 % of the time.

### 5.2 Magnitude of the supply voltage

The magnitude is given by the declared voltage  $U_c$ .

### 5.3 Supply voltage variations

Under normal operating conditions excluding voltage interruptions, during each period of one week, 95 % of the 10 min mean r.m.s. values of the supply voltage shall be within the range of  $U_c \pm 10\%$ .

### 5.4 Rapid voltage changes

#### 5.4.1 Magnitude of rapid voltage changes

Rapid voltage changes of the supply voltage are mainly caused either by load changes in the network users' installations or by switching in the system.

Under normal operating conditions rapid voltage changes generally do not exceed 4 %  $U_c$  but changes of up to 6 %  $U_c$  with a short duration might occur some times per day in some circumstances.

#### 5.4.2 Flicker severity

Under normal operating conditions, in any period of one week the long term flicker severity caused by voltage fluctuation should be  $P_{lt} \leq 1$  for 95 % of the time.

### 5.5 Supply voltage dips

Voltage dips are generally caused by faults occurring in the network users' installations or in the public distribution network. The annual frequency varies greatly depending on the type of supply system and on the point of observation. Moreover, the distribution over the year can be very irregular.

Indicative values:

Under normal operating conditions the expected number of voltage dips in a year can be from up to a few tens to up to one thousand. The majority of voltage dips have a duration less than 1 s and a retained voltage greater than 40 %. However, voltage dips with greater depth and duration can occur infrequently. In some areas voltage dips with depths between 10 % to 15 % of  $U_c$  can occur very frequently as a result of the switching of loads in network users' installations.

### 5.6 Short interruptions of the supply voltage

Indicative values:

Under normal operating conditions the annual occurrence of short interruptions of the supply voltage ranges from up to a few tens to up to several hundreds. The duration of approximately 70 % of the short interruptions may be less than one second.

NOTE In some documents short interruptions are considered as having durations not exceeding one minute. But sometimes control schemes are applied which need operating times of up to three minutes in order to avoid long voltage interruptions.

### 5.7 Long interruptions of the supply voltage

**Accidental interruptions** are usually caused by external events or actions which cannot be prevented by the supplier. It is not possible to indicate typical values for the annual frequency and durations of long interruptions. This is due to wide differences in system configurations and structure in various countries and also because of the unpredictable effects of the actions of third parties and of the weather.



Indicative values:

Under normal operating conditions the annual frequency of voltage interruptions longer than three minutes may be less than 10 or up to 50 depending on the area.

Indicative values are not given for **prearranged interruptions**, because they are announced in advance.

### **5.8 Temporary power frequency overvoltages between live conductors and earth**

A temporary power frequency overvoltage generally appears during an earth fault in the public distribution network or in a network user's installation and disappears when the fault is cleared. The expected value of such an overvoltage depends on the type of earthing of the system. In systems with a solidly or impedance earthed neutral the overvoltage shall generally not exceed  $1,7 U_c$ . In isolated or resonant earthed systems the overvoltage shall generally not exceed  $2,0 U_c$ . The type of earthing will be indicated by the distributor.

### **5.9 Transient overvoltage between live conductors and earth**

Transient overvoltages in MV supply systems are caused by switching or, directly or by induction, by lightning. Switching overvoltages generally are lower in amplitude than lightning overvoltages, but they may have a shorter rise time and/or longer duration.

NOTE The network users' insulation coordination scheme must be compatible with that adopted by the supplier.

### **5.10 Supply voltage unbalance**

Under normal operating conditions, during each period of one week, 95 % of the 10 min mean r.m.s. values of the negative phase sequence component of the supply voltage shall be within the range 0 % to 2 % of the positive phase sequence component. In some areas unbalances up to 3 % occur.

NOTE In this European Standard only values for the negative sequence component are given because this component is the relevant one for the possible interference of appliances connected to the system.

### **5.11 Harmonic voltage**

Under normal operating conditions, during each period of one week, 95 % of 10 min mean r.m.s. values of each individual harmonic voltage shall be less than or equal to the value given in Table 2. Resonances may cause higher voltages for an individual harmonic.

Moreover, the THD of the supply voltage (including all harmonics up to the order 40) shall be less than or equal to 8 %.

NOTE The limitation to order 40 is conventional.

**Table 2 - Values of individual harmonic voltages at the supply terminals for orders up to 25 given in percent of the fundamental voltage  $U_1$**

Odd harmonics				Even harmonics	
Not multiples of 3		Multiples of 3		Order h	Relative voltage ( $U_n$ )
Order h	Relative voltage ( $U_n$ )	Order h	Relative voltage ( $U_n$ )		
5	6,0 %	3	5,0 % <sup>a</sup>	2	2,0 %
7	5,0 %	9	1,5 %	4	1,0 %
11	3,5 %	15	0,5 %	6 ... 24	0,5 %
13	3,0 %	21	0,5 %		
17	2,0 %				
19	1,5 %				
23	1,5 %				
25	1,5 %				

<sup>a</sup> Depending on the network design the value for the third harmonic order can be substantially lower.

NOTE No values are given for harmonics of order higher than 25, as they are usually small, but largely unpredictable due to resonance effects.

### 5.12 Interharmonic voltage

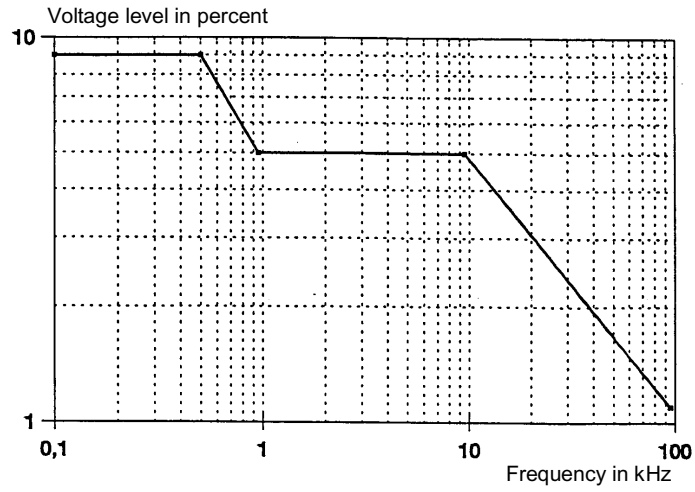
The level of interharmonics is increasing due to the development of frequency converters and similar control equipment. Levels are under consideration, pending more experience.

In certain cases interharmonics, even at low levels, give rise to flicker (see 5.4.2), or cause interference in ripple control system.

### 5.13 Mains signalling voltage on the supply voltage

In some countries the public distribution networks may be used by the public supplier for the transmission of signals. Over 99 % of a day the 3 s mean of the signal voltages shall be less or equal to the values given in Figure 2. For frequencies from 9 kHz to 95 kHz the values are under consideration.

NOTE It is assumed that network users do not use the public MV network for signalling purposes.



**Figure 2 - Voltage levels of signal frequencies in percent of  $U_c$  used in public MV distribution networks**

## **Annex A** (informative)

### **Special nature of electricity**

Electricity is an energy form which is particularly versatile and adaptable. It is utilised by being converted into several other forms of energy: heat, light, mechanical energy, and the many electromagnetic, electronic, acoustic and visual forms which are the bases of modern telecommunications, information technology and entertainment.

Electricity as delivered to the network users has several characteristics which are variable and which affect its usefulness to the network user. This standard describes characteristics of electricity in terms of the alternating voltage. With respect to the use of electricity it is desirable that the supply voltage would alternate at a constant frequency, with a perfect sine wave and a constant magnitude. In practice, there are many factors which cause departures from this. In contrast to normal products, application is one of the main factors which influence the variation of "characteristics".

The flow of energy to the network user's appliances gives rise to electric currents which are more or less proportional to the magnitudes of the network users' demands. As these currents flow through the conductors of the supply system, they give rise to voltage drops. The magnitude of the supply voltage for an individual network user at any instant is a function of the cumulative voltage drops on all the components of the system through which that network user is supplied, and is determined both by the individual demand and by the simultaneous demands of other network users. Since each network user's demand is constantly varying, and there is a further variation in the degree of coincidence between the demands of several network users, the supply voltage is also variable. For this reason, this standard deals with the voltage characteristics in statistical or probabilistic terms. It is in the economic interests of the network user that the standard of supply should relate to normally expected conditions rather than to rare contingencies, such as an unusual degree of coincidence between the demands of several appliances or several network users.

Electricity reaches the network user through a system of generation, transmission and distribution equipment. Each component of the system is subject to damage or failure due to the electrical, mechanical and chemical stresses which arise from several causes, including extremes of weather, the ordinary processes of wear and deterioration with age, and interference by human activities, birds, animals, etc. Such damage can affect or even interrupt the supply to one or to many network users.

To keep the frequency constant requires the amount of running generation capacity to be matched instant by instant to the simultaneous combined demand. Because both the generation capacity and the demand are liable to change in discrete amounts, especially in the event of faults on the generation, transmission or distribution networks, there is always a risk of a mismatch, resulting in an increase or decrease of the frequency. This risk is reduced, however, by connecting many systems into one large interconnected system, the generation capacity of which is very great relative to the changes which are likely to occur.

There are several other characteristics that may have a disturbing or damaging effect on network users' equipment, or even on the network users. Some of these disturbing characteristics arise from unavoidable transient events in the supply system itself, resulting from faults or switching, or caused by atmospheric phenomena (lightning). Others, however, are the result of various uses of electricity which directly alter the waveform of the voltage, impose a particular pattern on its magnitude, or superimpose signalling voltages. Coincidentally with the modern proliferation of equipment which has these effects, there is also an increase in the equipment which is susceptible to the disturbances.

This European Standard defines where possible the variations of the characteristics normally to be expected. In other cases the standard provides the best possible indication of what, in quantitative terms, is to be expected.

Since there is a considerable diversity in the structures of the distribution networks in different areas, arising from differences in load density, population dispersion, local topography, etc. many network users will experience considerably smaller variations of the voltage characteristics than the values given in this standard.

It is a particular feature of electricity that, in respect of some of its characteristics, its quality is affected by the user rather than by the producer or supplier. In these cases the network user is an essential partner, with the supplier, in the effort to maintain the quality of electricity.

It should be noted that this question is addressed directly by other standards, already published or in preparation: Emission standards govern the levels of electromagnetic disturbances which network users' equipment may be allowed to generate. Immunity standards set down disturbance levels which the equipment should be capable of tolerating without undue damage or loss of function. A third set of standards, for electromagnetic compatibility levels, has the function of enabling coordination and coherence of the emission and immunity standards, with the overall objective of achieving electromagnetic compatibility.

Although this standard has obvious links with compatibility levels, it is important to note that it relates to voltage characteristics of electricity. It is not a standard for compatibility levels. It should be especially noted that the performance of equipment might be impaired, if the equipment is subjected to supply conditions more severe than specified in their product standard.

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