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Značilnosti napetosti v javnih razdelilnih omrežjih

Voltage characteristics of electricity supplied by public distribution networks

Merkmale der Spannung in öffentlichen Energieversorgungsnetzen

Caractéristiques de la tension fournie par les réseaux publics de distribution

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English Version

Voltage characteristics of electricity supplied by public electricity networks

Caractéristiques de la tension fournie par les réseaux publics d´electricité

Merkmale der Spannung in öffentlichen Energieversorgungsnetzen

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

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Contents

European foreword

This document (EN 50160:2022) has been prepared by CLC TC8X “System aspects of electrical energy supply”.

The following dates are fixed:

• latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2023-11-07
• latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	2025-11-07

This document supersedes EN 50160:2010 and all of its amendments and corrigenda (if any).

EN 50160:2022 includes the following significant technical changes with respect to EN 50160:2010:

— implementation of amendments A2 (new frequency range 2-150 kHz, amendment on power frequency) and A3 (changed value on 15th and 21st harmonic in LV);

— The Norway A-deviation (amendment A1) was slightly modified;

— slight clarifications in the scope;

— integration of a new clause “extra high voltage”;

— clarification to dips and swells;

— new Annex D: PQ versus EMC.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

Any feedback and questions on this document should be directed to the users’ national committee. A complete listing of these bodies can be found on the CENELEC website.

1 Scope

1.1 Application

This document specifies the main characteristics of the voltage at a network user's supply terminals in public low voltage, medium, high, and extra-high voltage AC electricity networks under normal operating conditions. This document specifies the limits or values within which the voltage characteristics can be expected to remain at any supply terminal in public European electricity networks, only. Industrial networks are excluded from the scope of EN 50160.

NOTE 1 If non-public networks (e.g. residential quarters, energy communities, office centres, shopping centres) have similar end-users as public networks, it is strongly advised to apply the same requirements as for public networks.

This document does not apply under abnormal operating conditions, including the following:

a) a temporary supply arrangement to keep network users supplied during conditions arising as a result of a fault, maintenance and construction work, or to minimize the extent and duration of a loss of supply;

b) in the 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 network operator, including the limits for the emission of conducted disturbances;

NOTE 2 A network user’s installation can include load and generation.

c) in exceptional situations, in particular:

1) exceptional weather conditions and other natural disasters;

2) third party interference;

3) acts by public authorities,

4) industrial actions (subject to legal requirements);

5) force majeure;

6) power shortages resulting from external events.

The voltage characteristics given in this document refer to conducted disturbances in public electric power networks. They are not intended to be used as electromagnetic compatibility (EMC) levels or product emission limits.

Power quality is related to EMC in several ways – especially because compliance with power quality requirements depends on the control of cumulative effect of electromagnetic emissions from all/multiple equipment and/or installations. Therefore, the voltage characteristics given in this document gives guidance for specifying 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.

NOTE 4 This document can be superseded in total or in part by the terms of a contract between the individual network user and the network operator.

The sharing of complaint management and problem mitigation costs between the involved parties is outside the scope of EN 50160.

Measurement methods to be applied in this document are described in EN 61000-4-30.

1.2 Objective

The objective of this document is to define, describe and specify the characteristics of the supply voltage concerning:

a) Frequency;

b) Magnitude;

c) Waveform;

d) Symmetry of the line voltages.

This document also covers the continuous characteristics of the supply voltage and other foreseeable phenomena which may influence the voltage characteristics, such as e.g. operational communication, monitoring or measurement signals which are transmitted via power lines.

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 values given in this document for 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 document for the voltage characteristics associated with such phenomena, e.g. voltage dips and voltage interruptions, are interpreted accordingly.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 61000-4-30:2015, *Electromagnetic compatibility (EMC) — Part 4-30: Testing and measurement techniques — Power quality measurement methods (IEC 61000-4-30:2015)*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Electric power network

3.1.1
public electric power network
electric power network to which any network user has access, and which is operated by a regulated (licenced) network operator

3.1.2
closed distribution network
system which distributes electricity within an industrial, commercial, or shared service or residential sites, that is geographically confined

Note 1 to entry: Closed distribution networks may be private networks.

[SOURCE: Directive 2009/72/EC, Article 28, modified].

3.1.3
point of supply POS
supply terminal
point in an electric power network designated as such and contractually fixed, at which electric energy is exchanged between contractual partners

[SOURCE: IEV 614-01-02]

Note 1 to entry: In practice it is the location of the interface between the public supply network and a closed distribution network or a network user. The characteristics of the voltage that a network user can expect according to EN 50160 apply at the Point of Supply (supply terminals).

3.1.4
point of connection POC
reference point on the electric power system where the user's electrical facility is connected

[SOURCE: IEV 617-04-01]

Note 1 to entry: In some regions the point of supply (supply terminals) is labelled as the point of connection (POC). In practice, the connection to a power system can be one to the public supply network or in some cases to a closed distribution network one. It is worth noting that many standards use the term "point of connection" generally for an interface which is dealt with in the relevant context of the standard.

3.1.5
network operator
party responsible for operating, ensuring the maintenance of, and if necessary, developing, the supply network in a given area and responsible for ensuring the long term ability of the network to meet reasonable demands for electricity supply

3.1.6
(power) network user
party being supplied by or supplying to an electricity supply network

Note 1 to entry: In several countries, the term network user includes network operators connected to a supply network with the same or higher voltage level.

3.1.7
power quality PQ
characteristics of the electricity at a given point on an electrical system, evaluated against a set of reference technical parameters

Note 1 to entry: These parameters might, in some cases, relate to the compatibility between electricity supplied on a network and the loads connected to that network.

Note 2 to entry: In the context of this document, power quality refers to the supply terminals and focusses on defining the characteristics of the voltage and frequency.

3.1.8
conducted disturbance
electromagnetic phenomenon propagated along the line conductors of a supply network

Note 1 to entry: 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.

3.1.9
normal operating condition
operating condition for an electricity network, where load and generation demands are met, system switching operations are made and faults are cleared by automatic protection systems, in the absence of exceptional circumstances

Note 1 to entry: Frequent examples of exceptional circumstances are:

- temporary supply arrangement;
- in the case of non-compliance of a network user’s installation or equipment with the relevant standards or with the technical requirements for connection;
- exceptional situations, such as:
  - 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.

3.1.10
supply interruption
condition in which the voltage at the supply terminals is lower than 5 % of the reference voltage

Note 1 to entry: Classification: a supply interruption can be classified as prearranged, when network users are informed in advance, 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 3 min).

— a short interruption (up to and including 3 min).

Note 2 to entry: Normally, interruptions are caused by the operation of switches or protective devices.

Note 3 to entry: The effect of a prearranged interruption can be minimized by network users by taking appropriate measures.

Note 4 to entry: Prearranged interruptions are typically due to the execution of scheduled works on the electricity network.

Note 5 to entry: Accidental supply interruptions are unpredictable, largely random events.

Note 6 to entry: For polyphase systems, an interruption occurs when the voltage falls below 5 % of the reference voltage on all phases (otherwise, it is considered to be a dip).

Note 7 to entry: In some countries, the term Very Short Interruptions (VSI) or transitory interruptions are used to classify interruptions with duration shorter than 1 s to 5 s. Such interruptions are related to automatic reclosing device operation.

Note 8 to entry: This point can differ from, for example, the electricity metering point or the point of common coupling.

3.2 Reference voltages and frequency

3.2.1
extra high voltage
EHV
voltage with a nominal rms-value 150 kV < U_n ≤ 800 kV

3.2.2
high voltage
HV
voltage with a nominal rms-value 36 kV < U_n ≤ 150 kV

3.2.3
medium voltage
MV
voltage with a nominal rms-value is 1 kV < U_n ≤ 36 kV

3.2.4
low voltage
LV
voltage with a nominal rms-value is U_n ≤ 1 kV

3.2.5
nominal voltage
$\boldsymbol{U_n}$
voltage by which a supply network is designated or identified and to which certain operating characteristics are referred

3.2.6
supply voltage
rms-value of the voltage at a given time at the supply terminal, measured over a given interval

3.2.7
declared supply voltage
$\boldsymbol{U_C}$
supply voltage agreed by the network operator and the network user

Note 1 to entry: Generally declared supply voltage U_c is the nominal voltage U_n but it may be different according to the agreement between the network operator and the network user.

3.2.8
reference voltage
value specified as the base on which residual voltage, thresholds and other values are expressed in per unit or percentage terms

Note 1 to entry: For the purpose of this document, the reference voltage is the nominal or declared voltage of the supply system.

Note 2 to entry: This term is used in relation to interruptions, voltage dips and voltage swell evaluation.

3.2.9
frequency of the supply voltage
repetition rate of the fundamental wave of the supply voltage measured over a given interval of time

3.2.10
nominal frequency
nominal value of the frequency of the supply voltage

3.3 Phenomena

3.3.1
voltage variation
increase or decrease of rms-voltage normally due to load variations

3.3.2
voltage fluctuation
series of voltage changes or a cyclic variation of the voltage envelope

[SOURCE: IEV 161-08-05, modified]

3.3.3
rapid voltage change
single rapid variation of the rms-value of a voltage between two consecutive levels which are sustained for definite but unspecified durations

Note 1 to entry: For more information see EN 61000-3-3 and EN 61000-4-30.

3.3.4
flicker
impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time

[SOURCE: IEV 161-08-13]

3.3.5
flicker severity
intensity of flicker annoyance 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 twelve P_{st}-values over a two-hour interval, according to the following expression

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

3.3.6
harmonic voltage U_h
sinusoidal voltage with a frequency equal to an integer multiple of the fundamental frequency of the supply voltage

Note 1 to entry: Application: Harmonic voltages can be evaluated individually, by their relative amplitude (u_h) which is the harmonic voltage related to the fundamental voltage U1, where h is the order of the harmonic, or globally, for example by the total harmonic distortion factor THD, calculated using the following expression:

$$THD = \sqrt{\sum_{n=2}^{40} \left(U_h / U_n \right)^2}$$

3.3.7
interharmonic voltage
sinusoidal voltage with a frequency not equal to an integer multiple of the fundamental

Note 1 to entry: Interharmonic voltages at closely adjacent frequencies can appear at the same time forming a wide band spectrum.

3.3.8
voltage unbalance
condition in a polyphase system in which the rms-values of the line-to-line voltages (fundamental component), or the phase angles between consecutive line voltages, are not all equal

Note 1 to entry: The degree of the inequality is usually expressed as the ratios of the negative and zero sequence components to the positive sequence component.

Note 2 to entry: In this document, voltage unbalance is considered in relation to three-phase systems and negative phase sequence only.

[SOURCE: IEV 161-08-09, modified]

3.3.9
voltage dip
temporary reduction of the rms-voltage at a point in the electrical supply system below a specified start threshold

Note 1 to entry: Application: for the purpose of this document, the dip start threshold is equal to 90 % of the reference voltage.

Note 2 to entry: Typically, a dip is associated with the occurrence and termination of a short circuit or other extreme current increase on the system or installations connected to it.

Note 3 to entry: For the purpose of this document, a voltage dip is a two-dimensional electromagnetic disturbance, the level of which is determined by both voltage and time (duration).

3.3.10
voltage dip duration
time between the instant at which the rms-voltage at a particular point of an electricity supply system falls below the start threshold and the instant at which it rises to the end threshold

Note 1 to entry: Application: for the purpose of the standard, the duration of a voltage dip is from 10 ms up to and including 1 min.

Note 2 to entry: For polyphase events, a dip begins when one voltage falls below the dip start threshold and ends when all voltages are equal to or above the dip end threshold.

3.3.11
voltage dip start threshold
rms-value of the voltage on an electricity supply system specified for the purpose of defining the start of a voltage dip

3.3.12
voltage dip end threshold
rms-value of the voltage on an electricity supply system specified for the purpose of defining the end of a voltage dip

3.3.13
voltage dip residual voltage
minimum value of rms- voltage recorded during a voltage dip

Note 1 to entry: For the purpose of this document, the residual voltage is expressed as a percentage of the reference voltage.

3.3.14
transient overvoltage
short duration oscillatory or non-oscillatory overvoltage usually highly damped and with a duration of a few milliseconds or less

Note 1 to entry: 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.

[SOURCE: IEV 604-03-14, modified]

3.3.15
voltage swell
temporary power frequency overvoltage
temporary increase of the rms-voltage at a point in the electrical supply system above a specified start threshold

Note 1 to entry: Application: for the purpose of this document, the swell start threshold is equal to the 110 % of the reference voltage (see CLC/TR 50542-1:2018, Clause 3, for more information).

Note 2 to entry: For the purpose of this document, a voltage swell is a two-dimensional electromagnetic disturbance, the level of which is determined by both voltage and time (duration).

Note 3 to entry: Voltage swells may appear between live conductors or between live conductors and earth. Depending on the neutral arrangement, faults to ground may also give rise to overvoltages between healthy phases and neutral.

3.3.16
voltage swell duration
time between the instant at which the rms-voltage at a particular point of an electricity supply system exceeds the start threshold and the instant at which it falls below the end threshold

Note 1 to entry: Application: for the purpose of this document, the duration of a voltage swell is from 10 ms up to and including 1 min.

3.3.17
voltage swell end threshold
rms-value of the voltage on an electricity supply system specified for the purpose of defining the end of a voltage swell

3.3.18
voltage swell start threshold
rms-value of the voltage on an electricity supply system specified for the purpose of defining the start of a voltage swell

3.3.19
mains communicating system
MCS
electrical system using signals to transmit information on electricity supply systems, either on the public electric power network or within installations of network users

3.3.20
mains signalling voltage
signal superimposed on the supply voltage for the purpose of transmission of information in the public supply network and to network users' premises

Note 1 to entry: Classification: three types of signals in the public supply network can be classified:

— ripple control signals: superimposed sinusoidal voltage signals in the frequency range 110 Hz to 3 000 Hz;

— power-line-carrier signals: superimposed sinusoidal voltage signals in the frequency range 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 General

This clause describes the voltage characteristics of electricity supplied by public low voltage networks. In the following, a distinction is made between

— continuous phenomena, i.e. deviations from the nominal value that occur continuously over time. Such phenomena occur mainly due to load or generation pattern, changes of load or nonlinear loads;

— voltage events, i.e. sudden, and significant deviations from normal or desired wave shape. Voltage events typically occur due to unpredictable events (e.g. faults) or to external causes (e.g. weather conditions, third party actions);

— other phenomena, i.e. phenomena occurring in the presence of mains communicating systems (MCS) and/or equipment using switch-mode technology connected to the grid.

For some continuous phenomena, limits are specified [1] [2]; for voltage events, only indicative values can be given at present (see Annex B).

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.

4.2 Continuous phenomena

4.2.1 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 ± 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 ± 2 %	(i.e. 49 Hz ... 51 Hz)	during 95 % of a week;

[1] For single rapid voltage changes, only indicative values are given for the time being.

[2] For some specific parameters, in some national regulations stricter limits may exist.

50 Hz ± 15 % (i.e. 42,5 Hz ... 57,5 Hz) during 100 % of the time.

NOTE 1 This document defines the frequency range for normal operating conditions. During exceptional conditions wider frequency can apply temporarily in order to maintain the continuity of electricity supply.

NOTE 2 Related monitoring is usually done by the Control Area Operator.

4.2.2 Supply voltage variations

4.2.2.1 Requirements

Under normal operating conditions excluding the periods with interruptions, supply voltage variations should not exceed ± 10 % of the nominal voltage U_n.

In cases of electricity supplies in networks not interconnected with transmission systems or for special remote network users, voltage variations should not exceed + 10 % / - 15 % of U_n. Network users should be informed of the conditions.

The actual power consumption or generation required by individual network users is not fully predictable, in terms of amount and of contemporaneity. Therefore, networks are generally designed on a probabilistic basis. If, following a complaint, measurements carried out by the network operator according to 4.2.2.2 indicate that the magnitude of the supply voltage departs beyond the limits given in 4.2.2.2 causing negative consequences for the network user, the network operator should take remedial action in collaboration with the network user(s) depending on a risk assessment. Temporarily, for the time needed to solve the problem, voltage variations should be within the range + 10 % / - 15 % of U_n, unless otherwise agreed with the network users.

NOTE 1 In accordance with relevant product and installation standards and application of IEC 60038, network users' appliances are typically designed to tolerate supply voltages of ± 10 % around the nominal system voltage, which is sufficient to cover an overwhelming majority of supply conditions. Generally, appliances do not need to be designed to handle wider voltage variations.

NOTE 2 Identification of what is a "special remote network user" can vary between countries, taking into account different characteristics of national electric systems as, for instance, limitation of power on the supply terminal and/or power factor limits.

4.2.2.2 Test method

Under normal operating conditions:

— during each period of one week 95 % of the 10 min rms-values of the supply voltage shall be within the range of U_n ± 10 %; and

— all 10 min rms-values of the supply voltage shall be within the range of U_n + 10 % / - 15 %.

NOTE 1 The percentages above are referred to a measuring period of one week (i.e. to 1.008 intervals of 10 min).

For the evaluation of measurement results, care should be taken of flagged intervals. The data flagged due to interruptions are excluded. The principles for the use of other flagged data are under consideration.

NOTE 2 The test method does not apply in cases of electricity supplies in networks not interconnected with transmission systems or for special remote network users.

4.2.3 Rapid voltage changes

4.2.3.1 Single rapid voltage change

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