PD CLC/TR 50422:2013

BSI Standards Publication

Guide for the application of the European Standard EN 50160

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National foreword

This Published Document is the UK implementation of CLC/TR 50422:2013. It supersedes PD CLC/TR 50422:2003 which is withdrawn.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.

Published by BSI Standards Limited 2013

ISBN 978 0 580 78453 8
ICS 29.020; 71.100.60

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 30 September 2013.

Amendments/corrigenda issued since publication

Date	Text affected

TECHNICAL REPORT
RAPPORT TECHNIQUE
TECHNISCHER BERICHT

CLC/TR 50422

September 2013

ICS 29.020

Supersedes CLC/TR 50422:2003 + corr. Jun.2005

English version

Guide for the application of the European Standard EN 50160

Guide d'application de la Norme Européenne EN 50160

Leitfaden zur Anwendung der Europäischen Norm EN 50160

This Technical Report was approved by CENELEC on 2013-07-22.

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

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Ref. No. CLC/TR 50422:2013 E

Contents

Foreword

This document (CLC/TR 50422:2013) has been prepared by CLC/TC 8X "System aspects of electrical energy supply".

This Technical Report, prepared by TF 8 of CLC/TC 8X/WG 1 "Physical characteristics of electrical energy", is based on CLC/TR 50422:2003 (first edition) [4] and the development having taken place since.

This document supersedes CLC/TR 50422:2003 + corrigendum June 2005.

CLC/TR 50422:2013 includes the following significant technical changes with respect to CLC/TR 50422:2003: this second edition has been extended, with regard to

- the inclusion of high voltage (HV) supply in the Standard,
- the relation between EN 50160 and other standards,
- the choice of power quality (PQ) values and related probabilities,
- actual trends in network use, which might lead to further development of the Standard.

For the purpose of this Technical Report, “the Standard” refers to EN 50160:2010 [8]. Likewise, “the Guide” refers to this Application Guide, CLC/TR 50422:2013.

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.

This document has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association.

Introduction

By its very nature, a standard has to be concise and cannot give a comprehensive background of the subject being dealt with. It was accordingly decided to prepare a guide providing additional information and clarification of the Standard, whose first edition was published in 1994. The recent Application Guide represents the 2nd edition of such a guide, which considers the development of the Standard having taken place since the publication of the 1st edition..

1 Scope

The aim of this Technical Report is to provide background information and explanations on EN 50160 with regard to the history of its development as well as to its correct application.

2 Historical overview of the Standard and its development

2.1 Historical development

The very first document dealing with some set of PQ characteristics – and therefore the origin of a related European Standard some 13 years later – was an article published by the International Union of Producers and Distributors of Electric Energy (UNIPEDE) in their magazine “Electricity Supply”, in May 1981 [32]. Experts of UNIPEDE WG “DISPERT” were commissioned “to define the different kinds of disturbances, which can affect LV distribution voltage, caused by periodical or transient phenomena, resulting in overvoltages, voltage dips, or other kinds of irregularities in the voltage wave”.

This document was prepared on the basis of information collected by European distributors, for the purpose of providing information to network users fed from LV systems and to appliance designers on the actual characteristics of the voltage distributed. It provided information about a set of characteristics:

- being recognised as representing the main irregularities in the LV supply voltage;
- being assumed as covering about 95 % of the cases;
- representing real supply voltage characteristics, to be taken into account at designing electrical and electronic equipment with respect to their undegraded operation on mains supply;
- not intended to represent limit values, but with a view to acceptable values,

distinguished in four groups:

a) (quasi)stationary phenomena, mostly with close relation to 50 Hz:
  - slow voltage variations;
  - frequency variation;
  - unbalance of three-phase voltages;
  - harmonic voltage distortion;
  - sudden voltage changes;
  - DC component;

b) caused by occasional transient phenomena:
  - voltage dips;
  - transient voltage depressions;
  - spikes originating in the operation of electrical equipment;
  - surges of atmospheric origin;

c) ripple control signals (or similar);

d) HF signals.

The existing levels of harmonic distortion, which were later used as the basis for the voltage characteristics of harmonics, were published in 1981 in a paper published by the International Council on Large Electric Systems (CIGRE) [29].

Eight years later, in September 1989, UNIPEDE published document DISNORM 12 [33],

- which kept the main principles of the afore-mentioned document, in particular the consideration of a remaining “low probability – approximately 5 % – to find the characteristics in question”,
- laying down the values of the supply voltage at the supply terminals which may reasonably be expected under the present state of technologies,
- by grouping the considered set of characteristics into the 4 groups:
    1) frequency;
    2) magnitude of the voltage wave;
    3) voltage waveform;
    4) symmetry of the three-phase system.

In 1991, the European Commission (EC) published two Directives that subsequently led to an EC request to CENELEC to work out (a) related standard(s):

i) Directive 85/374/EEC on the liability for defective products [41],

specifying amongst others that “the producer shall be liable for damage caused by a defect in his product”, and that “ ‘product’ includes electricity.”

ii) Directive 89/336/EEC on the electromagnetic compatibility [42];

specifying amongst others that Member states are “responsible for ensuring that electric energy distribution networks are protected from electromagnetic disturbance which can affect them and, consequently, equipment fed by them”.

Additionally, two further aspects as being mentioned in the related Draft request to CENELEC as of 11 January 1991 were to be considered:

I) the development of electronic components in electrical equipment, in particular power electronics which are bringing about a relative deterioration in the quality of “electricity” as a product, while at the same time there is an increase in the level of network users’ requirements;

II) widely varying regulations, specifications or contracts in force in the various Member States from one to another.

The related Draft request to CENELEC required the preparation of (a) European Standard(s)

- giving the physical characteristics [1] of electricity supplied by low, medium and high voltage public distribution networks,
- on the basis of UNIPEDE DISNORM 12 [33],
- by trying to comply with international standards and in particular IEC standards as far as possible.

With involvement of manufacturers, network operators and consultants, CENELEC BT set up BTTF 68-6, whose result, the first edition of EN 50160, was ratified on 5 July 1994 [5]. As a first step, this standard dealt with PQ on LV and MV level (see 2.4).

According to the originally given task of describing physical characteristics of the electricity, the values given in this first edition of EN 50160 [5] represented PQ levels, which can be expected to be present at the supply terminals in Europe.

With the next editions [6] and [7], since the establishment of CLC/TC 8X/WG 1 by CLC/TC 8X (System aspects of electricity supply), EN 50160 experienced some actualisation. Related development was intensified when the Council of European Energy Regulators (CEER) joined this CENELEC work in 2006, leading to the present edition 2010 of EN 50160 [8], which is the base of this Technical Report.

With regard to the quite complex characteristics of electricity, it was deemed necessary to provide explanations to its background as well as to its specifications in more detail. That was done at first by UNIPEDE, who published a first Application Guide to the European Standard EN 50160 in January 1995 [34], followed by a related Eurelectric publication in July 1995 [30]. In 2003, CENELEC published CLC/TR 50422:2003 (edition 1), experiencing one Corrigendum in June 2005 [4].

During a phase of further developing EN 50160, some major changes took place, which were to be considered at related standardisation work.

- Move from the LV nominal voltage 220 V to 230 V U_n, for continental Europe, and from 240 V to 230 V for the UK, according to HD 472 S1:1989 [16]. With consideration of some transition periods, this HD specified the nominal voltage U_n in Europe with 230 V on from 01/01/1996 at latest; for reaching the voltage band of U_n ± 10 %, finally, with corrigendum February 2002 to HD 472 S1:1989, a deadline of 01/01/2009 was specified.
- Extension of CENELEC membership from the National Committees from 18 countries [2] in 1994 to those of 33 countries in 2013 [3].
- Increase of the application of electronic components in electrical equipment and installations and therefore of related emissions into the supply network.
- Increase of the susceptibility of electrical equipment and installations to disturbing voltage components.
- Increase of network users' requirements on power quality.

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[1] Frequency, magnitude of the voltage wave (slow variations of the voltage level, rapid variations of the voltage level, voltage dips, 50 Hz overvoltage, transient overvoltage), harmonics, unbalance, voltage interruptions, signal transmissions through the network.

[2] AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IS, IT, LU, NL, NO, PT, SE

[3] AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR

An important change in the European electricity industry has been the deregulation of the electricity market by introducing open competition for production and sale of electricity while at the same time introducing a natural and regulated monopoly in the form of the electricity network operators. According to European Directive 2009/72/EC [3] the role of national regulatory authorities is amongst others “setting and approving standards and requirements for quality of supply” which has resulted in a stronger engagement of regulatory authorities in power quality issues on national as well as on European level, for example resulting in a cooperation between the European Energy Regulators and CENELEC.

2.2 Structure

On from the very beginning of PQ specifications, i.e. when UNIPEDE published their „Characteristics of the Low Voltage Electricity Supply“ in 1981 [32] and their Application Guide to EN 50160 [34], it was recognised that such specifications would deal with a quite specific product, showing particular characteristics, somehow different from any other product (see 3.7.1). Informative **Annex A** of EN 50160:2010 [8] provides related information in more detail.

Contrary to the primary perception of electricity, which might be described by parameters like continuity, voltage magnitude and frequency, there are lots of PQ characteristics when considering electricity supply in detail. On from the first publications by UNIPEDE, an appropriate choice out of this number of PQ characteristics has been made for being dealt with as the main characteristics of the supply voltage.

Considering PQ phenomena, a classification can be made based on different principles, e.g. on

- the predictability of phenomena affecting the voltage, enabling the specification of definite values for the corresponding characteristics.

  That leads to a classification in definite and indicative values,

- the – more or less, to some degree given – continuity of occurrence of phenomena.

  That leads to a classification in continuous phenomena and in events.

UNIPEDE started with a classification similar to the first example, which was kept for the EN 50160 editions from 1994 to 2007. Table 1 shows the classification as it was used in the first edition of EN 50160 as of 1994.

Table 1 — Classification of PQ phenomena according to EN 50160:1994 [5] – Definite and indicative values

Definite values	Indicative values
Power frequency	Supply voltage dips
Magnitude of the supply voltage variations	Short interruptions of the supply voltage
	Long interruptions of the supply voltage
Rapid voltage changes including flicker severity	Temporary power frequency overvoltages
Unsymmetry	Transient overvoltages
Harmonic voltage	Interharmonic voltage
	Mains signalling voltages on the supply voltage

After edition 2007, the classification of PQ phenomena for EN 50160 has been changed to a distinction between

- continuous phenomena, i.e. deviations from the nominal value that occur continuously over time. Such phenomena occur mainly due to load pattern, changes of load, non-linear loads or distributed generation,

- voltage events, i.e. sudden and significant deviations from normal or desired weave shape which typically occur due to unpredictable events (e.g. faults) or to external causes (e.g. weather conditions, third party actions, force majeure)

See Table 2 for the classification used in the Standard. The classification is independent of the cause of the phenomenon, but continuous phenomena mainly occur due to load patterns, changes in load or non-linear load whereas voltage events typically occur due to unpredictable events (e.g. faults) or to external causes (e.g. weather conditions, third party actions, force majeure).

Table 2 — Classification of PQ phenomena according to EN 50160:2010 [8] – Continuous phenomena and voltage events

Continuous phenomena	Voltage events
Variations in power frequency	Interruptions of the supply voltage
Supply voltage variations	Supply voltage dips
Rapid voltage changes including those resulting in light flicker	Supply voltage swells
Supply voltage unbalance	Transient overvoltages
Harmonic voltage	
Interharmonic voltage	
Mains signalling voltages	

EN 50160:2010 [8] gives limits for most continuous phenomena. No limits are given for single rapid voltage changes and for interharmonics.

Only indicative values for voltage events are given in EN 50160:2010 [8] pending the gathering of additional information from actual measurements and other investigations.

In EN 50160:2010 [8], an Informative Annex provides information about

a) indicative values currently available at a European level for some of the events defined and described in the Standard,

b) the way of using these values,

c) recommendations for the way of collecting further measurement data, in order to allow for comparisons between different systems and for obtaining homogeneous data at a European level.

2.3 New versions of EN 50160. A move towards limits and requirements

As explained in 2.1, the objective for EN 50160 was to establish (a) standard(s) giving the physical characteristics of electricity energy supplied by low, medium and high voltage public distribution networks, similar to the formerly published document DISNORM 12 of UNIPEDE, complying with inter-national standards and in particular IEC standards as far as possible.

When considering the development from the very first UNIPEDE document dated 1981 to the first edition of EN 50160, already some movement in the meaning of values – at least from the chosen terminology – can be recognised. While, considering the cases, where values are specified, except irregularities caused by occasional transient phenomena,

a) the 1981 UNIPEDE document uses wording like “should not differ” (e.g. slow voltage variations), “does not vary by more” (e.g. frequency variation), “values which the distributors endeavour not to exceed” (e.g. harmonics), “are usually …” (e.g. voltage changes)

b) UNIPEDE DISNORM 12 explicitly talks of “values” at the supply terminals, which “are” (e.g. frequency), “is usually” (e.g. unbalance), “will generally be lower” (e.g. 50 Hz overvoltages), represent a “normal limit which may be exceeded” (e.g. rapid variations), figure as “compatibility levels” (e.g. harmonics),

c) EN 50160:1994 – for definite values – uses a somehow more distinct wording, giving information about values which under normal operating conditions are not exceeded with a certain probability, i.e. between 95 % and 100 % of the averaging times during an observation period (see 3.1, 3.2),

all three documents having a really **describing character**.

With the following versions, besides

- the extension of the scope also to HV (see 2.4) and
- the phenomena dealt with
  - in principle (voltage swells on from 2010)
  - in more detail (e.g. voltage dips and swells),

the standard tends to have more and more set limits, with decreasing probabilities of it being exceeded, e.g.

- frequency for systems with synchronous connection to an interconnected system,
- slow voltage variations (drop of exception for remote areas for LV, decrease of residual probability for variations of U_n outside the limits of U_n ± 10 %),

with the increasing meaning of distinct **requirements the network operator shall meet.**

2.4 HV chapter

HV was one of the voltage levels addressed by the European Commission (EC) in their Draft request to CENELEC in 1991. From the practical point of view, at this time – not only but also with regard to the very small number HV customers, compared with MV and, in particular, LV customers – HV appeared as less important for getting a specification of PQ characteristics; following to that, the first edition of EN 50160 was worked out for the voltage levels LV and MV only.

In the meantime, due to liberalisation and, resulting from that, the separation of distribution network operators as well as of generating companies from transmission system operators, for regulatory as well as for contractual purposes the specification of PQ characteristics for the interface to HV systems got some more importance, although the number of related complaints was quite limited. The interface with HV systems concerns different types of network users: large industrial installations, production units and distribution networks. With regard to the lack of related EN 50160 specifications, as a first step related questions were sometimes dealt with by referring to EN 50160 with recommending to apply it using the specifications of the Standard for lower voltage levels, either using the same limits or with some correction made.

After edition 2007 of EN 50160, with due regard to meshed network structures of transmission systems being somehow different from LV and MV networks, it was decided to extend the scope of EN 50160 from LV and MV also to higher voltages. For the purpose of EN 50160, PQ should be described for the supply terminals in public networks but it was decided that single network users connected to EHV should not be covered. As a result, the Scope of EN 50160 got extended to voltages up to 150 kV. Further work on transmission systems and EHV systems was postponed, although being aware of the fact, that PQ in lower voltage levels is also affected by the quality on higher voltage levels.

With regard to

- the before-mentioned differences of HV systems from LV and MV systems
- some open questions of assigning shares of PQ characteristics to the network levels
- the nearly complete lack of standardised electromagnetic compatibility (EMC) specifications for HV (only two IEC/TRs for planning levels for harmonics and voltage fluctuations available)
- the lack of broader experience with PQ on this voltage level in Europe

some specific solutions different from the chapters for LV and MV, have been chosen for providing PQ specifications, e.g.

- due to the limited relevance for this voltage level, no values are given for several phenomena like supply voltage variations, harmonic voltages for the 17th, 19th, 23rd, 25th order, mains signalling voltages
- for several phenomena like harmonics, EN 50160:2010 [8] gives only indicative values; in particular, specification of THD is under further consideration. In the case of complaints, limits for harmonics in HV networks should be chosen on the base of MV network limits, suitably modified by agreement between HV network operator and the connected network user;
- the flicker limit was chosen equal to the LV and MV limit but drawing attention to the uncertainty of transmission coefficients and requiring mitigation measures in case of excession of $P_{lt} = 1$.

Further consideration of PQ specifications for this voltage level is envisaged.

3 The Standard

3.1 General

EN 50160 is a CENELEC Product Standard, which defines, describes and specifies the main voltage characteristics that can be expected at the supply terminals in European public low, medium or high voltage networks. It is not harmonised under any EU New Approach Directive. According to the CENELEC Internal Regulations, the Standard is to be implemented as a national standard in all CENELEC Member countries.

In accordance with the general status of a standard, the specifications given in the main part of EN 50160 are not mandatory by themselves, but can become mandatory by being referred to in a contract between partners, local regulation and also network codes.

The Standard considers the fact that electricity distribution systems have to be developed taking into account

a) the provision of adequate conditions for the operation of network users’ equipment and, at the same time,

b) avoidance of unnecessary increases in the cost of the electricity supply.

An economic [28] balance is to be kept between the costs attributable to creating a more benign environment for the use of equipment connected to the public electricity network and the costs of achieving appropriate emission and immunity of the equipment to the environment in which it is intended to be used.

Initially the costs for creating a more benign environment are borne by the network operator and the costs for achieving appropriately low emission and high immunity are borne by the equipment manufacturer. Often, but not always, those costs are included in the network tariffs and/or in the price of equipment.

Specifications on the voltage quality and different types of deviations from the ideal voltage are given by means of a number of voltage-quality indices related to the point of delivery, with a range of values for a number of phenomena. These values

- are generally higher than the actually occurring values for these parameters in the vast majority of networks. Even at the worst served locations, the value of the voltage quality indices will be below the defined values most of the time. These defined values may be exceeded with a defined small residual probability, as stated in the Standard.

- should not be interpreted as typical values or description of PQ at a certain supply terminal or in a certain network area. Most of the network users receive a PQ far better than specified in EN 50160, i.e. at most locations the value of the voltage-quality indices will always be well below the limits all the time.

- of the 2010 edition of the Standard, with regard to the change of character of the Standard (see also 2.3), represent kind of minimum requirements on the PQ in public European supply networks.

In the Standard all phenomena are equally treated; no attempt is made to rank them related to importance; also with regard to such importance

- being different for different types of network users, and even for different network users of the same type

- being even changing over the years as new types of equipment with different emission and immunity properties are coming on the market.

3.2 Applicability

By its Scope, the Standard is restricted to the electricity supplied at the supply terminals (see 3.4.3), and does not deal with the supply system or the network user´s installation or equipment.

As the Standard is intended to deal only with the characteristics of the voltage at specified points on the public distribution networks, it does not deal directly with the properties of networks themselves, such as short circuit power/network impedance. Clearly, however, the network characteristics will have an effect upon the magnitude of several of the phenomena described by the Standard.

The limits in EN 50160 apply irrespective of the kind of network user, to

- network users only consuming electricity all the time

- network users only producing electricity all the time

- network users consuming as well as producing electricity

However, the technical details of keeping the voltage characteristics within their limits change when large single units or significant numbers of small production units are connected to the distribution network. Although the technical details on how to keep the limits are beyond the scope of EN 50160, the impact of distributed generation is discussed in some detail in **Annex A** of this Application Guide.

According to the task having been assigned to EN 50160 in the early nineties, the applicability of EN 50160 is to be considered with regard to locality, time and the operating conditions on the supply network. Considering this classification, the PQ specifications of EN 50160 relate to

a) **any supply terminal to a network user in European electricity supply networks** (100 % of sites). It does thus not apply

- to any point in the network user's installation,
- to any point in the public supply network that is not itself a supply terminal.

There are several hundred million such points in the present European Union, and each point is unique with respect to the characteristics of the electricity delivered. The characteristics are caused to vary by various actions of the operators of the public electricity networks, and also by the actions of the network users.

Note that network users include also other network operators.

b) **the expectable meeting of the specified values with a defined probability** (x % of time; x close to 100 %) (see 3.7.1)

For the network operator, network users are randomly switching their appliances on and off and changing their operating conditions. Every such action results in a change in the characteristics.

In addition, appliances operated by network users may generate disturbances in the current and inject them on the electricity networks; the result of this is an increased level of voltage disturbances, with possible detrimental effects on some of the voltage characteristics.

Due to the development in equipment technology and the resulting – cumulative – effect of operation equipment of similar technical design to the electricity network, the resulting values of disturbances represent an additional important item to be considered when talking about PQ (see also 4.2.1).

c) **normal operating conditions on the supply network**. This includes also the correct operation of protection devices in the case of a fault in the network (e.g. blowing of a fuse, operation of a circuit-breaker); the operation of loads agreed between network user and distribution network operator and changes in network configuration. Conditions other than the normal operating conditions, and therefore out of Scope of EN 50160, are a rarity.

EN 50160 does not apply under exceptional conditions, for which the Standard lists several specific examples, which

- are beyond the network operator's control and which
- can cause one or more of the characteristics to depart from the values given.

Table 3 gives explanations to examples for exceptional conditions listed in the Standard and their causes.

A specific example would be conditions under which the network operator is prevented from carrying out repair or maintenance work due to weather conditions of extreme severity or duration (long lasting blizzards, flood situations, landslides, extreme wind conditions etc.).

In addition, effects of several types of external events (atmospheric phenomena, construction activities, malicious damage or vandalism, traffic mishaps etc.) impact the PQ. Neither the timing nor effect of such external events can be known in advance. Also equipment failure can result in interruptions of the supply voltage. Whenever the supply is interrupted, the other voltage characteristics lose their technical meaning.

If supply can be maintained to all or as many network users as possible, even at the expense of some temporary deterioration of one or more of the voltage characteristics, for most network users this is normally preferable to an outright interruption.

Table 3 — Exceptional conditions and examples

Exceptional condition	Examples
Extreme weather conditions and other natural disasters	Storm of extreme severity (exceeding the legally required design conditions of the network equipment; when impacting a HV network, the same disturbances are detected on MV and LV networks), land-slides, earthquakes, long lasting blizzards, extremer wind conditions, avalanches, floods.
Third party interference	Intentional damage (sabotage, vandalism, terrorism)
Acts by public authorities	Constraints imposed by government or other public authorities for public safety or environmental concerns, animal protection laws Prevention of the DNO from carrying out necessary alterations to the supply system, by government or other public authorities
Industrial actions (subject to legal requirements)	Withdrawal of labour, strike
Power shortages resulting from external events	Generation restrictions or interruption of transmission lines.
Force majeure	

According to the Scope of the Standard, its specifications may be superseded in total or in part by terms of a contract between an individual network user and the network operator. Such a contract is most likely to arise for network users with relatively large electricity demand, supplied from the MV or HV network. It may also arise in sparsely populated or difficult terrain, such as mountain regions, where supply costs are high. In such an area, a network user may be willing to accept a supply, at lower cost, which does not entirely comply with EN 50160.

Requirements set by a national Regulatory Authority on the PQ as delivered by a network operator can be more stringent than the specifications given by the Standard.

3.3 Covered / Not covered phenomena

The description of electricity as a product is done by means of giving a range of PQ indices at the supply terminal of the network user.

Related to voltage characteristics, EN 50160 covers:

a) the main characteristics (called “phenomena”) of the voltage (at a network user´s supply terminals in public networks for low, medium and high voltage levels). This covers a large part of the electromagnetic disturbances that are present at the supply terminals.

b) limits or values within which the voltage characteristics can be expected;

c) main conditions when the Standard is not applicable.

Some electromagnetic disturbances having gained importance since the publication of the first version of EN 50160 are not covered in the Standard. Some examples are briefly summarised below, in arbitrary order and without indicating their importance:

— interruptions with a duration less than a few seconds are labelled as “transient interruptions”. The reason for this separate label is that their impact on end-user equipment is different, sometimes more severe, from the impact of short interruptions with a longer duration.

— waveform distortion in the frequency range between 2 kHz and 150 kHz is getting increased attention due to a number of reasons. This is discussed in more detail in **Annex B** of this Guide.

3.4 Specific terms

3.4.1 General

Related to voltages, in EN 50160 the following voltage terms are used:

- supply voltage,
- supply terminal / point of delivery,
- nominal voltage U_n,
- declared voltage U_c.

The following explanations should support correct application.

3.4.2 Supply voltage

With regard to the original task given to the Standard, to "*define, describe and specify the characteristics of electrical energy*", the supply voltage should be interpreted here as the actual value of the voltage, waveform or voltage as a function of time, occurring at a network user's supply terminal (see 3.4.3).

Different voltage characteristics (like "*r.m.s. voltage*" and "*total harmonic distortion*") are calculated from this waveform.

The term "*supply voltage*" should not be confused with the voltage being supplied at the load points (see 3.4.3), i.e. inside the network user's installation, for which

- the term "utilisation voltage" is used, e.g. in EN 60038 [11],
- EN 50160 does not set any limits.

Note that the term "*supply voltage*" is also defined in EN 50160 (definition 3.21) as "*r.m.s. voltage at a given time at the supply terminal, measured over a given interval*".

3.4.3 Supply terminal and other reference points

When talking about electricity supply, different points are to be considered as reference points:

a) the point, where electric energy is delivered to the network user's installation or fed into the public supply network by a generator

   For this point, the term

   - "supply terminal" is defined in EN 60038 and EN 50160:

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

- “supply terminal” is also referred to in IEV 617-4-2
- “delivery point” is defined in IEV 601-02-33

  “Interface point between an electric power system and a user of electric energy.

  NOTE The user may be the end user or an organisation for the distribution of electric energy to end users."

EN 50160 defines (3.20 of the Standard) and uses the first-mentioned term, which is also more actual with regard to the consideration also of distributed generators as network users; the voltage characteristics being specified in the Standard are referring to the supply terminals.

For network users in some countries, the “supply terminal” corresponds to the electricity metering point.

b) the “point of a power supply network, electrically nearest to a particular load, at which other loads are, or may be, connected”, called Point of common coupling (PCC), as such defined in IEV 161-07-15.

NOTE The text “may be connected” relates to the study of the impact of future installations on the voltage quality.

Due to an interconnection via a PCC, loads may interact with each other in terms of EMC; the PCC can be far away from the supply terminals for any of these network users.

c) points in a network user’s installation, where electrical equipment is connected to the electricity supply. For such points, the following terms

- outlet
- utilisation point
- utilisation terminal
- equipment terminal
- load point

have been used in the past. Only the last term is used in actual standardisation, i.e. in HD 60364-5-52 [19].

With regard to the impedance of the lines between the supply terminal and a network user’s installation, the voltage characteristics at the load points can differ from those at the supply terminals. Depending on the current, according to HD 60364-5-52, a voltage drop may occur, but can also be negligible.

The change in voltage characteristics between the network user's supply terminal and the load points is also different for different phenomena / electromagnetic disturbances.

3.4.4 Nominal voltage (U_n) and declared voltage (U_c)

Voltage limits or values specified by EN 50160 in percentage terms are based

- on the nominal voltage in the case of low voltage (LV) supply characteristics and
- on the declared supply voltage in the case of medium (MV) and high (HV) voltage.

MV and HV supply networks are sometimes operated with reference to a voltage that differs from the nominal voltage. This is done for example to obtain an average LV supply inside the stated supply voltage range.

3.5 “Measurement according to EN 50160”

EN 50160 specifies the characteristics of the voltage at the supply terminals, but not how to measure values of these characteristics. Specification of related measurement methods can be found in EN 61000-4-30 [15] (see also 4.2.4).

PQ measurements according to the Standard should be performed at the supply terminals in general since that is the point where the Standard relates to and network operators’ contractual commitment ends. On the other hand, voltage events, such as dips and swells, are often more cost-effectively detected at locations in the public electricity supply network other than the supply terminal. The severity and duration at single network users’ supply terminals can then be calculated. The reason for this is mainly the stochastic nature of those events and that the results can be used for more than one network user. When installing measurement apparatus it is normal practice to do so in high and medium voltage stations in order to cover as large an area as possible.

3.6 Averaging times, observation periods

Regarding continuous phenomena, voltage variations that occur continuously over time, the limits in the Standard require that the observation period should be at least one week in order to take account of variation in loads.

For voltage events such as voltage dips and voltage swells a relatively long period of measurement is needed. Depending on the wanted level of statistical accuracy, this period can vary from a single season of a year to several years. It should also be recognised that measurement is not always the most suitable method, in which case a stochastic prediction could be considered.

As mentioned before, the voltage characteristics are determined from the measured waveform of the supply voltage, using methods defined in EN 61000-4-30 [15].

Measurement of most continuous phenomena require an averaging window. Both regarding the actual calculation of the voltage (it makes for example no sense to determine the amplitude of the voltage waveform over a period much less than 20 ms) and for the sake of comparability between results at different points in time. When determining the timescale to be used as an averaging window one shall take into account that the shorter the averaging window used the bigger the impact of single events, such as individual load switching and faults, will have on the results. On the other hand, these events are part of the overall voltage characteristics and should as such impact the measurement result; therefore, the averaging window shall not be too long.

A balance needs to be found, and in the case of this Standard, the 10-minutes-averaging time proposed in the measurement standard EN 61000-4-30 is used. EN 61000-4-30 allows for the use of shorter time windows (10 cycles; 150 cycles), but these are not used in the Standard.

Decreasing the width of the averaging windows, e.g. by reducing its width from 10 min to a lower value, does not influence the PQ situation on a supply network. However, it results into the need for the choice of higher maximum values and lower minimum values in order to represent the same PQ.

The reason behind the 10-minute averaging window is the expected time for the utility to effectively control the voltage, which is typically in the range from 3 min up to 5 min. Since this voltage regulation is done by means of on-load tap changers at the substations, faster phenomena caused by sudden load changes cannot be counteracted. In order to keep these voltage variations under reasonable limits, standard or specific compatibility requirements are placed on consumers and generators.

Exceptions represent rapid voltage changes leading to flicker, where a measurement window of 2 h is used to calculate the long-term flicker severity, power frequency (10 s) and mains signalling voltages (3 s).

It is also important to note that certain fast PQ phenomena, such as voltage dips, may distort some aggregate variables even if the average window is much longer. That is the case of short-term flicker, which is seriously affected by the occurrence of voltage dips during its calculation period. In that case, it is important to flag those windows so they can be properly analysed.

3.7 PQ values & test methods

3.7.1 Probability factors

Considering the original task having been given to EN 50160 (see 2.1), the values given in the Standard were not to be taken as limits in the real sense of the term, i.e. as a value not to be exceeded in any case.

When setting values for characterising the quality of the supply voltage, i.e. when establishing the set of reference technical parameters mentioned in the definition of PQ (see 3.7.2), the occurrence of the voltage at a supply terminal is to be considered and evaluated.

Electricity is energy in a particular form, not a concrete substance or object. It is produced from primary energy sources at many generating stations and delivered via a large and complex system of public transmission and distribution networks to individual network users, each of whom has a private distribution system to deliver it to the final points at which appliances convert it for such purposes as lighting, heating, motive power and the many electronic applications used in modern society. Its 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, and therefore under continuous change over the whole of that complex network, both public and private.

The voltage delivered to any supply terminal is the cumulative result of the current flow in a succession of circuits on the transmission and distribution networks. It is a function of two basic variables,

1) the impedance of the circuit

2) the current flowing on it

and of external influences including external power sources (e.g. distributed generation).

Only the first-mentioned one, the impedance, can be controlled, and that control extends mainly to

- selecting the conductor when constructing the circuit
- changing configuration/topology of electricity networks with new network developments.

The current at any instant depends on what appliances are in use at that instant by the particular group of users served by the circuit concerned as well as the additional power sources put in place, such as distributed generation.

With regard to the particular versatility and adaptability of electricity, in the former UNIPEDE documents [32] and [33] – indicating a probability of 95 % – as well as in EN 50160 up until now, the given task has been managed by assigning some probability factors to the specified values for PQ characteristics, giving information with which probability of time (related to averaging times and observation periods) a specified value is expected as not being exceeded.

With reference to the given complexity of setting values for PQ characteristics and some uncertainties in interpreting it, the following can be stated:

a) Choice of values and probability factors:

   Load forecasts enable network operators to predict currents in a given circuit with a reasonable degree of confidence. Based on these predicted loads, suitable conductors are chosen in order to keep the individual line loadings and node voltages within the design tolerances. However, because the prediction itself is subject to a certain probability the predicted values can occasionally be exceeded.

b) Duration of exceeding specified values

A figure is assigned to the probability of the particular PQ characteristic not being within the defined values within the defined observation period.

Application of such defined residual probabilities on a higher number of succeeding observation periods of PQ measurement could result in unacceptable impacts on electrical equipment and is not intended when specifying such residual probabilities.

c) Alterations of PQ values or probability factors

When considering a change of specified values for PQ characteristics, to more restrictive ones the resulting declination of the confidence level or the incurrence of expenditures on network reinforcement to support a more conservative prediction of current levels were to be taken into account.

Likewise, when considering a reduction of a specified rest probability for exceeding specified PQ values, the need for additional investment in network reinforcement or a change of the load profile were to be taken into account.

The choice of, for example, a 95 % level is of concern for a small number of network users only, as is illustrated in Figure 1. The figure shows how often a disturbance level is below the threshold. As an example, consider the fifth harmonic voltage and a threshold equal to 6,0 % U_n (Table 1, Section 4.2.6 in the Standard).

The design principles for the electricity network are such that most network users experience a fifth harmonic voltage that is always less than 6 % U_n. Only for a small number of network users, this limit is occasionally exceeded, but even for those network users the fifth harmonic voltage is less than 6 % for at least 95 % of the time.

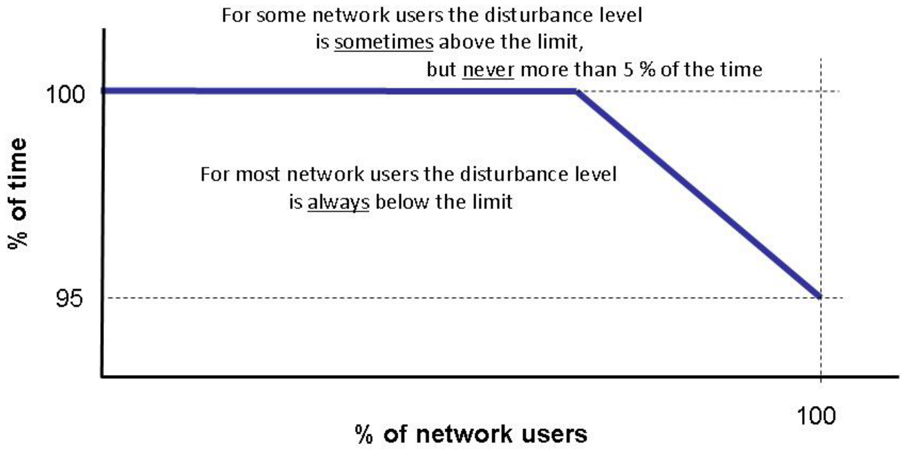


Figure 1 — Percentage of time that a disturbance level is below the limit, for different network users

The size of the triangle in the figure differs strongly between network operators depending amongst others on the customer density, but for almost all network operators this concerns only a small fraction of network users. Network operators' design methods aim at keeping the disturbance levels below the limits all of the time for all network users. There are however sometimes reasons why this cannot be achieved for all network users. In most cases, these are economic reasons, typically for remotely-located network users, but occasionally there are also other reasons.

3.7.2 Verification of compliance with EN 50160

For related tests, several specifications are necessary as concerning classes of measurement performance, measurement uncertainties, measurement aggregation over time intervals, observation periods and flagging concepts for avoiding unreliable aggregated values in case of dips, swells and interruptions.

It is not the task of EN 50160 to define measurement methods for PQ measurement. With regard to that, EN 50160 was complemented by EN 61000-4-30 [15] in 2003 (see also 4.2.3); besides that, with this EN also the first standardised definition for PQ was given:

> *"Power quality: characteristics of the electricity at a given point on an electrical system, evaluated against a set of reference technical parameters.*
>
> *NOTE These parameters might, in some cases, relate to the compatibility between electricity supplied on a network and the loads connected to that network."*

3.8 Rapid voltage changes and flicker

The Standard distinguishes between two types of rapid voltage changes:

a) "single rapid voltage changes" and

b) continuous rapid voltage changes, i.e. "voltage fluctuations" according to the Standard, for which the heading "flicker severity" is used in the Standard (see Figure 2).

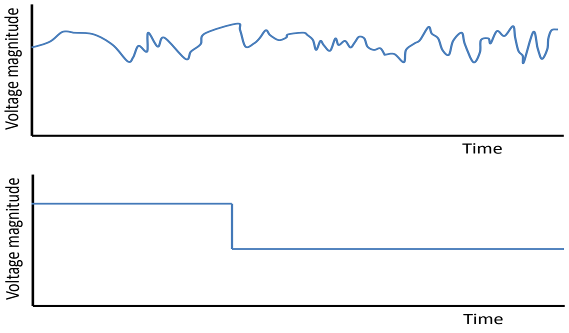


Figure 2 — Continuous rapid voltage changes (top) and an occasional rapid voltage change (bottom)

The term "*rapid voltage changes*" refers to changes in voltage magnitude at a time scale significantly less than 10 min. Changes at a time scale of 10 min and longer are considered under "*supply voltage variations*".

Network users, especially domestic network users typically refer to both continuous and single rapid voltage changes as "flicker" as both impact the light intensity with most types of lighting. The term flicker is however reserved for a physiological phenomenon where an observer notices a non-steadiness in light intensity. This is by definition a continuous phenomenon. Continuous rapid voltage changes at a time scale of a few seconds or less are able to result in disturbing levels of light flicker.

The impact of single rapid voltage changes is a single change in light intensity. This is noticed as a "blink" in the light by human observers. Also voltage dips and swells result in such "blinks" and com-plaints from network users about flicker can therefore be related to different phenomena in the voltage.

There are as yet no common methods for quantifying single rapid voltage changes, but work towards a definition is ongoing in IEC/TC 77A/WG 9 for inclusion in IEC 61000-4-30 / EN 61000-4-30 [15]. The number of such events also varies enormously between network users' supply terminals. It is therefore not possible to give any indicative values for the number of single rapid voltage changes. Upper values for the change in voltage magnitude before and after the rapid voltage change are given in an Informative **Annex B** of the Standard.

The long-term flicker severity has been developed for continuous phenomena, not for events like single rapid voltage changes, voltage dips or swells. It is very important to remove high values of the long-term flicker severity due to rapid voltage changes, voltage dips or swells from the statistics before checking the compliance with the Standard.

The method for calculating the flicker severity, as defined in the flickermeter standard EN 61000-4-15 [14], is based on the impact of voltage magnitude variations on the light intensity of a 60-W-incandescent lamp. The replacement of incandescent lamps with more energy-efficient lighting will require a reconsideration of the flickermeter standard. Energy-efficient lighting is generally assumed to be less sensitive to voltage magnitude variations than incandescent lamps but this does not hold in all cases.

3.9 Voltage dips & swells classification tables

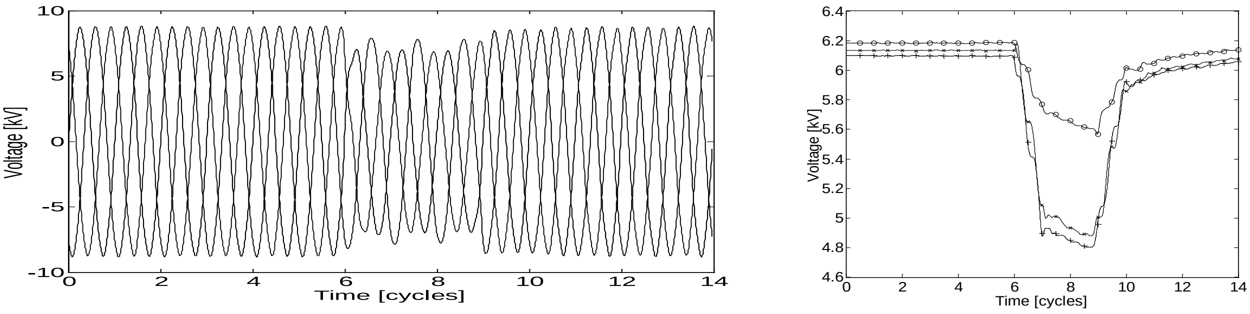
3.9.1 Voltage dips characteristics

A voltage dip is a sudden reduction of the r.m.s. voltage value below 90 % of the reference voltage, followed by a return to a value higher than 90 % of the declared one, in a time varying from 10 ms to 1 min (see also definitions 3.23 – 3.27 of the Standard).

Figure 3 shows a voltage dip, to point out the fundamental parameters by which it is characterised:

- residual voltage (u)
- duration (t).

For a detailed description of voltage dips, reference is made to IEC/TR 61000-2-8 [21] and CIGRE TB 261 [26], for measurement methods to EN 61000-4-30 [15].



a) voltage waveforms **b) r.m.s. voltages vs. time**

The markers in the right-hand figure indicate the one-cycle r.m.s. voltages updated every half-cycle in accordance with EN 61000-4-30.

Figure 3 — Example of a voltage dip

3.9.2 Residual voltage (u)

According to EN 61000-4-30 [15] the depth of a voltage dip should be described by quoting the residual voltage, i.e. the lowest value of the voltage magnitude recorded during the dip, as a % value of the reference voltage. If statistics are collected, voltage dips shall be classified according to the classification tables in EN 50160.

A voltage dip is classified as one event, irrespective of the shape and of the number of phases affected. This is because whilst most industrial and commercial network users receive a three-phase supply, these installations often also contain single-phase equipment, which is sensitive to voltage dips. Three-phase equipment might have different immunity against voltage dips involving one, two, or three of the phase-to-neutral or phase-to-phase voltages.

A multiphase event is considered a single occurrence if the events on the different phases overlap in time.

It is also necessary to make a distinction between a voltage dip and an interruption (absence of supply voltage). For a single-phase supply, an interruption is defined as an event for which the residual voltage is less than the interruption threshold. For a three-phase supply, an event is classified as an interruption when all three (phase-to-phase or phase-to-neutral) voltages are less than the threshold.

If the supply voltage value drops below 5 % U_c (for all three voltages in case of a three-phase supply) the event is considered an interruption, otherwise it is classified a voltage dip. The choice of this threshold is however somewhat arbitrary and other standards documents use threshold values of 1 % or 10 %. What matters however most is not the actual choice of this interruption threshold but ensuring that each event is counted exactly one time.

Causes and effects of voltage dips are described in several reports, books and technical papers, e.g. in the UNIPEDE Report [35].

3.9.3 Duration (t)

From EN 61000-4-30 [15], the duration of a voltage dip is defined as the time interval between when the voltage falls below the dip threshold, until the time when the voltage is equal to or above the dip threshold plus any hysteresis voltage that may be applied. Where hysteresis is a margin applied to measurement thresholds to avoid hunting, when the r.m.s. voltage hovers around the threshold level.

The lower limit for duration is naturally 10 ms (half a 50 Hz cycle), the minimum time period over which an r.m.s. value can be calculated. The upper limit of duration according to the Standard is 1 min, considering effects of load switching.

3.9.4 Voltage-dips statistics

Residual voltage and duration are the characteristics of one individual voltage-dip event. Several or even many of such events, with different characteristics, typically occur at the network user’s terminals during a year. What matters to the network user, and what is thus an appropriate way of quantifying the power quality, is the number of events per year of different characteristics. There are different ways of presenting this, see for example IEC/TR 61000-2-8 [21], CIGRE TB 261 [26] or the forthcoming IEEE Std.1564 [31]. In the Standard it has been decided to use so-called “voltage-dip tables” to quantify this aspect of the voltage characteristics.

An example of a voltage-dip table is shown in Table 4. This table shows the average number of voltage dips per year as obtained from a 6-year measurement in an HV substation. Each of the cells in the table indicates the average number of events per year with residual voltage and duration in the indicated range. There were for example on average 2,0 dips per year with duration between 0,5 s and 1 s and a residual voltage between 70 % and 80 % of the reference voltage. No short interruptions are included in the table; the 0,2 events per year in the bottom row are events for which one or two of the three (phase-to-neutral or phase-to-phase) voltages are less than 5 %.

Table 4 — Example of voltage dip table for HV, values in percent of reference voltage (Recalculated version of [36])

Residual voltage u [%]	**Voltage dip duration [ms]**				
	10 ≤ t < 200	***200 ≤ t < 500***	***500 ≤ t < 1000***	***1 000 ≤ t < 5 000***	***5 000 ≤ t < 60 000***
90 > u ≥ 80	26,6	2,8	1,6	0,4	0,2
80 > u ≥ 70	9,8	0,7	2,0	0	0
70 > u ≥ 40	9,5	0,5	0,2	0	0
40 > u ≥ 5	1,3	0	0	0	0
5 > u	0,2	0	0	0	0

It should be noted that this table serves only as an illustrative example; the values in the table should not be interpreted as typical values. As is shown for example in CIGRE TB 412 [27], the number of dips per year shows a wide variation between different sites. This is an important reason why it is not possible to give more specific indicative values for the number of voltage dips in the Standard.

3.9.5 Voltage-swells characteristics

According to the Standard (see 3.29), a voltage swell or temporary (power frequency) overvoltage, is defined as a temporary increase of the r.m.s. voltage at a point in the electrical supply system above a specified start threshold of 110 % of the reference voltage. Other standards and common literature refer to them as "*power frequency*", "*temporary*" or even "*sustained overvoltages*".

Voltage swells are quantified in a similar fashion to voltage dips, the fundamental parameters being in this case the peak (r.m.s) voltage and the duration. Indicative values about overvoltages on distribution networks can be found in IEC/TR 61000-2-14 [22]. The swells treated in this Standard are between live conductors, for the classification of swells between live conductors and earth, reference can be made to HD 60364-4-442 [17].

Voltage swells statistics

When collecting statistics on voltage swells, they should be classified according to the table in the Standard, also presented below in Table 5. It should be noted the table presented reflects the poly-phase network performance.

Table 5 — Classification of swells according to maximum voltage and duration [36]

Swell voltage *u* %	**Duration *t*** ms		
	10 ≤ *t* ≤ 500	500 < *t* ≤ 5 000	5 000 < *t* ≤ 60 000
u ≥ 120			
120 > *u* > 110			

3.9.6 Transient overvoltages

Transient overvoltages are shorter than voltage swells (less than 10 ms). No limits are given in EN 50160 since they are random and uncontrollable. It becomes a question of sufficient immunity of end-user equipment and protection methods, such as surge arresters.

Transient overvoltages are covered in **Annex C** in more detail.

3.10 Trends

By its nature, a standard needs to further develop, following the development of the environment this Scope stands for.

As examples, in **Annexes A** and **B**, two issues are highlighted which have been getting increasing weight in affecting voltage quality in the recent past and will probably in the near future show an increasing impact:

- distributed generation;

- voltage / current components in the frequency range 2 kHz – 150 kHz.

Further, according to what is said in 2.4 related to the extension of the Standard to HV up to 150 kV, for edition 2010, additional specifications for HV as well maybe further extension of the voltage level up to higher values may be subject to discussion.

4 Position of EN 50160 in the standards scenario

4.1 EMC & PQ. Relationship

EN 50160 concerns the voltage at the supply terminals to a network user. This voltage is determined by voltages and currents at different locations in the electricity supply network as well as by the impedances of components in this network. This holds for the power-frequency (50 Hz) component as well as for all electromagnetic disturbances.

Next to its intended function of transporting electric energy from the generating units to the network users, the supply network also transports electromagnetic disturbances, thus acting as a deliverer of the emissions of all network users' equipment connected to the network (loads, generators), actually of its cumulative effect, to network users. The level of any electromagnetic disturbance at the supply terminals is the sum of the contributions from many different sources. Part of these sources is with the network users, whereas others are within the public electricity supply network. The same holds for the propagation of the disturbances (i.e. the extent to which a source impacts the disturbance level elsewhere in the network): it is impacted by the public electricity supply network as well as by the network users. A further discussion on sources and propagation of electromagnetic disturbances is beyond the scope of EN 50160 and this Application Guide. The reader is instead referred to the technical literature on power quality and on EMC.

The terms "*quality of supply*" and "*power quality*" are used to cover all electromagnetic disturbances (deviations from the ideal voltage waveform) at the supply terminals and elsewhere in the public network and in the internal networks of the network users.

As mentioned before, a (voltage) disturbance includes any deviation from the ideal voltage. The presence of a certain disturbance level is thus not directly a reason of concern. Equipment connected to the electricity supply network (typically inside of a customer installation) is immune up to certain disturbance levels. As long as disturbance levels at the equipment terminals do not exceed the immunity level of the equipment, the equipment will operate normally. Only in case of the disturbance level exceeds the immunity level, the equipment may show an undegraded performance. In such cases, the term "interference" is used.

The actual immunity level of a device depends on a range of factors, including the relative levels of the different electromagnetic disturbances. For example, a device might be immune to a certain amount of harmonic distortion when the voltage magnitude is close to its nominal value but not when the voltage magnitude is significantly above its nominal value. It is therefore practically impossible for an equipment manufacturer to rule out interference with the supply network under all circumstances.

The aim of the IEC and CENELEC standards on EMC is to ensure a high probability that electromagnetic compatibility (the lack of interference) is achieved. This is done by setting immunity requirements and emission limits for equipment in combination with reproducible emission and immunity tests. Although devices are not tested for the actual disturbance levels, the tests are such that passing the tests gives a high probability that the equipment will be immune to the disturbance levels that occur in reality. See, amongst others, IEC/TR 61000-1-1 [20] for a description of the approach used in the EMC Standards.

The setting of immunity requirements is directly linked to the so-called "*compatibility levels*" that indicate the levels for different electromagnetic disturbances that have only a small probability of being exceeded. Once the compatibility levels are known, the immunity limits are set somewhat above the compatibility levels. For public LV electricity supply networks, the compatibility levels are defined in EN 61000-2-2 [12].

Concerning emission limits, the situation becomes more complicated. As mentioned before, the disturbance level at a certain location in the network is determined by emission sources at different locations. It is therefore essential to consider not only one single device, but the cumulative effect of all devices of similar technical construction that might be expected to be connected to a supply network at the same time. The emission limits are set in the EMC Standards such that the combined effect of the emission by all devices, with a high probability, will result in disturbance levels below the compatibility levels.

This is also specifically mentioned in the latest EMC Directive [1], requiring related consideration in standardisation.

Figure 4 shows the principal interdependence between emission, PQ and immunity including the related (series of) standards.

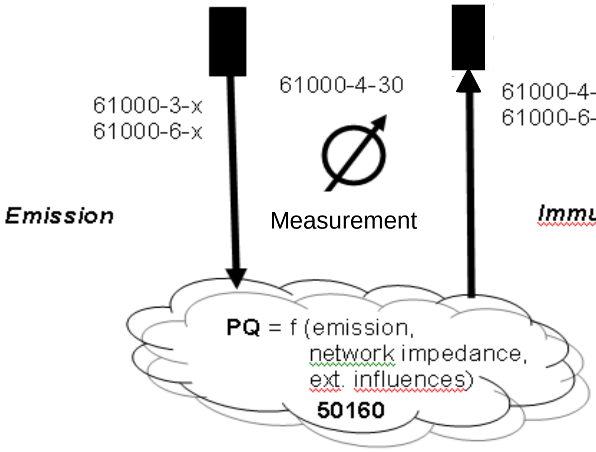


Figure 4 — Interdependence between PQ and EMC

The measured PQ is being determined also by the characteristics of the measurement equipment including the applied measurement evaluation. For PQ measurement, EN 61000-4-30 [15] is available (see 4.2.3).

Compared with PQ, EMC between electrical equipment connected to a supply network is additionally determined by the immunity level of the connected equipment.

4.2 Position to other standards

4.2.1 EMC Standards

As stated in its Scope, EN 50160 is not an EMC Standard and therefore not part of the CENELEC/IEC family of standards on EMC, but it is related to it in a number of ways.

As EN 50160 is not an EMC standard, the limits and indicative values in EN 50160 are

- not intended to be used as EMC levels or user emission limits for conducted disturbances in public distribution systems.
- not intended to be used to specify requirements in equipment product standards, but should be considered. In any case there is to be considered, that the performance of equipment might be impaired if it is subjected to supply conditions which are not taken into account in the equipment product standard.
- not to be taken as requirements for network users´ installations.

Concerning several phenomena, these values are equal or close to those of the compatibility standard, but basically with a different meaning, amongst others also concerning their probability of being exceeded.

Nevertheless, the position of the Product Standard EN 50160 to EMC Standards is of some interest – and impetus for some discussions – also and in particular, whether EN 50160 specifications were in conflict with other (EMC and Product) Standards.

Network user´s installation and equipment connected to this installation can be a source of disturbing interferences, and it is important to keep the level of disturbances within acceptable limits. Therefore, the network operator has to put requirements on the emission from network users' installations.

It has always been an important consideration in the management of the networks to maintain adequate control with respect to network users who operate equipment that is a potential source of disturbances that are injected on to the networks and become part of the characteristics of the electricity delivered to other users. At one time, this was a relatively easy matter to accomplish, since the sources tended to be in large industrial or other installations, which were studied individually by the network operator, with careful planning of their connection to the network. The result of those efforts was that harmonic voltages, for example, were kept to extremely low levels. The electronic developments of more recent decades, however, created a multitude of small devices that cannot be controlled in the same way.

As mentioned in the previous section, the emission and immunity limits in the EMC Standards are based on the choice of a compatibility level, chosen for a related phenomenon. For network operators, being assigned the obligation to comply with the limits set in EN 50160, and striving for that by avoiding unreasonable costs, the emissions from network users' installations needs to be limited.

For large loads, like industrial installations, besides existing standards, local or national grid codes or technical rules are available for assessing the connection of such loads to the supply network, thus ensuring co-existence all devices and systems connected to the mains. Such tools are often based on so-called "*planning levels*" – disturbance levels that should not be exceeded by all loads connected to a certain supply network area. Indicative values for some planning levels are given in three technical reports (IEC/TR 61000-3-6 [23], IEC/TR 61000-3-7 [24], and EN 61000-3-12 [13]).

For smaller network users it is not appropriate to evaluate its connection to the supply network, although it is necessary to ensure that the sum of emissions from electrical equipment connected to a certain supply network area does not exceed values endangering an undegraded performance of the equipment connected. While the disturbance emitted by the individual device is quite small, the impact of the aggregated emission from all such devices can be much larger than the disturbance levels of the large installations that traditionally have been the focus of so much effort by network operators. In fact, by sheer force of numbers and the cumulative effect of mass concurrent operation, these devices now are arguably the most serious source of disturbance on electricity networks. That is particularly the case in regard to the pollution of the networks by unwanted currents and voltages (e.g. harmonics and interharmonics) at several frequencies other than the standard 50 Hz of the public supply.

The only means of controlling disturbances from these sources is the application of effective emission limits in design and construction of electronic equipment. That is particularly necessary for the equipment that uses switched mode power supplies to extract the d.c. supply demanded by such equipment from the 50 Hz a.c. supply provided by the public network.

Over all, the EMC Directive [1] and related harmonised EMC Standards, with consideration of the cumulative effect of loads, are of utmost importance for maintaining the electricity characteristics within the values specified in EN 50160, which today, to some degree, are already far higher than the levels that used to be achieved.

4.2.2 Other product standards

The Product Standard EN 50160 applies to the supply voltage at a supply terminal (see 3.4.3).

A lot of discussions have been led about the relationship between equipment Product Standards and EN 50160.

In fact, electricity supply is connected with some uncertainty of occurrence of PQ phenomena in general and its levels and durations in particular. Specification of immunity requirements aiming at safety and undegraded performance of equipment in 100 % of the cases would imply impracticable and un-economic equipment. On the other side, requirements on network design to support a highest possible PQ level will inevitably lead to financial burdens to all network users for avoiding PQ situations that would seldom affect only a quite minor part of them.

In this quite complex scenario, for a solution of the problem, it needs to find a compromise between the contribution of the providers of electrical equipment on the one side and those of network operators on the other side.

Theoretically, taking into account the task given to EN 50160, specifying of its values cannot be a question of alignment with requirements specified in equipment Product Standards. Basically, apart from any question of safety and of obligations to meet any requirements, the following facts can be stated.

- When thinking about a need for alignment between EN 50160 and equipment Product Standards, the task given to EN 50160 and equipment Product standards is to be considered.
- Compared with the characteristics at the supply terminals and therefore with the values specified in EN 50160, the characteristics of the voltage at the load points is somehow different in general.

EN 50160 provides part of the necessary information about the real conditions being expectable or foreseeable for the operation of electrical appliances by network users, those appliances being subject to the Low Voltage Directive (LVD) [2]; Annex I of the LVD requires protection against hazards arising from "*foreseeable conditions*" and in "*expected environmental conditions*".

Like EMC Standards, Equipment Product Standards with their EMC specifications have some impact on power quality; this is valid for loads as well as for generating units (see also **Annex A** and e.g. EN 50438 [9]).

4.2.3 EN 60038

According to its Scope, EN 60038:2011 [11], also replacing HD 472 S1:1989 [16], specifies standard voltage values that are intended to serve

- as preferential values for the nominal voltage of electrical supply systems, and
- as reference values for equipment and system design.

As said in related notes,

a) the values of nominal voltage (or highest voltage for equipment) specified EN 60038 are mainly based on the historical development of electrical supply systems throughout the world, since these values turned out to be the most common ones, and have achieved worldwide recognition,

b) the voltage ranges mentioned in EN 60038 have been recognised to be the most appropriate ones as a basis for design and testing of electrical equipment and systems,

c) it is nevertheless the task of system and product standards to define appropriate testing values, testing conditions and acceptance criteria.

The only relation with EN 60038 is that EN 50160 as well as other product standards for equipment to be used in LV systems is using the EN 60038 nominal voltages as reference.

4.2.4 EN 61000-4-30

EN 50160 states in its Scope that "*Measurement methods to be applied in this standard are described in EN 61000-4-30*".

While EN 50160 and EN 61000-4-30 are dealing with the most essential phenomena to be considered related to PQ, the phenomena dealt with in EMC Standards and Product Standards – as far as related to EMC properties – are, representing an identical subset of those ones dealt with in EN 50160 in general.

Where it concerns continuous phenomena, the measurement methods are well-defined in EN 61000-4-30, with the exception of single rapid voltage changes and mains signalling voltages. As for single rapid voltage changes there are only indicative values given, this does not impact the applicability of EN 50160. For mains signalling voltages, limits are given in EN 50160, but as yet they are very rarely applied. Where EN 61000-4-30 defines different averaging windows (from 10 cycles of the power frequency up to 2 h), EN 50160 clearly defines the averaging window, in most cases 10 min.

The averaging windows and observation periods stated by EN 50160 (see also **3.6** and **3.7** of this Guide) should be used to verify the voltage characteristics at the supply terminals of network users.

Where it concerns voltage events, the measurement methods are well defined in EN 61000-4-30 for voltage dips, swells and interruptions, but not for transient overvoltages.

In EN 61000-4-30, the “*flagging concept*” has been introduced to mark the values for continuous phenomena obtained over averaging windows during which an event occurs. These flagged values should be handled with care: some ones should be processed as normal ones; others should be removed from the statistics.

It should be also noted that the flagging concept as defined in EN 61000-4-30 only covers flagging due to voltage dips, swells and interruptions. But also transients and single rapid voltage changes might result in values for continuous phenomena that should be removed from the statistics.

Annex A
(informative)

Distributed generation and its impact on the supply voltage

EU energy policy is strongly promoting the increased use of distributed generation (DG) systems primarily based on renewable energy sources like wind, solar, thermal, hydropower, biomass, etc. into the electricity networks. Thus, grids will have to accommodate an increasing number of DG-sources.

Increasing amounts of distributed generation can impact the quality of supply experienced by other network users in a number of ways. Examples being discussed in several publications include amongst others harmonic emission and resonances, increased level of flicker and single rapid voltage changes, an increased number of interruptions due to incorrect operation of the protection and component overload, and an increased risk of too high supply voltage magnitude. Some impacts are local, others are global; some impacts are minor and occur only for extreme locations, other impacts are major and more general. For a complete overview, including discussions on the amount of distributed generation that can be connected without reducing the quality of supply for other network users to unacceptable levels, the reader is referred to the extensive literature on this subject.

The presence of DG impacts the flow of active and reactive power, which impacts the magnitude of the supply voltage. Already small amounts of DG can result in a voltage magnitude close to or above the overvoltage limit.

The magnitude of the supply voltage depends on the structure and the impedances of the lines, cables and transformers of the network and on the active and reactive power flows. Throughout the power network supply voltage variations are kept within a definite range by means of

- on-line tap changers located on the high voltage side of the HV/MV transformers, to maintain the voltage at the main bus in the MV network at a fixed level,
- adjustment of the transformation ratio of the MV/LV transformers, so as to partly compensate for the voltage drop along long LV- or MV- lines and cables,
- limitation of the length of cables and lines and limitation of the amount of load per cable or line.

Typically, worst-case conditions are considered: without DG, this is maximum consumption and minimum consumption. With DG-supply, the worst-case conditions are DG operating at full capacity whilst local consumption is at a minimum and no DG-supply at maximum consumption. The risk for overvoltages is biggest in rural areas where supply voltage variations tend to be the most significant

Both design and operation of a distribution network has to ensure that the supply voltage magnitude remains above the undervoltage limit during maximum consumption and below the overvoltage limit during minimum consumption. The presence of DG results in a reduction of the active power flow during minimum consumption or even a reversed power flow. The result is a rise in the maximum value of the supply voltage magnitude and thus an increasing risk that the overvoltage limit is exceeded.

This is schematically illustrated in Figure A.1 below:

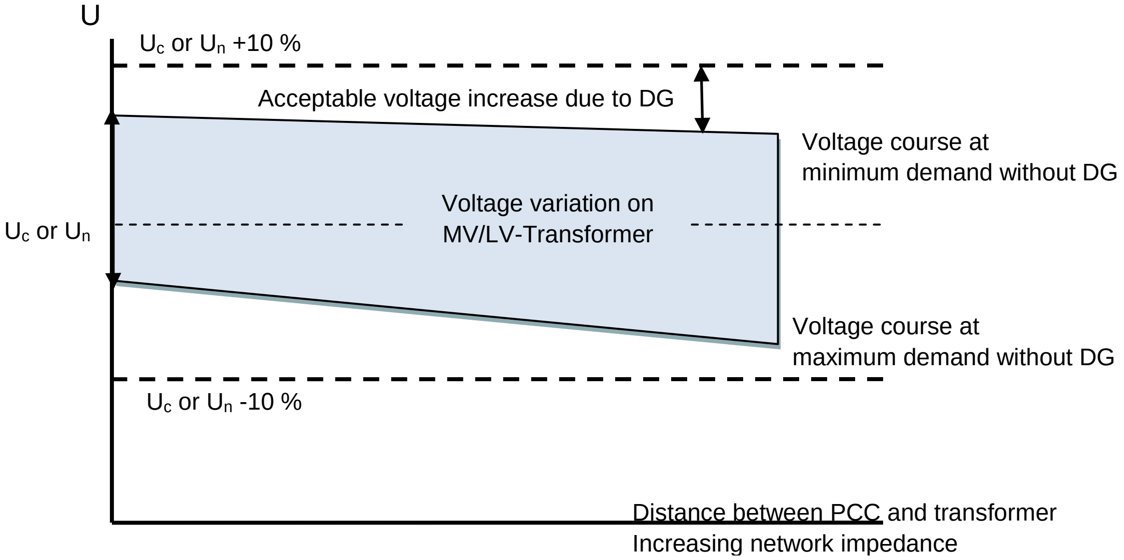


Figure A.1 — Exemplary schematic diagram for the voltage conditions on an MV or LV line with regard to the presence of DG

Due to the presence of MV/LV transformers, with different transformation ratio, the actual situation is somehow more complicated than illustrated in the figure. As a result, an overvoltage can occur for LV network users due to DG at MV level without the voltage at MV being outside of their acceptable limits. The situation gets even more complicated due to the requirement to be able to operate important parts of the distribution network through a backup supply during longer outages of a line, cable or transformer.

Several methods for addressing this issue are available and more ones are being developed or studied; further discussion on these methods is beyond the Scope of this Application Guide.

Literature: [39], [40]

Annex B
(informative)

Voltage / current components in the frequency range 2 kHz – 150 kHz and its impact on the supply voltage

Electromagnetic disturbances in the frequency range 2 kHz – 150 kHz [2] are gaining increasing attention due to a number of developments.

a) An increasing number of devices that emit currents in this frequency range: these are mainly devices with so-called “active power factor correction” aiming at a reduction of low frequency emission causing a wave-form distortion at higher frequencies.

b) The application of power-line communication in the frequency range from 3 kHz to 95 kHz, today also in combination with remotely-read meters, and other communication between network users and the electricity network operator and markets.

c) The recognition of lacking coverage of the frequency range 2 kHz – 150 kHz in standardization.

Emission in this frequency range and its resulting impact on electricity supply networks has not yet been fully mapped and investigations are ongoing at different locations. Preliminary studies indicated that the following sources of emission can be distinguished at the terminals of network users’ equipment:

- narrow-band emission at individual frequencies due to switching frequencies used in active power electronic devices or internally in the device. This emission can further be amplified by resonances between neighbouring devices;

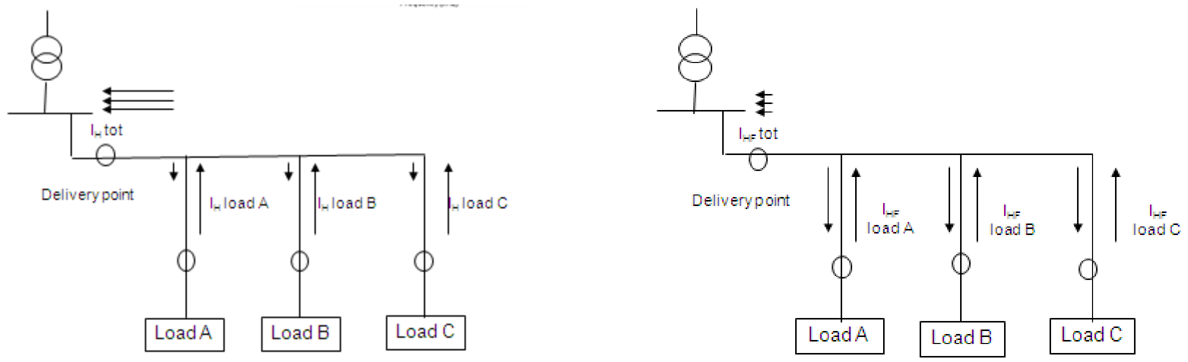
- apparent broadband emission due to fast-varying switching frequencies. Several of the control algorithms used for active power-factor correction results in such emission;

- oscillations of relatively low frequency (several kHz) occurring at specific locations of the voltage or current waveform, e.g. at the zero crossing.

For electromagnetic disturbances in the frequency range between 2 kHz and 150 kHz, the interaction between devices plays a much bigger role than for lower frequencies. As a result of this, the emission of a complete installation (e.g. a domestic network user or a shop) into the public electricity supply network is rather different from the emission due to the individual devices. There are clear indications that the main interaction takes place between neighbouring devices and that only a small part of the emission reaches the public electricity supply network. An exception may be the above-mentioned oscillations of relatively low frequency that have shown to be of additive nature at the terminals of an installation.

In the public electricity supply network, the capacitance of low-voltage cables will have an additional damping effect on the level of disturbances. Nevertheless, no specific studies (neither theoretical nor experimental) have yet been conducted to quantify the spread of electromagnetic disturbances in this frequency range through the public electricity supply network.

The difference in propagation from individual devices to the public network between low and high frequency disturbances is illustrated in Figure B.1. The transition between these two modes of propagation will depend on the specifics of the installation but preliminary studies indicate a transition frequency from less than 1 kHz to about 10 kHz. There is a theoretical possibility of amplification due to resonances at the transition frequency, but experimental results have not found any such amplification yet in low-voltage installations.



a) For low frequencies **b) For high frequencies**

Figure B.1 — Spread of electromagnetic disturbances from individual devices into the public electricity supply network

In larger installations, the situation could be different as large emitting devices could be connected directly to the public electricity supply network. Also are amplifications due to resonances more likely because of the lower amount of damping in such installations. But also here there remains a lack of both experimental as well as theoretical studies.

Related investigations have been started with regard to electromagnetic interference (EMI) cases with automated meter reading systems using PLC for data transmission

- as a source of disturbances to other electrical equipment, due to signal voltages in the frequency range 3 kHz to 95 kHz as being standardised for related appliances

- as a victim of voltage components generated from other electrical equipment, which resulted in degraded performance of the metering equipment, up to not accurately recording the energy flowing

and the results have been published in [25], [37] and [38].

An overview of the interaction and possible interference between power-line communication and end-user equipment is given in Table B.1. The main source of interference, according to experience in Sweden, is type II where end-user equipment creates a low-impedance path for the communication signal.

Table B.1 — Interaction between powerline communication and network users' equipment

	Disturbance	Interference
I	Voltage or current distortion due to net-work user's equipment at frequencies used for communication	The communication signal drowns in the disturbance and the communication does not succeed.
II	The network-user's equipment creates a low-impedance path at the communication frequency.	Only a small amount of the communication signal arrives at the receiver and the communication does not succeed.
III	The communication signal results in large currents through network users' equipment.	Reduction in life-length and incorrect operation of equipment.
IV	Non-linear network user's equipment exposed to the communication signal results in currents at other frequencies.	Any possible adverse impact due to the new frequency components, including interference with communication.
V	Distortion of the voltage waveform due to the communication signal.	Incorrect operation of network user's equipment.

As further investigations show, the automated meter system is only one example of electrical equipment being involved in related electromagnetic interference cases [25]; in case of automated meters, they may figure as a source or a victim of related disturbances.

Indeed, when dealing with such interferences, it appears to be necessary to consider voltage components as they occur when transmitting data via powerline communication, but may be emitted also from certain other sorts of equipment; likewise also other sorts of equipment have been recognised as victims of interferences through such voltage / current components.

Further investigations are under way.

With regard to the proven gap in standardization, considerations on solving the problem have been started, resulting in first proposals for reviewing existing and establishing lacking EMC standards of the EN 61000 series.

Annex C
(informative)

Overvoltages

C.1 Temporary (power frequency) overvoltages between live conductors and earth

C.1.1 General

Faults on the MV network can result in temporary power frequency overvoltages between live conductors and earth on the LV network. The duration and magnitude of these overvoltages is dependent on the fault conditions, particularly the MV earth impedance.

Voltages between active conductors are usually not affected by these temporary overvoltages between live conductors and earth. The presence of a Dy-connected distribution transformer between MV and LV ensures that network user's equipment is not impacted by these overvoltages.

C.1.2 LV distribution systems

The majority of public LV distribution systems are operated with a solidly grounded neutral. Therefore, when ground faults occur on the MV network that raise the ground potential in the vicinity of the LV network an overvoltage may occur between phase and earth (ground) conductors of the LV network. 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. The magnitude is generally limited at 1,5 kV r.m.s., this figure is dependent upon the impedance of the LV ground connection and the magnitude of the MV earth fault current.

C.1.3 MV distribution systems

C.1.3.1 Introduction

Events causing temporary overvoltages on the MV networks are mainly of two types:

a) single line to earth faults,

b) ferroresonance.

C.1.3.2 Overvoltages due to single line to earth faults

In MV networks with isolated or impedance grounded neutral, this kind of fault can produce line to ground temporary overvoltages on the healthy phases. The overvoltage will last for the duration of the fault (from parts of a second up to some hours). The magnitude of the overvoltage does generally not exceed twice the nominal phase to ground voltage, i.e. it is square root of 3 × U, where U can be up to 1,1 × U_n if the voltage is at the maximum of the acceptable MV range.

C.1.3.3 Overvoltages due to ferroresonance

C.1.3.3.1 Introduction

Ferroresonance is a phenomenon associated with the saturation of magnetic cores. The overvoltages that result are not power frequency overvoltages, but are characterised by a heavy distortion due to presence of subharmonic and harmonic voltage components, generally from a few Hz up to 150 Hz.

Ferroresonance is a rare phenomenon compared to single line earth faults. In practice, two conditions might cause this kind of overvoltage in MV networks:

- open conductors;
- grounded voltage transformers in MV networks with an isolated neutral.

C.1.3.3.2 Open circuit condition

This condition stems from one or two-phase open circuits (fuse operation, broken conductors etc.) that remain energised by the healthy phase, via the primary winding of a MV/LV transformer, under light load condition.

Phase to ground overvoltages maximum magnitude is in the range 2,5 - 3 times the nominal voltage with a waveform affected by harmonic distortion (up to 150 Hz). These overvoltages appear only on the particular feeder with the open circuit condition.

C.1.3.3.3 Grounded voltage transformers in isolated neutral MV networks

Line to ground overvoltages appear due to ferroresonance effects if excited by a sudden change in the network condition e.g. fault application/clearing, switching operations, etc.

The overvoltages maximum magnitude is in the range 1,8 - 2,5 times the nominal voltage with a waveform affected by subharmonic and/or harmonic distortion (from a few Hz to 150 Hz); these over-voltages do not affect the line to line voltage.

C.2 Transient overvoltages between live conductors and earth

C.2.1 General

Transient overvoltages present very different characteristics and might be classified in relation to amplitude, frequency of occurrence, duration, surge main frequency, rate of voltage change and energy content. In the following sub-sections, a short description is given of transient overvoltages occurring in LV and MV distribution systems grouped in relation to duration.

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 over-voltage caused by switching, because of the generally longer duration of the latter.

C.2.2 LV distribution system

C.2.2.1 General

Conventionally transient overvoltages are unlikely to exceed 6 kV peak in public networks. Equipment in public networks is generally specified and selected on this basis.

The rise time covers a wide range from milliseconds down to much less than a microsecond.

It should be noted however that equipment’s withstand capability may be different depending on whether we are dealing with safety or just EMC. As long as safety is not compromised, occasional damage of equipment may be allowed. That is the reason why EMC standards do not usually place more than 1 kV or 2 kV for immunity test levels (between active conductors or between active conductors and earth respectively), while HD 60364-4-443 [18] raises those levels up to 2,5 kV, 4 kV or even 6 kV.

C.2.2.2 Long duration surges (> 100 µs)

The origins are mainly:

a) operation of current-limiting fuses (generally: amplitude: up to 2 kV, waveform: unidirectional, high energy levels);

b) switching of power factor correction capacitors (generally: amplitude: up to 1,8 times nominal peak voltage, waveform: oscillatory with frequency in the range a fraction to a few kHz, high energy levels). When there is a second transformer present close to the supply terminals amplification could occur resulting in values up to 3 times nominal peak voltage;

c) transfer of transient overvoltages from MV to the LV of the transformers by electromagnetic coupling (generally: amplitude: up to 1 kV, waveform: oscillatory with frequencies up to a few tens of kHz).

C.2.2.3 Medium duration surges (1 µs to 100 µs)

The origin of these overvoltages are mainly related to lightning, typical instances are listed below:

a) a direct lightning strike on the LV line conductors (no controlled surges: amplitude: up to 20 kV, waveform: unidirectional, high energy levels).

b) induction coupling of a lightning strike in the vicinity of a LV line. Generally the amplitude will not exceed 6 kV, but it can be up to 20 kV, the waveform is typically unidirectional and sometimes a unidirectional oscillatory waveform.

c) resistive coupling associated with lightning ground currents flowing in the common earth paths of a network. Generally the amplitude will not exceed 10 kV, the waveform has high energy levels and is typically unidirectional or sometimes a unidirectional oscillatory waveform.

d) transfer of surges from MV to LV by capacitive transformer coupling. Where the surge is due to a direct lightning strike on the MV, this in turn can lead to a rapid drop in voltage caused by the operation of gap-type arresters to clear the fault. The amplitude of the overvoltage on the LV network will generally not exceed 6 kV, typically with a unidirectional or sometimes oscillatory waveform.

e) arcing associated with switching on the LV network can resonate with the natural frequency of the local network. The amplitude of the overvoltage can be up to several times the nominal voltage. The waveform is typically oscillatory and complex with a frequency in the range from a few tens of kHz to 1 MHz.

f) operation of circuit breakers with very short arcing times, < 2 µs. The amplitude is typically up to several times the nominal voltage. The waveform is oscillatory, with a frequency in the range from a few tens of kHz to 1 MHz.

g) operation of switching devices within the customer's installation. These overvoltages generally have a low energy content and attenuate quickly with distance. Typically they will not exceed 2,5 kV.

C.2.2.4 Short duration surges (< 1 µs)

The origins are mainly

a) local load switching of small inductive currents and short wiring (amplitude generally up to 1 kV – 2 kV, oscillatory waveform with frequency from a few MHz to a few tens of MHz);

b) fast transients due to switching in LV by air-gap switches (relays and contactors) giving a succession of clearings and re-ignitions (bursts of surges, one surge: rise time of about 5 ns, duration of about 50 ns).

C.2.3 MV distribution systems

C.2.3.1 Long duration surges (> 100 µs)

These overvoltages are mainly caused by switching events (disconnection of inductive loads with/ without virtual chopping, opening/closing of power factor compensating capacitors with/without restrikes on MV feeders, etc.), fault application, arcing ground faults, and transient overvoltages transferred from the HV to MV winding of the transformer by electromagnetic coupling.

At certain points of the systems the amplitude of these overvoltages is limited by the protection levels of gaps and/or arresters required for insulation coordination (amplitude generally up to 3 - 5 times peak line to earth voltage, oscillatory waveform with frequencies in the range from a few hundred Hz to some hundreds kHz).

C.2.3.2 Medium duration surges 1 µs to 100 µs

The origins are mainly:

a) Induction from lightning strikes in the vicinity of MV lines and less commonly from direct lightning strikes on MV lines. Along the line, the maximum amplitude of these stresses is limited by the clearances of the line; in primary HV/MV substations and MV/LV secondary transformers it is limited by the protection measures, e.g. arc gaps and/or diverters.

b) Circuit breaker operation prone to re-ignition, e.g. vacuum circuit breakers (amplitude depending on protection levels assured by insulation co-ordination; in general up to 8 -10 times the peak value of the nominal voltage, oscillatory waveform with a frequency of a few MHz).

The majority of the stresses are of induced type, the amplitude depending on clearance sparkover voltage and the protection levels ensured by insulation co-ordination, unidirectional waveform some-times oscillatory, the rise time is in the range of 1 µs - 50 µs, with the half value time about 100 µs high energy content.

C.2.3.3 Short duration surges < 1 µs

The origin is mainly due to switching in gas insulated switchgear (GIS) using e.g. SF6. The amplitude of the overvoltage is typically up to a few times the peak value of the nominal voltage.

The waveform is oscillatory with a frequency higher than 1 MHz.

C.3 Temporary (power frequency) overvoltages between live conductors

This duration of overvoltages may last from several seconds up to minutes. Three main causes can be addressed.

a) Incorrect operation of on-load tap changers at substation, giving a rise in voltage from MV down to LV.

b) Loss of neutral within a 4-wire LV supply (3 phases plus neutral). In such a case, up to a complete phase-to-phase voltage may be expected. Causes for this loss may be various, such as simple material degradation or loose bolts between supply terminals and internal wiring. Thus, the fault may be on customer’s private installation.

c) Incorrect connection of mobile generators during controlled island operation of low-voltage networks.

It shall be pointed out that both disturbances may be counteracted close to equipment at LV by using correct protective devices. European Standard EN 50550 [10] gives construction and functional specifications for such devices.

Annex D
(informative)

Abbreviations

BT	Technical Board (of CENELEC)
BTTF	BT Task Force
CEER	Council of European Energy Regulators
CENELEC	European Committee for Electrotechnical Standardization
CHP	Combined heat power
CIGRE	International Council on Large Electric Systems
CLC	CENELEC (European Committee for Electrotechnical Standardization)
DC	Direct current
DG	Distributed generation
DNO	Distribution network operator
DSM	Demand side management
EC	European Commission
ECG	Energie Control GmbH (Austrian Regulator)
EEA	European Economic Area
EEC	European Economic Community
EHV	Extra high voltage
EM	Electromagnetic
EMC	Electromagnetic compatibility
EMI	Electromagnetic interference
EN	European Standard
EU	European Union
Eurelectric	Union of the Electricity Industry
GIS	Gas insulated switchgear
HD	Harmonisation Document
HV	High voltage

IEC	International Electrotechnical Commission
IEEE	The Institute of Electrical and Electronic Engineers
IEV	International Electrotechnical Vocabulary
IT	Information technology
LV	Low voltage
LVD	Low Voltage Directive
MV	Medium voltage
OJ	Official Journal (EU)
PCC	Point of common coupling
PQ	Power quality
RES	Renewable energy source
TC	Technical Committee
TF	Task Force
THD	Total harmonic distortion factor
TOR	Technische und organisatorische Regeln für Betreiber und Benutzer von Netzen (Energie Control GmbH, Austria)
TR	Technical Report
UNIPEDE	International Union of Producers and Distributors of Electric Energy
WG	Working Group

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