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TECHNICAL SPECIFICATION

colour
inside

Assessment of power quality – Characteristics of electricity supplied by public networks

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ASSESSMENT OF POWER QUALITY – CHARACTERISTICS OF ELECTRICITY SUPPLIED BY PUBLIC NETWORKS

FOREWORD

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The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a Technical Specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical Specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62749, which is a technical specification, has been prepared by IEC technical committee 8: System aspects of electrical energy supply.

The text of this Technical Specification is based on the following documents:

Draft TS	Report on voting
8/1512/DTS	8/1524/RVDTS

Full information on the voting for the approval of this Technical Specification can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

This second edition cancels and replaces the first edition published in 2015. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) minimum number of remaining data for weekly analysis,

b) improvement of the compatibility between EN 50160 and IEC TS 62749,

c) further explanation of the conception of daily sliding window,

d) further explanation of the aggregation method used for events,

e) further explanation of the relation between Power Quality and EMC,

f) addition of a new definition of mains communicating system (MCS),

g) addition of a new Annex G: Other phenomena,

h) transfer of the main content of IEC TR 62510 to IEC TS 62749.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

The description of electricity is of fundamental importance within electricity supply systems. In ~~general~~ the past, its characteristics depended less on its generation than on the way in which it ~~is~~ was transported by networks and being used by the equipment of the multiple users. Faults or other events such as short-circuit and lightning strikes occurring within users' installations or public networks also disturb or degrade it.

Nowadays, Smart Grid construction and massive deployment of renewable energy sources increase the complexity of power quality management. For more information about power quality issues related to distributed generation and micro-grids, refer to Annex D.

NOTE For more information about role of stakeholders for power quality management, see Annex H.

There is a need for a common set of power quality (PQ) indices and measurement methods in order to allow different system operators to measure and report power quality in a consistent manner.

Regarding the limits or levels of power quality, the situation differs. Historically, the electrical systems in different countries/regions have been designed in different ways to cater for national/regional variations like different geographic, climatic or commercial conditions, etc. It is thus essential that any set of internationally agreed power quality limits or levels also recognize these differences, which depends namely on the system configuration, the transfer characteristics between the different voltage levels (attenuation or amplification), the actual disturbance levels on the system, etc.

~~Also, the level of power quality is not absolute rather it depends on the price that clients are willing to pay for it. Optimizing power quality should be carried out in a cost-effective manner in that if NETWORK USERs expect power quality to be an intrinsic characteristic of the product they also want it at the lowest price.~~

Also, the quality of power is not absolute. Optimizing power quality should be carried out in a cost-effective manner to balance network user power quality requirements and willingness to pay for it with power quality supply costs.

Therefore, some of the objectives recommended hereafter allow for a range of values, or options, while still ensuring the coordination of disturbance levels between different parts of the system or voltage levels.

Then, the requirements to be applied can be expressed by the association of the IEC Power Quality framework from the normative part of this document and profiles. Examples of profiles are given in Annex A.

ASSESSMENT OF POWER QUALITY – CHARACTERISTICS OF ELECTRICITY SUPPLIED BY PUBLIC NETWORKS

1 Scope

This Technical Specification specifies the expected characteristics of electricity at the ~~SUPPLY TERMINALS~~ point of supply of public low, medium and high voltage, 50 Hz or 60 Hz, networks, as well as power quality assessment methods.

NOTE 1 The boundaries between the various voltage levels ~~may~~ can be different for different countries/regions. In the context of this TS, the following terms for system voltage are used:

- low voltage (LV) refers to $U_N \leq 1$ kV;
- medium voltage (MV) refers to 1 kV $< U_N \leq$ 35 kV;
- high voltage (HV) refers to 35 kV $< U_N \leq$ 230 kV.

NOTE 2 Because of existing network structures, in some countries/regions, the boundary between medium and high voltage can be different.

This document applies to the phenomena listed in Table 1.

Table 1 – Classification of electromagnetic phenomena addressed by power quality indices

Continuous phenomena	Discontinuous phenomena – Events	Other phenomena
FREQUENCY DEVIATION	SUPPLY INTERRUPTION	MAINS COMMUNICATING VOLTAGES
SUPPLY VOLTAGE DEVIATION	VOLTAGE DIP	
VOLTAGE UNBALANCE	VOLTAGE SWELL	
HARMONIC VOLTAGE	TRANSIENT OVERVOLTAGE	
INTERHARMONIC VOLTAGE	RAPID VOLTAGE CHANGE	
FLICKER (VOLTAGE FLUCTUATION)		
~~MAINS SIGNALLING VOLTAGES~~		

NOTE 3 Specification of related measurement methods can be found in IEC 61000-4-30~~, *EMC – Testing and measurement techniques – Power Quality measurement methods*~~.

NOTE 4 Specification of the performance of related measuring instruments can be found in IEC 62586~~, *Power quality measurement in power supply systems*~~.

While power quality is related to EMC in a number of ways, especially because compliance with power quality requirements depends on the control of cumulative effect of electromagnetic emission from all/multiple equipment and/or installations, this document is not an EMC publication (see also Annex F).

2 Normative references

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

IEC 60038, *IEC standard voltages*

IEC 60364-4-44, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*

IEC 60364-5-53, *Low-voltage electrical installations ~~of buildings~~ – Part 5-53: Selection and erection of electrical equipment – Devices for protection for safety, isolation, switching, control and monitoring*

IEC 61000-2-2:2002, *Electromagnetic compatibility (EMC) – Part 2-2: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems*
IEC 61000-2-2:2002/AMD1:2017
IEC 61000-2-2:2002/AMD2:2018

~~IEC TR 61000-2-8, *Electromagnetic compatibility (EMC) – Part 1-8: Environment – Voltage dips and short interruptions on public electric power supply systems with statistical measurement results*~~

IEC 61000-2-12, *Electromagnetic compatibility (EMC) – Part 2-12: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public medium-voltage power supply systems*

IEC TR 61000-2-14, *Electromagnetic compatibility (EMC) – Part 2-14: Environment – Overvoltages on public electricity distribution networks*

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

~~IEC 61000-3-3, *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection*~~

~~IEC TR 61000-3-6, *Electromagnetic compatibility (EMC) – Part 3-6: Limits – Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems*~~

~~IEC TR 61000-3-7, *Electromagnetic compatibility (EMC) – Part 3-7: Limits – Assessment of emission limits for the connection of fluctuating load installations to MV, HV and EHV power systems*~~

~~IEC 61000-3-11, *Electromagnetic compatibility (EMC) – Part 3-11: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems – Equipment with rated current ≤ 75 A and subject to conditional connection*~~

~~IEC 61000-3-12, *Electromagnetic compatibility (EMC) – Part 3-12: Limits – Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and ≤ 75 A per phase*~~

~~IEC TR 61000-3-13, *Electromagnetic compatibility (EMC) – Part 3-13: Limits – Assessment of emission limits for the connection of unbalanced installations to MV, HV and EHV power systems*~~

~~IEC TR 61000-3-14, *Electromagnetic compatibility (EMC) – Part 3-14: Limits – Assessment of emission limits for the connection of disturbing installations to LV power systems*~~

~~IEC 61000-4-7:2009, *Electromagnetic compatibility (EMC) – Part 4-7: Testing and measurement techniques – General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto*~~

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

IEC 61000-4-30:~~2008~~2015, *Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods*

~~IEC 62586-1, *Power quality measurement in power supply systems – Part 1: Power quality instruments (PQI)*~~

~~IEC 62586-2, *Power quality measurement in power supply systems – Part 2: Functional tests and uncertainty requirements*~~

3 Terms and definitions

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

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

NOTE Terms are listed in alphabetical order.

3.1
code ~~(in electric power system)~~
collection of rules concerning rights and duties of the parties involved in a certain part of the electric power system

Note 1 to entry: For example: grid code, distribution code, code in electric power system.

[SOURCE: IEC 60050-617:2009, 617-03-03, modified – "code in electric power system" has been added in the Note to entry]

3.2
connection agreement
agreement entered between the system operator and a system user which governs the procedure and conditions for connection

[SOURCE: IEC 60050-617:2009, 617-04-03]

3.3
declared supply voltage
U_c
supply voltage agreed by the network operator and the network user

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

3.4
electricity
set of the phenomena associated with electric charges and electric currents

~~[SOURCE: IEC 60050-121:1998, 121-11-76]~~

Note 1 to entry: In the context of electric power systems, electricity is often described as a product with particular characteristics.

[SOURCE: IEC 60050-121:1998, 121-11-76, modified – The note has been added]

3.5
electromagnetic environment
totality of electromagnetic phenomena existing at a given location

Note 1 to entry: In general, the electromagnetic environment is time-dependent and its description can need a statistical approach.

[SOURCE: IEC 60050-161:2018, 161-01-01]

3.6
electromagnetic disturbance
electromagnetic phenomenon that can degrade the performance of a device, equipment or system, or adversely affect living or inert matter

Note 1 to entry: An electromagnetic disturbance can be an electromagnetic noise, an unwanted signal or a change in the propagation medium itself.

Note 2 to entry: Electromagnetic disturbance in this TS refers to low frequency conducted phenomena.

[SOURCE: IEC 60050-161:2018, 161-01-05, modified – Note 2 to entry has been replaced and Note 3 to entry has been deleted]

3.7
electromagnetic compatibility
ability of equipment or a system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

[SOURCE: IEC 60050-161:~~1990~~2018, 161-01-07]

3.8
(electromagnetic) compatibility level
specified electromagnetic disturbance level used as a reference level for co-ordination in the setting of emission and immunity limits

Note 1 to entry: By convention, the compatibility level is chosen so that there is only a small probability that it will be exceeded by the actual disturbance level.

[SOURCE: IEC 60050-161:1990, 161-03-10, modified – Note has been shortened and Note 2 has been deleted]

3.9
flagged data
data that has been marked to indicate that its measurement or its aggregation may have been affected by interruptions, dips, or swells

[SOURCE: IEC 61000-4-30:2015, 3.5, modified – modified to better understand this term]

3.10
flicker
impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time

Note 1 to entry: Voltage fluctuation cause changes of the luminance of lamps which can create the visual phenomenon called flicker. Above a certain threshold, flicker becomes annoying. The annoyance grows very rapidly with the amplitude of the fluctuation. At certain repetition rates, even very small amplitudes can be annoying.

Note 2 to entry: For the time being, flicker is qualified based on incandescent lamp's behaviour.

[SOURCE: IEC 60050-161:1990, 161-08-13, modified – Notes to entry have been added]

3.11
flicker severity
intensity of flicker annoyance evaluated by the following quantities:

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

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

Note 1 to entry: For details of P_{st} and P_{lt} , see IEC 61000-4-15.

3.12
frequency deviation
difference between power supply frequency ($f_{H,1}$) and nominal frequency (f_N)

[SOURCE: IEC 60050-614:2016, 614-01-10, modified – "system frequency at a given instant and its nominal value" has been changed to "power supply frequency ($f_{H,1}$) and nominal frequency (f_N)"]

3.13
group total harmonic distortion
THDG (abbreviation)
$THDG_Y$ (symbol)
ratio of the RMS value of the harmonic groups ($Y_{g,h}$) to the RMS value of the group associated with the fundamental ($Y_{g,1}$):

$$THDG_Y = \sqrt{\sum_{h=2}^{h_{max}} \left(\frac{Y_{g,h}}{Y_{g,1}}\right)^2}$$

Note 1 to entry: The symbol Y is replaced, as required, by the symbol I for currents or by the symbol U for voltages.

[SOURCE: IEC 61000-4-7:~~2009~~2002/AMD1:2008, 3.3.2]

3.14
harmonic frequency
$f_{H,h}$
frequency which is an integer multiple of the power supply (fundamental) frequency

[SOURCE: IEC 61000-4-7:~~2009~~2002/AMD1:2008, 3.2.1, modified – "fundamental frequency of the power system" has been changed to "power supply (fundamental) frequency", the formula and Note to entry have been removed]

3.15
harmonic order
h
(integer) ratio of a harmonic frequency ($f_{H,h}$) to the power supply frequency ($f_{H,1}$)

[SOURCE: IEC 60050-161:1990, 161-02-19, modified – "the integral number given by the ratio of the frequency of a harmonic to the fundamental frequency" has been changed to "(integer) ratio of a harmonic frequency ($f_{H,h}$) to the power supply frequency ($f_{H,1}$)"]

3.16
harmonic ratio
HR
ratio of individual harmonic order component (U_h or I_h) to the fundamental component (U_1 or I_1)

3.17
mains communicating system
MCS
system using mains power lines to transmit information signals, either on the public electricity distribution network or within installations of network users

[SOURCE: IEC 61000-2-2 :2002/AMD1:2017, 3.1.8, modified – "electrical" has been deleted]

3.18
mains ~~signalling~~ communicating voltage
signal superimposed on the supply voltage for the purpose of transmission of information in the public supply network and to network users' premises

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

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

3.19
system operator
network operator
party responsible for safe and reliable operation of a part of the electric power system in a certain area and for connection to other parts of the electric power system

[SOURCE: IEC 60050-617:2009, 617-02-09]

3.20
nominal frequency
f_N
value of frequency used to designate or identify a system

3.21
nominal ~~system~~ voltage
U_N
value of voltage used to designate or identify a system

Note 1 to entry: For example: nominal voltage of a system.

[SOURCE: IEC 60050-601:1985, 601-01-21, modified – the abbreviation has been added, "suitable approximate" from beginning of definition has been removed]

3.22
normal operating conditions ~~(of a public electricity supply system)~~
operating conditions of a public electricity supply system typically including all generation variations, load variations and reactive compensation or filter states (e.g. shunt capacitor states), planned outages and planned arrangements during maintenance and construction work, non-ideal operating conditions and normal contingencies under which the considered system has been designed to operate

Note 1 to entry: Normal system operating conditions typically exclude exceptional situations such as: conditions arising as a result of a fault or a combination of faults beyond that planned for under the system security standard, unavoidable circumstances (for example: force majeure, exceptional weather conditions and other natural disasters, acts by public authorities, industrial actions), cases where Network users significantly exceed their emission limits or do not comply with the connection requirements, and temporary generation or supply arrangements adopted to maintain supply to Network users during maintenance or construction work, where otherwise supply would be interrupted.

Note 2 to entry: For example: nominal operating conditions of a public electricity supply system.

[SOURCE: IEC TR 61000-3-6:2008, 3.~~14~~15, modified –"of the system or of the disturbing installation" has been replaced by "of a public electricity supply system", "and planned" has been added to~~ term and definition~~ "arrangements", "or the disturbing installation" has been deleted and "the Note to entry has been slightly changed]

3.23
percentile value
$U_{x\%}$ (symbol)
value such that x percent (x %) of measurements are smaller than or equal to that value, over a given period

3.24
planning level
level of a particular disturbance in a particular environment, adopted as a reference value for the limits to be set for the emissions from the installations in a particular system, in order to co-ordinate those limits with all the limits adopted for equipment and installations intended to be connected to the power supply system

Note 1 to entry: Planning levels are considered internal quality objectives to be specified at a local level by those responsible for planning and operating the power supply system in the relevant area.

[SOURCE: IEC TR 61000-3-6:2008, 3.16]

3.25
point of common coupling
PCC
point in a public power supply network, electrically nearest to a particular load, at which other loads are, or may be, connected

Note 1 to entry: These loads can be either devices, equipment or systems, or distinct network user's installations.

[SOURCE: IEC 60050-161:1990,161-07-15, modified –~~ ("consumer's installation" replaced by "load")~~ "of a power supply network" has been changed to "in a public power supply network", In the first note, "customer's" has been changed to "user's" and Note 2 to entry has been deleted]

3.26
point of supply
supply terminal
point in a distribution or transmission network designated as such and contractually fixed, at which electric energy is exchanged between contractual partners

Note 1 to entry:~~ Supply terminals may~~ Point of supply can be different from the boundary between the electricity supply system and the user's own installation or from the metering point.

[SOURCE: IEC 60050-617:2009, 617-04-02, modified – "or transmission" has been added after "distribution" and "may" has been changed to "can" in the Note to entry]

3.27
~~(power)~~ network user
party supplying electric power and energy to, or being supplied with electric power and energy from, a transmission system or a distribution system

Note 1 to entry: For example: power network user.

[SOURCE: IEC 60050-617:2009, 617-02-07, modified – The note to entry has been added]

3.28
power quality
characteristics of the electricity at a given point on an electrical system, evaluated against a set of reference technical parameters

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

Note 2 to entry: In the context of this Technical Specification, power quality refers to point of supply ~~terminals~~ and focuses on defining the characteristics of the voltage and frequency.

[SOURCE: IEC 60050-617:2009, 617-01-05, modified – "electric current, voltage and frequencies" have been replaced by "electricity", In Note 1 to entry "electric power system" has been replaced by "network" and Note 2 to entry has been added]

3.29
power quality indices
technical parameters characterizing the quality of electricity, measured at a given point, relevant for the assessment of the quality of the electricity delivered by a network operator

3.30
profile
specification that supplements a standard by limiting options, in order to serve the needs of users in a geographic area or in an application domain

3.31
RMS value of a harmonic component
$Y_{\mathrm{H},h}$
RMS value of one of the components having a harmonic frequency in the analysis of a non-sinusoidal waveform. For brevity, such a component may be referred to simply as a 'harmonic'

Note 1 to entry: The symbol Y is replaced, as required by the symbol I for currents, by the symbol U for voltages.

Note 2 to entry: For more details, see IEC 61000-4-7:~~2009~~2002/AMD1:2008.

[SOURCE: IEC 61000-4-7:~~2009~~2002/AMD1:2008, 3.2.3, modified – The three notes have been replaced]

3.32
RMS value of a harmonic group
$Y_{g,h}$
square root of the sum of the squares of the RMS value of a harmonic and the spectral components adjacent to it within the time window, thus summing the energy contents of the neighboring components with that of the harmonic proper

Note 1 to entry: The symbol Y is replaced, as required by the symbol I for currents, by the symbol U for voltages.

Note 2 to entry: For more details, see IEC 61000-4-7:~~2009~~2002/AMD1:2008.

[SOURCE: IEC 61000-4-7:~~2009~~2002/AMD1:2008, 3.2.4, modified – The end of the definition has been deleted]

3.33
RMS value of an interharmonic centred subgroup
$Y_{isg,h}$
RMS value of all interharmonic components in the interval between two consecutive harmonic frequencies, excluding frequency components directly adjacent to the harmonic frequencies

Note 1 to entry: The RMS value of the centred subgroup between the harmonic orders h and $h + 1$ is designated as $Y_{isg,h}$; for example, the centred subgroup between $h = 5$ and $h = 6$ is designated as $Y_{isg,5}$.

Note 2 to entry: For more details, see IEC 61000-4-7:~~2009~~2002/AMD1:2008.

[SOURCE: IEC 61000-4-7:~~2009~~2002/AMD1:2008, 3.4.~~4~~3, modified – "spectral" has been replaced by "interharmonic", the end of the definition has been modified, Note 1 to entry has been modified and Note 2 to entry has been added]

3.34
RMS value of an interharmonic component
$Y_{C,i}$
RMS value of a spectral component of an electrical signal with a frequency between two consecutive harmonic frequencies

Note 1 to entry: For brevity, such a component may be referred to simply as an ‘interharmonic’.

Note ~~1~~2 to entry: For more details, see IEC 61000-4-7:~~2009~~2002/AMD1:2008, 3.4.2.

[SOURCE: IEC 61000-4-7:2002/AMD1:2008, 3.4.2, modified – The second part of the definition has been changed, the second sentence of the definition has been changed to a Note to entry and Note 2 to entry has been replaced]

3.35
rapid voltage change
RVC
quick transition (that may last more than several cycles) in RMS voltage between two steady-state conditions while the voltage stays in-between the thresholds defined for voltage swells and dips (otherwise, it would be considered as a swell or a dip)

~~RVC is expressed by the relative steady-state voltage change and/or by a maximum relative r.m.s. voltage change aggregated over several cycles.~~

Note 1 to entry: For more information, see IEC 61000-4-30.

3.36
recommended values
value under which, or values within which, the voltage characteristics should remain in view of providing an acceptable quality of the electricity supply

Note 1 to entry: The characteristics of electricity agreed between network operator and a network user or set by national/regional regulatory authority can be locally optimized.

3.37
reference voltage ~~**(for interruptions, voltage dips and voltage swells measurement and evaluation)**~~
value specified as the base on which residual voltage, thresholds and other values are expressed in per unit or percentage terms

Note 1 to entry: For example: reference voltage for interruptions, voltage dips and voltage swells measurement and evaluation.

3.38
supply voltage
RMS value of the line-to-line or line-to-neutral voltage at a given time at the point of supply ~~terminal~~, measured over a given interval

3.39
time aggregation
combination of several sequential values of a given parameter (each determined over identical time intervals) to provide a value for a longer time interval

Note 1 to entry: In this document, 3 s value refers to IEC 61000-4-30 150/180-cycle interval aggregation value (150 cycles for 50 Hz nominal or 180 cycles for 60 Hz nominal); 10 min value and 2 h value are also defined in IEC 61000-4-30.

[SOURCE: IEC 61000-4-30:2015, 3.31, modified –Note 1 to entry has been modified]

3.40
total harmonic distortion
THD (abbreviation)
$\boldsymbol{THD_Y}$ (symbol)
ratio of the RMS value of the sum of all the harmonic components ($Y_{H,h}$) up to a specified order (h_{max}) to the RMS value of the fundamental component ($Y_{H,1}$):

$$THD_Y = \sqrt{\sum_{h=2}^{h_{max}} \left(\frac{Y_{H,h}}{Y_{H,1}} \right)^2}$$

Note 1 to entry: The symbol Y is replaced, as required, by the symbol I for currents or by the symbol U for voltages.

Note 2 to entry: For more information, see IEC 61000-4-30:2015, 5.8.1.

3.41
transient overvoltage
voltage surge
transient voltage wave propagating along a line or a circuit and characterized by a rapid increase followed by a slower decrease of the voltage

[SOURCE: IEC 60050-161:1990, 161-08-11]

3.42
voltage deviation
difference between supply voltage (U) and nominal voltage (U_N), often expressed by relative value

Note 1 to entry: In some circumstances, U_N may be replaced by U_c by contract or agreement.

3.43
voltage dip
sudden reduction of the voltage at a point in an electrical system followed by voltage recovery after a short period of time, usually from a few cycles to a few seconds

Note 1 to entry: The starting threshold of voltage dip generally is 90% of reference voltage.

[SOURCE: IEC 60050-161:1990, 161-08-10, modified – "from" has been changed to "usually from" and Note 1 to entry has been added]

3.44
voltage fluctuation
series of voltage changes or a cyclic variation of the supply voltage envelope

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

[SOURCE: IEC 60050-161:1990, 161-08-05, modified ~~(addition~~ –"or a continuous variation of the RMS or peak value of the voltage" has been changed to "or a cyclic variation of the supply voltage envelope" and Note 1 to entry~~)~~ has been modified]

3.45
voltage short time interruption
disappearance of the supply voltage for a time interval whose duration is between two specified limits

Note 1 to entry: A short time interruption is considered to be a reduction of the supply voltage under the interruption threshold (usually 5 % or 10 % of the reference voltage)~~ of the nominal voltage)~~, with the lower limit of the duration typically a few tenths of a second, and its upper limit typically in the order of 1 min (or, in some cases up to 3 or 5 min).

[SOURCE: IEC 60050-161:1990, 161-08-20, modified – Note 1 to entry has been modified]

3.46
voltage swell
sudden increase of the voltage at a point in an electrical system followed by voltage recovery after a short period of time, usually from a few cycles to a few seconds

Note 1 to entry: The starting threshold of voltage swell generally is 110% of reference voltage.

3.47
voltage unbalance
in a polyphase system, a condition in which the magnitudes of the phase voltages or the phase angles between consecutive phases are not all equal (fundamental component)

[SOURCE: IEC 60050-161:1990, 161-08-09, modified –"RMS values" has been replaced by "magnitudes" and "(fundamental component)" has been added]

3.48
voltage unbalance factor
in a three-phase system, the degree of unbalance expressed by the ratio (in per cent)~~ between~~ of the RMS values of the negative sequence component (or~~, rarely, of~~ the zero sequence component~~ and~~) to the positive sequence component of the fundamental component of the voltage

[SOURCE: IEC 60050-614:~~1987~~2016, 614-01-~~30~~33, modified – addition of "voltage" to term, deletion of “or the electric current”]

4 Recommended values for power quality indices

4.1 General

Most of the recommendations for power quality at the~~ SUPPLY TERMINALS~~ point of supply are expressed as power quality indices that describe the manner in which the characteristics of electricity vary. Such variations may appear random in time, with reference to any specific point of supply~~ terminal~~, and random in location, with reference to any given instant of time. As such, the power quality indices are based on the occurrence of the applicable electromagnetic phenomena:

- 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,
- discontinuous phenomena or events, i.e. sudden and significant deviations from normal or desired wave shape which typically occur due to unpredictable events (e.g. faults) or external causes (e.g. weather conditions), and
- other phenomena, i.e. phenomena occurring in the presence of mains communicating systems (MCS) and/or equipment using switch-mode technology connected to the grid. For more information about other phenomena, see Annex G.

The power quality indices and the recommended values are intended to be used as technical reference for regulatory purposes (e.g. in network codes) or for contracts between network operator and network user (e.g. part of a connection agreement).

Power quality requirements combine the obligations of network operators with the requirements of equipment or installations on the electromagnetic environment. It is worth noting however, that the requirements of equipment or installations on the electromagnetic environment also include emission aspects that are addressed in other IEC standards (see Clause 2 and Annex F).

NOTE 1 Network operators are in charge of developing and operating the electricity supply system taking into account at the same time:

- provision of adequate conditions for equipment, installations or other networks connected to their network;
- avoidance of unnecessary costs.

NOTE 2 In many countries/regions, requirements concerning the essential characteristics of electricity at points of supply ~~terminals~~ of public networks are set, or controlled, by National/Regional Regulatory Authorities.

In some cases, additional requirements or differences in requirements can be agreed by terms of a contract (usually a connection agreement) 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, or having power quality sensitive load. It may also arise in sparsely populated or difficult terrain, such as mountain regions, where distribution costs are high. In such an area, a network user may be willing to accept a connection, at lower cost, which does not entirely comply with the power quality standards.

NOTE 3 The quality indices and the recommended values appropriately cover the vast majority of locations under acceptable economic conditions, despite the differences in situations, provided that:

- for mass-market products, emission requirements in standards such as IEC 61000-3-2, IEC 61000-3-3, IEC 61000-3-11 and/or IEC 61000-3-12 are regularly and appropriately updated to take into account the development of markets and changes in technologies;
- for large installations, emission levels are effectively controlled, e.g. through connection agreement (Annex E lists some methods to improve power quality);
- network operators make use of appropriate methodologies and engineering practices, e.g. based on planning levels and IEC TR 61000-3-6, IEC TR 61000-3-7, IEC TR 61000-3-13 and/or IEC TR 61000-3-14.

Regarding phenomena that occur continuously over time, this document provides the recommended or indicative values applicable during normal operating conditions. It considers an observation period of at least one week, e.g. in order to take account for variation in loads.

Measurement of voltage characteristics requires an aggregation time interval for both actual calculation of the voltage and for comparability between results at different points in time. In the case of this document, the 10-minute interval proposed in IEC 61000-4-30 is used for most phenomena.

NOTE 4 In some countries/regions, aggregation time intervals less than 10-minute are used.

NOTE 5 Voltage fluctuation leading to long term flicker and mains ~~Signalling~~ communicating voltage has specific observation period and/or aggregation time intervals.

The versatility and adaptability of electricity are managed by assigning some probability factors to the recommended values for some power quality indices. Percentile values are then compared to the recommended values expected to be statistically fulfilled within the observation periods. The related probability should never be less than 95 %.

Flagging concept is used in this document according to IEC 61000-4-30. Unless otherwise indicated (e.g. for voltage deviation), the flagged data is excluded in the calculation of percentile values.

For the relevance of the result, care should be taken regarding the number of the excluded and missing (for any reasons) data, e.g. for the weekly assessment, if more than 10 % of data are excluded or missing, a specific treatment should be performed. Percent of flagged data should be observed to ensure relevant data are not missed by default flagging.

Network disturbances corresponding to discontinuous phenomena or events shown in Table 1 require a relatively long observation period. Depending on the frequency of their occurrence and the wanted level of statistical accuracy, this period can vary between a single season to several years. These phenomena are mostly unpredictable, which makes it very difficult to give useful definite values for the corresponding characteristics. The values given in this document for the voltage characteristics associated with such phenomena, i.e. voltage dips/swells, voltage interruptions and rapid voltage changes, shall be interpreted as indicative.

For all phenomena, the measurements are performed according to IEC 61000-4-30.

4.2 Frequency deviation

The frequency shall be maintained within a given deviation from the specified value, 50 Hz or 60 Hz, in order to maintain a stable power system operation.

NOTE 1 In different synchronous areas, different requirements ~~may~~ can apply (generally originated from grid codes).

NOTE 2 For systems with no synchronous connection to an interconnected system (e.g. supply systems on certain islands or microgrids in islanding mode), specific requirements can apply.

4.3 Supply voltage deviation

4.3.1 General

~~The voltage deviation values are established according to Standard voltages and voltage ranges defined in IEC 60038.~~

Standard voltages are defined in IEC 60038.

4.3.2 Low voltage systems

For low voltage systems, recommended values are based on nominal voltage (U_N).

Data flagged by voltage dips and swells shall be included in the calculation of percentile values.

NOTE 1 In low voltage systems, declared and nominal voltage are equal.

NOTE 2 The nominal voltage U_N for public low voltage is either between line and neutral or between lines.

Under normal operating conditions, during each period of one week, the 10-minute RMS values of the voltage at the point of supply ~~terminals~~ (U), excluding the periods of interruptions, should comply with the following conditions:

- voltage percentile $U_{\rho\ \%}$ does not exceed $U_N + 10\ \%$;
- voltage percentile $U_{\beta\ \%}$ is not lower than $U_N - 10\ \%$;

  ρ having a value in the range [99, 100] according to national/regional conditions,

  β having a value of 5 or in the range of [0, 1] according to national/regional conditions,
- and, if $\beta > 100 - \rho$, voltage percentile $U_{(100-\rho)\ \%}$ is not lower than $U_N - 15\ \%$.

NOTE 3 The limits of the supply voltage deviation are more restrictive in some countries/regions.

NOTE 4 In some countries/regions, the voltage range can be specified asymmetrically with regard to the nominal voltage, e.g. + 6 % ~ – 14 %.

NOTE 5 Voltage percentile $U_{100\ \%}$ is equal to the maximum value, voltage percentile $U_{0\ \%}$ is equal to the minimum value.

4.3.3 Medium voltage systems

Network users with demands exceeding the capacity of the LV network are generally supplied at nominal voltages above 1 kV. This subclause applies to such electricity supplies at nominal voltages up to and including 35 kV.

NOTE 1 Network users ~~may~~ can also be supplied at this voltage level to satisfy special requirements or to mitigate conducted disturbances emitted by their equipment.

For medium voltage systems, recommended values are based on the declared voltage (U_c).

Data flagged by voltage dips and swells shall be included in the calculation of percentile values.

Under normal operating conditions, during each period of one week, the 10-minute RMS values of the voltage at the point of supply ~~terminals~~ (U), excluding the periods of interruption, should comply with the following conditions:

- voltage percentile $U_{99\ \%}$ does not exceed U_c + 10 %;
- voltage percentile $U_{1\ \%}$ is not lower than U_c – 10 %;
- voltage percentile $U_{0\ \%}$ is not lower than U_c – 15 %.

NOTE 2 In some countries/regions, the voltage range can be specified asymmetrically with regard to the declared voltage.

NOTE 3 In some countries/regions, $U_{100\ \%}$ doesn't exceed U_c + 15 %.

NOTE 4 Voltage percentile $U_{100\ \%}$ is equal to the maximum value, voltage percentile $U_{0\ \%}$ is equal to the minimum value.

4.3.4 High voltage systems

This subclause applies to electricity supplies at nominal voltages above 35 kV and not exceeding 230 kV.

NOTE 1 Network users ~~may~~ can also be supplied at this voltage level to satisfy special requirements or to mitigate conducted disturbances emitted by their equipment.

NOTE 2 The number of network users supplied directly from HV networks is limited and normally the supply voltage is subject to individual contract.

For high voltage systems, recommended values are based on the declared voltage (U_c).

Data flagged by voltage dips and swells shall be included in the calculation of percentile values.

Under normal operating conditions, during each period of one week, the 10-minute RMS values of the voltage at the point of supply ~~terminals~~ (U), excluding the periods of interruption, should comply with the following conditions:

- voltage percentile $U_{99\ \%}$ does not exceed U_c + 10 %;
- voltage percentile $U_{1\%}$ is not lower than U_c - 10 %.

4.4 Voltage unbalance

Under normal operating conditions, during each period of one week, the 10-minute RMS value of ~~negative sequence~~ voltage unbalance factor (negative sequence) should be less than or equal to the recommended value for 95 % of the time or more.

For three phase LV, MV, and HV supply system, the negative sequence voltage unbalance factor $\varepsilon(\%)$ recommended value is 2 %.

NOTE In some countries/regions with part single phase or two phase connected network user's installations, an unbalance up to 3 % at the three phase point of supply ~~terminals may~~ can occur.

4.5 Flicker

Under normal operating conditions, during each period of one week, the flicker severity P_{lt} should be less than or equal to the recommended values defined in Table 2 for 95 % of the time or more.

In the case of complaints, the HV and MV limits, and appropriate mitigation measures, shall be chosen in such a way that at LV, the P_{lt} values do not exceed 1.

Table 2 – Flicker severity P_{lt} recommended values

Voltage levels	P_{lt}
LV/MV	1,0
HV	1,0

NOTE 1 The recommended values are based on the effect of voltage fluctuation on classical incandescent lamps. Modern types of lamps ~~may~~ can have different behaviour.

NOTE 2 These limits take into consideration the flicker attenuation from MV to LV and from HV to MV.

4.6 Harmonic and interharmonic voltage

4.6.1 General

Recommended or indicative values are given for individual harmonic voltages, namely harmonic ratio (*HR*), and for total harmonic distortion (*THD*).

Resonances may cause higher voltages for an individual harmonic, however these effects should be controlled whenever they may have an impact on the system or equipment (for main impact of poor power quality, refer to Annex C).

Recommended values (or limits) will be given hereafter for interharmonic voltages as well. However, these limits are not meant to control flicker effects or interference in ripple control systems~~, as those interharmonic levels are under consideration, pending more experience~~.

4.6.2 Low voltage systems

4.6.2.1 Harmonic voltages

Under normal operating conditions, during each period of one week, the voltage percentile $U_{h95\,\%}$ of the 10-minute RMS values of each individual harmonic voltage should be less than or equal to the values given in Table 3.

Table 3 – Recommended values of individual harmonic voltages at the low voltage points of supply ~~terminals~~ for orders up to 50 given in percent of the fundamental voltage U_1

Odd harmonics				Even harmonics	
Not multiples of 3		Multiples of 3 [a]			
Order h	$U_{h95\ \%}$ %	Order h	$U_{h95\ \%}$ %	Order h	$U_{h95\ \%}$ %
5	6,0	3	5,0 (6,0)	2	2,0
7	5,0	9	1,5 (3,5)	4	1,5
11	3,5	15	~~0,5~~ 1,0 (2, 0)	6 … 24	0,75
13	3,0	21	~~0,5~~ 0,75 (1,5)		
17	2,0				
19	1,8				
23	1,5				
25	1,5				
29 ≤ h ≤ 49	2,27 × (17/h) – 0,27	27 ≤ h ≤ 45	~~0,2~~ 0,5	26 ≤ h ≤ 50	~~0,25 × (10/h) + 0,25~~ 0,5

NOTE 1 Where national/regional circumstances make it appropriate, lower limits than the values given in Table 3 can be specified.

NOTE 2 Depending on the type of voltage transformer used, the measurement of high order harmonics could be not reliable; further information is given in IEC 61000-4-30:2015, A.3.3.

[a] Depending on the type of neutral grounding systems and transformer connections in some countries/regions, more triplen harmonics will flow in neutral conductors and ~~may~~ could cause higher harmonic voltages. In these cases, the highest value in brackets in Table 3 should adequately characterize the system harmonic voltages.

The total harmonic distortion (THD) of the supply voltage for harmonic orders up to 50 should be less than or equal to 8 %.

NOTE In some countries/regions, orders up to 40, only, are used to calculate the THD, maintaining the same recommended value.

4.6.2.2 Interharmonic voltages

The same statistical approach and the same range of values (see Table 3) should apply to harmonic (centred) group voltages as to individual harmonic voltages from ~~the previous section~~ Subclause 4.6.2.1. The group total harmonic distortion ($THDG$) of the supply voltage should also be less than or equal to 8 %.

In addition, based on a prudent consideration suggested in IEC 61000-2-2, indicative values and indices should be as follows. Under normal operating conditions, during each period of one week, the interharmonic voltage percentile $U_{h95\ \%}$ of the 10-minute RMS values of each interharmonic centred subgroup voltage should be no higher than those of the adjacent harmonic voltage given in Table 3.

4.6.3 Medium voltage systems

4.6.3.1 Harmonic voltages

Under normal operating conditions, during each period of one week, the voltage percentile $U_{h95\ \%}$ of the 10-minute RMS values of each individual harmonic voltage should be less than or equal to the values given in Table 4.

Table 4 – Recommended values of individual harmonic voltages at the medium voltage points of supply ~~terminals~~ for orders up to 50 given in percent of the fundamental voltage U_1

Odd harmonics				Even harmonics	
Not multiples of 3		Multiples of 3 [a]			
Order h	$U_{h95\ \%}$ %	Order h	$U_{h95\ \%}$ %	Order h	$U_{h95\ \%}$ %
5	6,0	3	5,0 (6,0)	2	2,0
7	5,0	9	1,5 (3,5)	4	1,5
11	3,5	15	~~0,5~~ 1,0 (2,0)	6 … 24	0,75
13	3,0	21	~~0,5~~ 0,75 (1,5)		
17	2,0				
19	1,8				
23	1,5				
25	1,5				
$29 \leq h \leq 49$	$2{,}27 \times (17/h) - 0{,}27$	$27 \leq h \leq 45$	~~0,2~~ 0,5	$26 \leq h \leq 50$	~~0,25 × (10/h) + 0,25~~ 0,5

NOTE 1 Where national/regional circumstances make it appropriate, lower limits ~~may be specified~~ than the values given in Table 4 can be specified.

NOTE 2 Depending on the type of voltage transformer used, the measurement of high order harmonics ~~may~~ could be not reliable; further information is given in IEC 61000-4-30:~~2008~~2015, A.3.3.

NOTE 3 When end-use equipment is not directly connected to the MV system, lower values for MV ~~may~~ could be more appropriate to allow coordination of disturbance levels between low and medium voltage systems.

[a] Depending on the type of neutral grounding systems and transformer connections in some countries/regions, more triplen harmonics will flow in neutral conductors and ~~may~~ could cause higher harmonic voltages. In these cases, the highest value in brackets in Table 4 should adequately characterize the system harmonic voltages.

The total harmonic distortion (THD) of the supply voltage for orders up to 50 should be less than or equal to 8 %.

NOTE In some countries/regions, orders up to 40, only, are used to calculate the THD, maintaining the same recommended value.

4.6.3.2 Interharmonic voltages

The same statistical approach and the same range of values (see Table 4) should apply to harmonic (centred) group voltages as to individual harmonic voltages from ~~the previous section~~ Subclause 4.6.3.1. The group total harmonic distortion ($THDG$) of the supply voltage should also be limited under the value of 8 %.

In addition, based on a prudent consideration suggested in IEC 61000-2-12, indicative values and indices should be as follows. Under normal operating conditions, during each period of one week, the interharmonic voltage percentile $U_{h95\ \%}$ of the 10-minute RMS values of each interharmonic centred subgroup voltage should be no higher than those of the adjacent harmonic voltage given in Table 4.

4.6.4 High voltage systems

4.6.4.1 Harmonic voltages

Under normal operating conditions, during each period of one week, the voltage percentile $U_{h95\ \%}$ of the 10-minute RMS values of each individual harmonic voltage should be less than or equal to the values given in Table 5.

It is worthwhile mentioning that for HV transmission systems, one must realize the different purpose of voltage quality objectives. In contrast to low or medium voltage systems, quality objectives for harmonics in HV transmission systems are generally not directly related to their impact on equipment as the end-use equipment is not directly connected at HV. Indeed, these indicative levels are well below the levels that could cause immediate disturbances on the equipment. The indicative values on transmission systems are aimed at coordinating disturbance levels between different parts of the system or different voltage levels and may serve as indication of holistic network problems which warrant consideration.

Consequently, the indicative values of individual harmonic voltages at the higher voltage level should not be higher than the value for the lower one (MV and LV).

Table 5 – Indicative values of individual harmonic voltages at the high voltage points of supply ~~terminals~~ given in percent of the fundamental voltage U_1

Odd harmonics				Even harmonics	
Not multiples of 3		Multiples of 3			
Order h	U_h %	Order h	U_h %	Order h	U_h %
5	2,0 to 5,0	3	2,0 to 3,0	2	1,5 to 1,9
7	2,0 to 4,0	9	1,0 to 2,0	4	0,8 to 1,0
11	1,5 to 3,0			6 …12	0,5
13	1,5 to 2,5				

NOTE 1 Limits for individual harmonic voltage of order higher than 13 are not defined due especially to the limited accuracy of voltage transformers currently in use on HV systems. For measurement accuracy, an appropriate type of voltage transformer ~~should~~ can be used, particularly for the measurement of higher order harmonics.

NOTE 2 Due to the wide range of voltage levels included in HV (35 kV to 230 kV) and where national/regional circumstances make it appropriate, limits for intermediate voltage levels ~~may~~ can be specified within the range of values given in Table 5.

The total harmonic distortion (THD) of the supply voltage should be limited under a value within 3 % to 6 % (including harmonics for orders up to 50).

NOTE In some countries/regions, orders up to 40, only, are used to calculate the THD, maintaining the same recommended value.

4.6.4.2 Interharmonic voltages

The same statistical approach and the same range of values (see Table 5) should apply to harmonic (centred) group voltages as to individual harmonic voltages from ~~the previous section~~ Subclause 4.6.4.1. The group total harmonic distortion ($THDG$) of the supply voltage should also be limited under a value within 3 % to 6 %.

In addition, based on a prudent consideration suggested in IEC 61000-2-12, indicative values and indices should be as follows. Under normal operating conditions, during each period of one week, the interharmonic voltage percentile $U_{h95\ \%}$ of the 10-minute RMS values of each interharmonic centred subgroup voltage should be no higher than those of the adjacent harmonic voltage given in Table 5.

4.7 Voltage dip

Voltage dips typically originate from short circuits occurring in the public network or in network users' installations. The annual frequency varies greatly depending on the type of supply system and on the point of observation. Moreover, the distribution over the year can be very irregular.

The power quality characteristics of individual events are defined for each individual phase, by residual voltage and duration, despite the specific shape of the RMS voltage variation. Recommended values of voltage dips are still under consideration. More assessment methods are described in 5.2 and 5.3 hereafter.

Where assessments are performed or statistics are collected to be provided to network users or authorities, voltage dips should be classified according to Table 10.

For polyphase measurements, it is recommended that the number of phases affected by each event be detected and stored.

Generally, according to the network user connection, or the concrete situation, line to line or line to neutral voltage shall be considered.

4.8 Voltage swell

Frequently, voltage swell phenomenon may occur to be unpredictable and random. Depending upon the magnitude and duration, voltage swell may affect different types of load differently for the same voltage swell event. Recommended values of voltage swells are still under consideration. More assessment methods are described in 5.2 and 5.3 hereafter.

Where assessment is performed or statistics are collected to be provided to network users or authorities, voltage swells should be classified according to Table 10.

For polyphase measurements, it is recommended that the number of phases affected by each event be detected and stored.

Generally, according to the network user connection, or the concrete situation, line to line or line to neutral voltage shall be considered.

4.9 Voltage interruption

On single-phase systems, a voltage interruption begins when the residual voltage falls under interruption threshold.

On polyphase systems, a voltage interruption begins when the residual voltage of all phases falls under interruption threshold.

Interruption threshold is generally 5 % or 10 % of the reference voltage.

Even when referring only to normal operating conditions, the annual frequency of supply interruptions varies substantially between areas. This is due, amongst other things, to differences in system layout (e.g. cable systems versus overhead line systems), environmental ~~and~~ or climatic conditions.

In most countries/regions, specific continuity of supply indices is established by regulators in order to facilitate the benchmarking of the performance of the network operators under their jurisdiction. The indices allow network operators to meet their obligation to routinely report continuity of supply performance.

In the context of this document, voltage short time interruptions are mostly addressed. The detection of short time voltage interruptions is referred to in IEC 61000-4-30 and more assessment methods are described in 5.2 and 5.3 hereafter.

Where assessment is performed or statistics are collected to be provided to network users or authorities, voltage short time interruption should be classified according to Table 10.

4.10 Mains ~~signalling~~ communicating voltage

The public networks may be used by the network operators or network users for the transmission of signals. Three types of systems are considered by standards:

- ripple control systems that are used by electrical utilities in public supply networks, in the range of 100 Hz to 3 kHz, generally below 500 Hz, with signals up to 5 % of U_N under normal circumstances and up to 9 % of U_N in cases of resonance;
- power-line carrier systems used by electrical utilities in public supply networks, in the range 3 kHz to 95 kHz, with allowed signal levels up to 5 % of U_N. These signals are strongly attenuated in the network (>40 dB);
- signalling systems for end-user premises (residential or industrial) in the range of 95 kHz to 148,5 kHz in Europe (ITU region 1), with allowed signal levels up to 0,6 % of U_N or 5 % of U_N, respectively. In some countries/regions, the upper frequency is 500 kHz, with allowed signal levels between 2 mV to 0,6 mV.

Signal voltages recommended values in LV and MV are indicated in Figure 1.

For 99 % of a day, the 3 s RMS value of signal voltages shall be less than or equal to the recommended values.

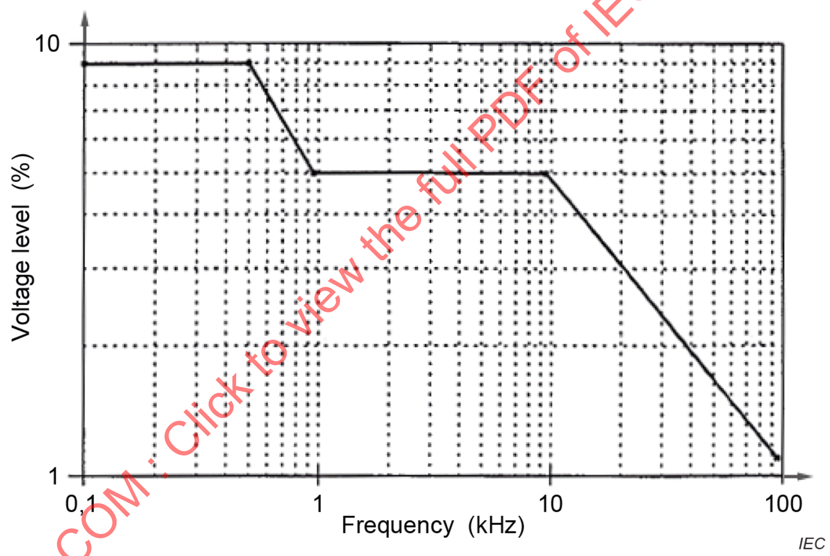


Figure 1 – ~~Signal~~ Mains communicating voltages recommended values in percent of U_N used in public LV networks (or U_c in public MV networks)

NOTE 1 Due to the low resonance frequency of the HV network, no values are given for mains ~~signalling~~ communicating voltages.

NOTE 2 The effective use of mains signalling is challenged by the presence of harmonic, interharmonic and high frequency conducted disturbances generated by power electronics (e.g. Active Infeed Converters). ~~Compatibility requirements addressing the intentional signals and disturbances are under consideration by EMC technical committees.~~ For compatibility levels for LV public network, refer to IEC 61000-2-2:2002/AMD1:2017, AMD2:2018 for MCS and NIE.

NOTE 3 Depending on the type of voltage transformer used, the measurement of high frequency mains communicating voltages can be not reliable; further information is given in IEC 61000-4-30:2015, A.3.3.

4.11 Rapid voltage change

Under normal operating conditions (excluding events), rapid voltage changes should not exceed indicative values.

Rapid voltage change indicative values are in the range of 3% ~5 % of U_N (U_c) for LV, MV and HV.

These values specifically refer to relative steady-state voltage changes aggregated over very-short time intervals, e.g. 150/180-cycle time intervals (all variations during these intervals are to be aggregated in the RMS value of the so-called steady-state voltage). They are based on the usual design criteria for reactive compensation equipment and motor starting, for example.

In some countries/regions, there are no RVC limits specified. Where national/regional circumstances make it appropriate, different limits may be specified than the values given in this document.

NOTE In this document, no values are given for the maximum voltage change (d_{max}) as defined in IEC 61000-3-3.

4.12 Transient overvoltage

4.12.1 Low voltage systems

Transient overvoltages at the points of supply ~~terminals~~ of LV systems are generally caused by lightning (induced overvoltage) or by switching in the system or in the installation. More information on overvoltage can be found in IEC TR 61000-2-14.

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

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

For withstanding transient overvoltages in the vast majority of cases, where necessary (see IEC 60364-4-44), surge protective devices should be selected according to IEC 60364-5-53, to take account of the actual situations. This is assumed to cover also induced overvoltages due to both lightning and switching.

4.12.2 Medium and high voltage systems

Transient overvoltages in MV or HV supply systems are caused by switching or by lightning, directly or by induction. Switching overvoltages generally are lower in amplitude than lightning overvoltages, but they can have a shorter rise time and/or longer duration. More information on overvoltage can be found in IEC TR 61000-2-14.

The network users' insulation coordination scheme should be compatible with that adopted by the network operator.

5 Objectives and methods for power quality assessment

5.1 General

Generally, power quality assessments are made for:

- Network operator performance evaluation

  This evaluation is often required by either regulatory authorities or by the network users to value power quality against relevant standards, e.g. assessment for survey, complaint, verification of compliance with connection agreement, compliance with quality regulation, or benchmarking.

- Trouble shooting

  To diagnose power quality related problems such as system harmonic resonance, custom producing process abnormal interruption, equipment malfunction, etc., typically, raw unaggregated power quality measurement data are most useful for troubleshooting, as they permit any type of post-processing preferred.

In this case, emphasis should be focused on the measurement of current which is invaluable in determining sources/causes of power quality disturbances, since it can help to determine if the cause of the problem is up stream or downstream of the measuring instrument.

- System planning

  Power quality is an important aspect for the development of the network for system expansion or connection of new sensitive or disturbing installations (these could be either a load or a generator).

Attention ~~must~~ shall be paid to the power quality assessment to ensure that the power quality evaluation process addresses the following 5 aspects explicitly:

- recommended or/indicative values;
- system conditions associated with recommended values;
- points on which power quality recommended values are applied;
- methods how power quality parameters are to be measured;
- methods by which assessment results come out from the large number of measurement field data. These methods are provided in 5.2 and 5.3 hereafter.

Although some types of disturbances are assumed to be continuous phenomena likely to be present on any point of supply ~~terminals~~, it is also important to keep in mind that these types of disturbances vary widely in time. Accordingly, any assessment approach used should carefully consider whether the time varying nature of these disturbances is properly addressed.

5.2 Site power quality assessment

5.2.1 General

For site power quality assessment, two kinds of methods are often used commonly depending on the concerning phenomena:

- statistical indices like percentile values, maximum or mean values over a certain period of time;
- event counting and tabulating.

5.2.2 Continuous phenomena

For continuous power quality phenomena assessment focusing on site, methods defined in Table 6 are recommended in this document.

Table 6 – Site power quality assessment methods

Phenomena	Minimum assessment period [a]	Assessment indices				Indicative value [d]
		not exceeding corresponding recommended values [b]			not exceeding k times corresponding recommended values [c]	
Supply voltage deviation	1 week	**Voltage**	**Low level**	**Upper level**	–	Max. upper level and low level supply voltage daily 3 s values with corresponding time stamp
		LV (see 4.3.2)	β % weekly 10-minute RMS values β = 5 or $\beta \in \frac{-b\pm\sqrt{b^2-4ac}}{2a}$ [0, 1]	P % weekly 10-minute RMS values $\rho \in$[99, 100]		
			if β > 100 – ρ, (100 – ρ) % weekly 10-minute RMS values			
		MV (see 4.3.3)	1 % weekly 10-minute RMS values	99 % weekly 10-minute RMS values		
			0 % weekly 10-minute RMS values			
		HV (see 4.3.4)	1 % weekly 10-minute RMS values	99 % weekly 10-minute RMS values		
Voltage unbalance	1 week	95 % weekly 10-minute RMS values (see 4.4)			99 % daily 3 s values	Max. daily 3 s values with corresponding time stamp
Flicker	1 week	95 % weekly 2 h P_{lt} values (see 4.5)			99 % daily 10-minute P_{st} values	Max. daily 10-minute P_{st} values with corresponding time stamp
Harmonics and inter-harmonics	1 week	95 % weekly 10-minute RMS values (see 4.6)			99 % daily 3 s values	Max. daily 3 s values with corresponding time stamp
Mains ~~signalling~~ communicating voltage	1 day	99 % daily 3 s values (see 4.10)			–	Max. daily 3 s values with corresponding time stamp

[a] For long time measurement assessment, an assessed weekly value should be retained on a daily sliding basis; Figure 2 is an example. See also Annex B.

[b] Assessment for survey, complaint, verification of compliance with connection agreement, compliance with quality regulation, or benchmarking.

[c] Assessment for more detailed power quality during assessment period. The coefficient k shall be determined by long term measurement campaigns in several sites in order to proper characterize the voltage supplied with the power quality very short-time indices given in Table 6. The ~~detailed value/or~~ range of k for each phenomenon is ~~under consideration~~ between 1,25 to 2.

[d] Only for trouble shooting purpose. Here corresponding time stamp with appropriate time resolution is needed for further post analysis in case of incident occurring at the same time to find out the relationship between the incident and the power quality parameter indices.

NOTE 1 Flagging concept is used in this document according to IEC 61000-4-30. Unless otherwise indicated, e.g. for voltage deviation, the flagged data is excluded in the calculation of percentile values.

NOTE 2 Here in Table 6, 10-minute RMS values are referred to '10 min interval' values defined by IEC 61000-4-30; 3 s values are referred to '150/180-cycle interval' values (150 cycles for 50 Hz nominal or 180 cycles for 60 Hz nominal) defined by IEC 61000-4-30.

NOTE 3 Where national/regional circumstances make it appropriate, different aggregation intervals can be specified.

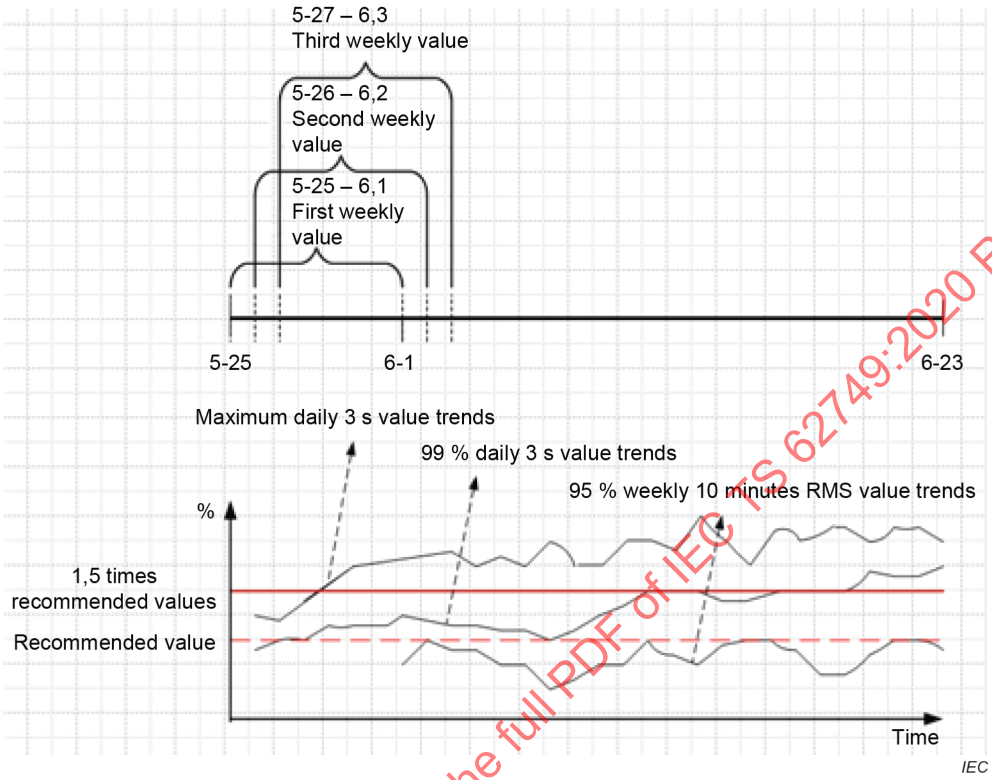


Figure 2 – Example for illustrating voltage *THD* assessment result trends

5.2.3 For discontinuous phenomena (single event)

~~For individual event evaluation, residual voltage and duration combined with the RMS voltage variation shape during each event can be tabulated like in the example for a single event assessment presented in Table 7 and Figure 3.~~

For individual event evaluation, useful parameters can be tabulated during each event.

For evaluation of voltage dip and voltage swell, residual voltage and duration combined with the RMS voltage variation shape can be tabulated as shown in Table 7 and Figure 3 for example.

~~NOTE~~ The measurement and detection methods for voltage swells, dips and short time interruptions should be in accordance with IEC 61000-4-30.

Table 7 – Example of single event assessment

Event attribution	Detailed characterization
Location	East station 10 kV busbar
Time stamp	2011-06-30 12 h:36 m:12.2150 s
Capturing threshold	80 %
Residual voltage	21 %
Time duration	81,9 ms
RMS variation shape	Upper part in Figure 3
Point on wave	Lower part in Figure 3

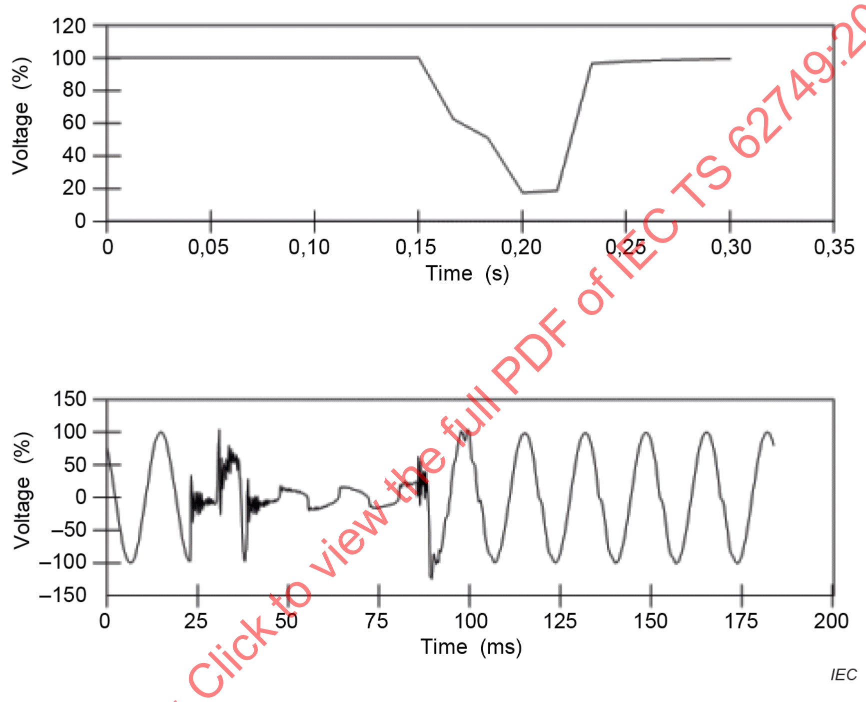


Figure 3 – Example showing information of single event assessment

5.3 System aspect power quality assessment

5.3.1 General

For system (sub-system/area) power quality assessment, weighting rules may be used applying both to statistical indices and events in order to get global results depending on the details of collection of single points.

NOTE For more information on weighting rules, see Bibliography [31].

5.3.2 For continuous phenomena

For system power quality indices, there are no corresponding recommended values, but the assessment based on site evaluation results can give very useful information for system power quality management.

Annex B gives an example of system aspect continuous disturbance evaluation.

5.3.3 For discontinuous phenomena (events)

5.3.3.1 General

For system aspect assessment of ~~events~~ voltage dips, voltage swells and supply interruptions, the following *SARFI* methods combining with the magnitude-duration table (Table 10) can be used.

NOTE 1 Detailed information about *SARFI* methods is presented in IEEE 1564.

NOTE 2 For system aspect assessment of ~~events~~ voltage dips, voltage swells and supply interruptions, several methods are also presented in CENELEC TR 50555~~, *Interruption indices*~~.

Time aggregation method, in the case of multiple successive ~~events~~ voltage dips, voltage swells and supply interruptions, should be used prior to the assessment. The time aggregation duration is defined as 1 minute in this document~~, within which all events can be counted as one event whose magnitude and duration are those of the most severe observed during this interval~~. Aggregation rules, if used, should be declared.

~~Different aggregation methods may be selected for individual purposes; some reference rules are given in IEC TR 61000-2-8.~~

For more information about time aggregation methods, see Annex B.

5.3.3.2 SARFI method

SARFI is an acronym for System Average RMS Variation Frequency Index (*SARFI*). It is a power quality index that provides a count or rate of voltage dips, swells, and/or interruptions for a system. The size of the system is scalable: It can be defined as a single monitoring location, a single network user service, a feeder, a substation, groups of substations, or for an entire power delivery system.

SARFI-X corresponds to a count or rate of voltage dips, swells and/or interruptions below or above a voltage threshold. For example, *SARFI-70* considers voltage dips and interruptions that are below 0,70 per unit, or 70 % of the reference voltage. *SARFI-110* considers voltage swells that are above 1,1 per unit, or 110 % of the reference voltage.

In this document, a rate of 30 days (number of events/30 days) is recommended for assessment of voltage dips, swells and/or interruptions below or above a voltage threshold. If the measured period of the events would be longer than or shorter than 30 days, *SARFI-X* indices will be calculated accordingly.

The following is an example using the *SARFI-X* method. Table 8 presents a list of residual voltages with corresponding events duration at a single monitoring site and Table 9 gives *SARFI-X* indices coming out of Table 8. The observation period is from Jul-01-2000 to Oct-1-2000, total 92 days.

Table 8 – List of individual events measured at a single monitoring site

Time stamp	Residual voltage (%)	Event duration (ms)
Jul-01-2000 09:48:52	73	180
Jul-01-2000 09:50:16	73	180
Jul-07-2000 14:20:12	0	1 640
Jul-10-2000 15:55:23	13	2 000
Jul-21-2000 09:48:52	0	2 600
Aug-08-2000 07:35:02	49	680

Sep-02-2000 08:30:28	0	41 000
Sep-08-2000 10:30:40	59	800

Table 9 – *SARFI-X* indices coming out of Table 8

Index	Count	Events per 30 days
SARFI-90	8	2,61
SARFI-70	6	1,96
SARFI-50	5	1,63
SARFI-10	3	0,98

5.3.3.3 Magnitude-duration table

It is clear that when using the *SARFI* method, the event time duration information is missing. This will be remedied by using the magnitude-duration table described hereafter.

Magnitude-duration table format is shown as Table 10. The columns of the tables represent ranges of duration, while the rows represent ranges of residual voltage. Each cell ~~populates the total count summing each event matching~~ in the table gives the number of events with the corresponding range of residual voltage and duration ~~restriction~~. The values in Table 10 are out of Table 8.

Table 10 – Magnitude-duration table format

Residual voltage U %	Duration t ms				
	$10 \leq t \leq 200$	**$200 < t \leq 500$**	**$500 < t \leq 1\ 000$**	**$1\ 000 < t \leq 5\ 000$**	**$5\ 000 < t \leq 60\ 000$**
$U \geq 120$	0	0	0	0	0
$120 > U > 110$	0	0	0	0	0
$90 > U \geq 80$	0	0	0	0	0
$80 > U \geq 70$	2	0	0	0	0
$70 > U \geq 40$	0	0	2	0	0
$40 > U \geq U_{ith}$	0	0	0	1	0
$U_{ith} > U$					
Voltage interruption	0	0	0	2	1

NOTE On a three phases system, voltage interruption begins when the U_{RMS} voltages of all three phases fall below the interruption threshold (U_{ith}). Refer to IEC 61000-4-30 for more information.

Annex A
(informative)

Examples of profiles for power quality specification

A.1 General

The following information is provided by experts from different countries/regions as examples.

NOTE Annex A is intended to address the flexibilities offered in this document, not to identify all the differences with applicable national/regional standards.

A.2 LV and MV public distribution networks in European countries

Table A.1 – Examples of profiles in European countries

LV and MV public distribution networks in European countries (applicable standard: EN 50160)	
4.2	For systems with synchronous connection to an interconnected system: – 50 Hz ± 1 % during 99,5 % of a year; – 50 Hz + 4 % / – 6 % during 100 % of the time. For systems with no synchronous connection to an interconnected system (e.g. supply systems on certain islands): – 50 Hz ± 2 % during 95 % of a week; – 50 Hz ± 15 % during 100 % of the time. European standard defines the frequency range for normal network conditions. During exceptional conditions, wider frequency tolerances may apply temporarily in order to maintain the continuity of electricity supply. NOTE The frequency assessment is based on 10 s values according to IEC 61000-4-30.
4.3.2	ρ = 100 β = 5
4.3.3	$U_{100\ \%}$ doesn't exceed U_c +15 %
4.4	–
4.5	–
4.6.2.1	*THD* is calculated with harmonic orders up to 40th only NOTE U_{19}, U_4 and $U_{6...24}$ in Table 3: see EN 50160 (Table 1)
4.6.2.2	–
4.7	–
4.8	–
4.9	Interruptions threshold = 5 % of reference voltage
4.10	–
4.11	No rapid voltage change limits are specified
4.12.1	–

A.3 LV, MV and HV power supply system in China

Table A.2 – Examples of profiles in China

<table>
<tr><th colspan="2">LV, MV and HV power supply system in China</th></tr>
<tr><td>4.2</td><td>For LV, MV, and HV power supply systems with synchronous connection to an interconnected system:
– 50 Hz ± 0,2 Hz

For systems with no synchronous connection to an interconnected system or for weaker systems:
– 50 Hz ± 0,5 Hz</td></tr>
<tr><td>4.3</td><td>ρ and β: not defined

For LV power supply systems:
– U_N ± 7 %

For MV and HV power supply systems:
– abs (plus deviation) + abs (minus deviation): 10 %

(abs: absolute value sign)</td></tr>
<tr><td>4.4</td><td>–</td></tr>
<tr><td>4.5</td><td>–</td></tr>
<tr><td>4.6.2.1, 4.6.3.1 and 4.6.4.1</td><td>– THD is calculated with harmonic orders up to 25th only
– Harmonics for LV, MV, and HV power supply systems:
<table>
<tr><th>Voltage
kV</th><th>THD
%</th><th colspan="2">HR (%)</th></tr>
<tr><th></th><th></th><th>Odd harmonics</th><th>Even harmonics</th></tr>
<tr><td>0,38</td><td>5,0</td><td>4,0</td><td>2,0</td></tr>
<tr><td>6</td><td rowspan="2">4,0</td><td rowspan="2">3,2</td><td rowspan="2">1,6</td></tr>
<tr><td>10</td></tr>
<tr><td>35</td><td rowspan="2">3,0</td><td rowspan="2">2,4</td><td rowspan="2">1,2</td></tr>
<tr><td>66</td></tr>
<tr><td>110</td><td>2,0</td><td>1,6</td><td>0,8</td></tr>
</table></td></tr>
<tr><td>4.6.2.2, 4.6.3.2 and 4.6.4.2</td><td>Interharmonics for LV, MV, and HV power supply systems:
<table>
<tr><th>Voltage</th><th><100 Hz</th><th>100 Hz ~ 800 Hz</th></tr>
<tr><td>$U_N \leq$ 1 000 V</td><td>0,2</td><td>0,5</td></tr>
<tr><td>$U_N >$ 1 000 V</td><td>0,16</td><td>0,4</td></tr>
</table>
NOTE Value here is for interharmonic ratio.</td></tr>
<tr><td>4.7</td><td>–</td></tr>
<tr><td>4.8</td><td>–</td></tr>
<tr><td>4.9</td><td>–</td></tr>
<tr><td>4.10</td><td>No mains ~~signalling~~ communicating voltage limits are specified</td></tr>
<tr><td>4.11</td><td>No rapid voltage change limits are specified</td></tr>
<tr><td>4.12</td><td>See GB/T 18481</td></tr>
</table>

A.4 Example of a transmission system in Canada

Table A.3 – Examples of profiles in Canada

<table>
<tr><th colspan="2">Applies to high voltage 60 Hz networks from 44 kV to 230 kV</th></tr>
<tr><td>4.2</td><td>60 Hz ± 1 % (i.e. 59,4 Hz to 60,6 Hz), during 99,9 % of a year;
NOTE Does not apply to islanded systems.</td></tr>
<tr><td>4.3.4</td><td>–</td></tr>
<tr><td>4.4</td><td>Negative voltage unbalance factor is:
– 1,5 % for nominal voltage 230 kV;
– 2 % for nominal voltage from 44 kV to 161 kV.</td></tr>
<tr><td>4.5</td><td>P_{lt} = 0,8</td></tr>
<tr><td>4.6.4.1</td><td>Table 5 – Indicatives values of individual harmonic voltages at the high voltage points of supply ~~terminals~~ given in percent of the fundamental voltage U_1
<table>
<tr><th colspan="2">Odd harmonics</th><th colspan="2">Even harmonics</th></tr>
<tr><th>Order
h</th><th>$U_{h95\ \%}$
%</th><th>Order
h</th><th>$U_{h95\ \%}$
%</th></tr>
<tr><td>3</td><td>2</td><td>2</td><td>1,5</td></tr>
<tr><td>5</td><td>2</td><td>4</td><td>1</td></tr>
<tr><td>7</td><td>2</td><td>$6 \leq h \leq 50$</td><td>0,5</td></tr>
<tr><td>9</td><td>1,5</td><td></td><td></td></tr>
<tr><td>11</td><td>1,5</td><td></td><td></td></tr>
<tr><td>13</td><td>1,5</td><td></td><td></td></tr>
<tr><td>15</td><td>1</td><td></td><td></td></tr>
<tr><td>$17 \leq h \leq 49$</td><td>$1,2 \times 17/h$</td><td></td><td></td></tr>
</table>
Voltage THD = 3 %</td></tr>
<tr><td>4.6.4.2</td><td>Voltage $THDG$ = 3 %</td></tr>
<tr><td>4.7</td><td>–</td></tr>
<tr><td>4.8</td><td>–</td></tr>
<tr><td>4.9</td><td>Interruption threshold is 10 % of reference voltage</td></tr>
<tr><td>4.10</td><td>n/a</td></tr>
<tr><td>4.11</td><td>RVC limit = 3 %. In some circumstances*, it can reach 6 % of nominal voltage.
* These are viewed as degraded operating conditions when equipment switching must be carried out to meet supply system or load requirements.</td></tr>
<tr><td>4.12.2</td><td>–</td></tr>
</table>

A.5 Examples of profiles in Australia

Table A.4 – Examples of profiles in Australia

<table>
<tr><th colspan="2">Examples of profiles in Australia</th></tr>
<tr><td>4.2</td><td>For the Australian mainland under normal conditions with no contingency or load event, the required frequency is:
– 49,75 Hz to 50,25 Hz, while maintaining 49,85 Hz to 50,15 Hz 99 % of the time over a 30 days period.
– For islanded systems, under normal conditions with no contingency or load event, the required frequency is: 49,5 Hz to 50,5 Hz
– Compliance is based on 4 second measurements</td></tr>
<tr><td>4.3.2</td><td>Based on what is published in AS 61000.3.100, it specifies V99 % and V1 %. However, this standard has not yet had widespread adoption by the various state regulators. Accordingly, a wide range of practices currently still be adopted.
In any case, according to AS61000.3.100, the parameters are:
– ρ = 99
– β = 1</td></tr>
<tr><td>4.4</td><td>Voltage unbalance is 2 % 30 minute values for 100 % of the time</td></tr>
<tr><td>4.5</td><td>– P_{lt} for LV/MV is 1,0 for 95 % of the time
– and P_{lt} for HV is 0,8 for 95 % of the time</td></tr>
<tr><td>4.6.2.1</td><td>Under consideration – however Victorian distribution code applies IEEE Standard 519-1992, and total harmonic distortion limit of 5 %</td></tr>
<tr><td>4.6.2.2</td><td>As per IEC 61000-2-2</td></tr>
<tr><td>4.7</td><td>Preferred 230 V voltage dip and swell measurement thresholds
<table>
<tr><th rowspan="2">Voltage threshold</th><th colspan="2">Phase-to-neutral voltage</th><th colspan="2">Phase-to-phase voltage</th><th colspan="2">1 phase 3 wire centre Neutral phase-to-phase voltage</th></tr>
<tr><th>dip</th><th>swell</th><th>dip</th><th>swell</th><th>dip</th><th>swell</th></tr>
<tr><td>1/2 cycle RMS</td><td>207 V</td><td>262 V</td><td>360 V</td><td>456 V</td><td>414 V</td><td>524 V</td></tr>
</table></td></tr>
<tr><td>4.8</td><td>See 4.7 above</td></tr>
<tr><td>4.9</td><td>(a) for single phase systems, falls below the interruption threshold of 10 % of the nominal voltage, U_N for at least a ½ cycle
(b) for poly-phase systems, falls below the interruption threshold of 10 % of the nominal voltage, U_N for at least a ½ cycle on all channels</td></tr>
<tr><td>4.10</td><td>Presently as per IEC</td></tr>
<tr><td>4.11</td><td>No limits specified other than via flicker requirements</td></tr>
<tr><td>4.12</td><td>No limits specified</td></tr>
</table>

Annex B
(informative)

Additional information on power quality assessments

B.1 Weekly percentile values assessed on a daily sliding basis

A weekly percentile value $U_{x\,\%}$ corresponds to a value such that x percent (x %) of measurements are smaller than or equal to that value, over one week. Weekly percentile values assessed on a daily sliding basis are weekly percentile values assessed each day with the last seven days measurements.

For measurement campaigns over more than one week, power quality levels resulting of weekly percentile values assessed on a daily sliding basis should better characterize the supply voltage than when assessed on defined weeks (with no overlapping). In the latter case, percentile values may differ depending on the defined first day of the week, for example when high disturbances are measured within seven consecutive days and not considered in the same assessed weekly percentile value.

Figure B.1 gives an example that compares weekly 95th percentile values assessed with the two different methods. These statistical assessments are based on the 7th harmonic voltage 10-minute aggregated values recorded at the HV point of connection of a given installation during a year measurement campaign. Six weeks are illustrated in this example.

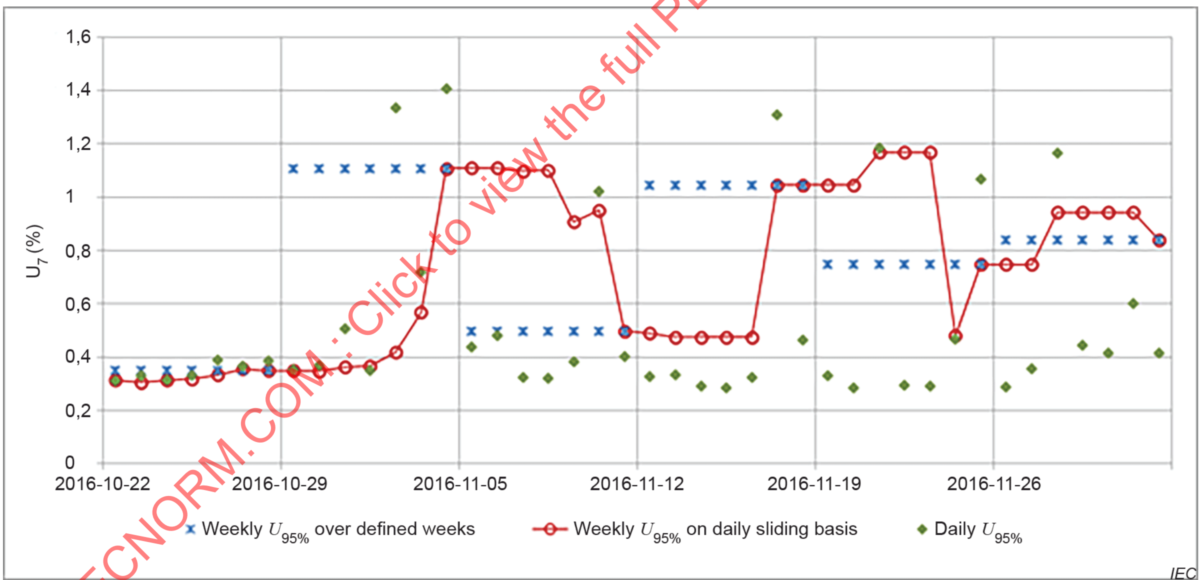


Figure B.1 – Comparison of two methods of assessing weekly 95th percentile values

In Figure B.1, the six plateaus (each shown by seven blue marks) correspond to the 95th percentile values assessed on six defined weeks (with no overlapping) and the curve shows the 95th percentile values assessed on a daily sliding basis (in red marks). In addition, the daily 95th percentile values are given (in green marks) to identify the days of higher disturbances.

Results show for example that the higher disturbances occurring on November 17th and November 21st, even though within seven days, are not considered in the same defined weeks, resulting of lower 7th harmonic level (approx. 1,0 %) than resulting level with the daily sliding method (approx. 1,2 %).

B.2 Example on system aspect continuous disturbance evaluation

Firstly, two variables named average index ($\overline{x}$) and sample standard deviation (s) are defined by formulae (B.1) and (B.2).

$$\overline{x} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{B.1}$$

$$s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \overline{x})^2}{n-1}} \tag{B.2}$$

where

$\overline{x}$ is the site average value of one kind of disturbances, e.g., unbalance, flicker, etc.;

x_i is the assessment result (percentile values) of individual site belonging to this system (area);

n is the total number of monitoring sites covered in this system (area);

s is the sample standard deviation.

Thus, average index $\overline{x}$ and sample standard deviation s are used for system (sub-system, or area) aspect power quality evaluation. Table B.1 is an example of the results using this method.

Table B.1 – Listing of system power quality evaluation

Disturbance		Average value	Sample standard deviation	Maximum of site value	Minimum of site value
Voltage *THD* (%)					
Unbalance (%)					
Flicker	P_{lt}				
NOTE The total number of sites ~~should~~ can be list here.					

NOTE Max. and Min. site values are based on site percentile values.

B.3 Aggregation method used for events

B.3.1 General

Annex B provides additional information about aggregation method used for events assessment. This annex is intended to help for further understanding the aggregation method defined in this document.

B.3.2 Time aggregation

The time aggregation is counting a single event if there is a succession of events within a short time according to the time stamps of each event. The rules of how the events are to be aggregated depend on the specific needs of a particular assessment. Of course, the time length chosen for aggregation is arbitrary. However, a one-minute aggregation time period is widely used.

Nevertheless, how to understand 'the most severe one' may lead to different aggregation results. For example, for the successive events list in Figure B.2, Figure B.3 different results may exist as:

- Event 1 (t_1 d_2): selecting the most severe parameters of each encompassed event. The duration of the aggregated event is in such a case chosen as the longest duration; its retained voltage is chosen as the lowest value for the individual dips.
- Event 2 (t_2 d_2): selecting the most severe one of each encompassed event according to the amplitude;
- Event 3 (t_1+t_2+t_3 d_2): for the case where the time between events is less than one second, it is more appropriate to take the sum of the durations of the individual dips as the duration of the aggregated.

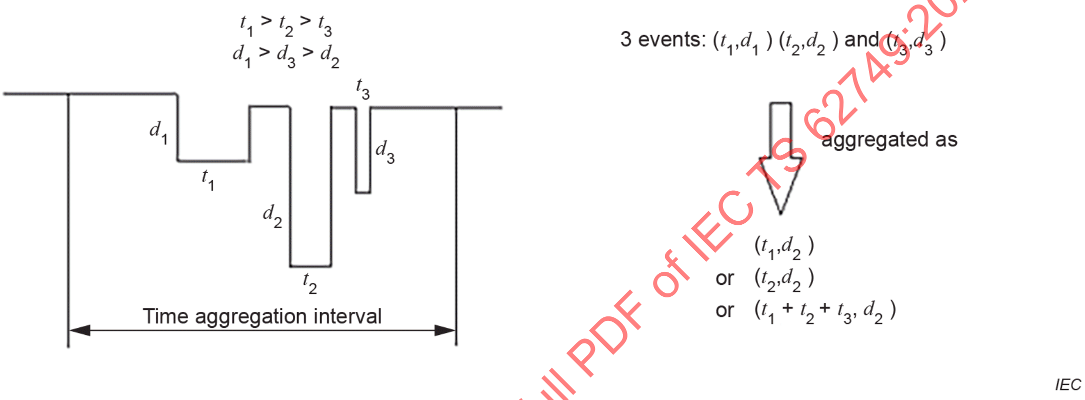
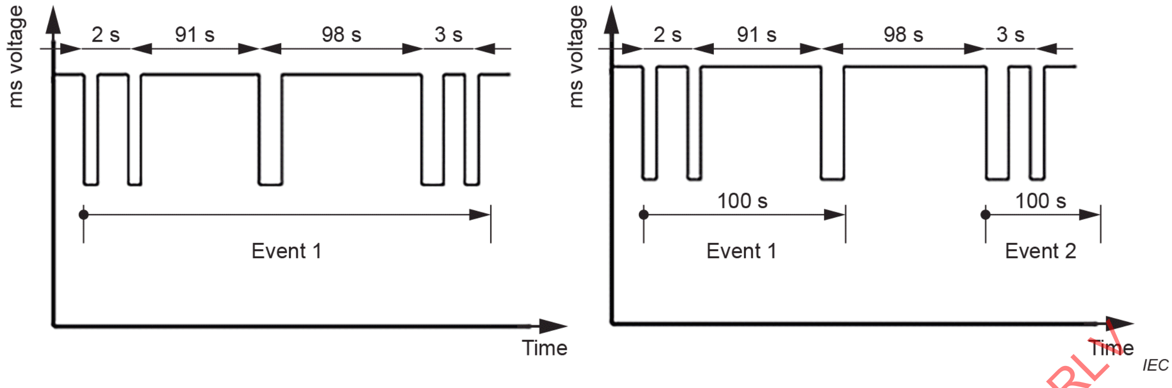


Figure B.2 – Example for illustrating the differences resulted by time aggregation method

B.3.2.1 Time aggregation interval [28] [31] [1]

With some surveys, aggregation is not based on the time elapsed since the end of the previous event but instead on the time elapsed since the start of the previous events. An example of a sequence of voltage dips that can be aggregated in two different ways is shown in Figure B.3, where a time-aggregation window of 100 seconds has been assumed. Using the time since the end of the previous dip, these five sags will be aggregated as one event (Figure B.3 a)). Using instead the time since the start of the previous will result in two aggregated events (Figure B.3.b)), the first one consisting of three voltage sags, the second of two sags.

1 Figures in square brackets refer to the Bibliography.



a) first way of dips aggregation b) second way of dips aggregation

Figure B.3 – Example of time sequence of voltage dips that can be aggregated in two different ways

B.3.2.2 Information from Cigré C4.07[31]

In many cases, time aggregation is used to prevent double counting of events close together in time. Different methods of aggregation are in use, each with their advantages and disadvantages. One possible method is the following: the retained voltage of the aggregated event is the lowest of the values of the individual dips; the duration of the aggregated event is the longest of the durations of the individual dips. When events are very close together in time (e.g. less than one second), the duration of the aggregated event is the sum of the durations of the individual dips. The discussion on the choice of time-aggregation window remains open.

There are several reasons for merging events that are close in time into one event.

- When two identical voltage dip events occur with a few minutes separation, the effect on end-use equipment will be the same as that of one single event. If the first event will cause the equipment to trip, the production process will still be down when the second event occurs. If, however, the equipment manages to ride through the first event, it will equally ride through the second event. Thus, two events that are separated in time less than the "production recovery time" may be aggregated into one single event. In case the two events are different, the most severe one will determine the behaviour of the equipment.
- Two voltage dips may be due to essentially the same event in the power system. The standard example is unsuccessful reclosing after a fault. Any customers not on the faulted feeder will experience two voltage dips with the same retained voltage. The duration may be different due to the difference in the breaker characteristic. Another example is a recurrent fault. Such a power-system event may lead to a number of voltage dips separated seconds through minutes in time.

The algorithm used for characterising voltage dips may detect the end of a dip before the event is actually over. The voltage may recover above the dip-ending threshold for a few cycles and then drop below the threshold again.

Annex C
(informative)

Main impact of poor power quality

C.1 General

When supplied by AC electricity, voltage magnitude and frequency are always the key factors of concern for power supplies and end users as these factors are indeed fundamental to the supply of quality power. If the supplied voltage or frequency is not within the reasonable range, the performance of network users' equipment will be impacted, and so will be the power system itself.

Power quality indices are described by the characteristics of supplied power in order to clarify the responsibility between the system operators and the end users. Power utilities should shoulder responsibility for maintaining the reasonable range of power quality levels. On the other hand, power quality also depends on the way in which it is being used at any instant by the equipment of multiple users. Thus, maintaining the preferred power quality condition is the responsibility of both the system operators and end users, namely through the enforcement of standards for controlling emission limits and ensuring a minimum immunity of end-use equipment.

C.2 Harmonic distortion

The long-time exposure to relatively high harmonic distortion conditions may cause some serious effects on the various pieces of equipment. Even very high short-term harmonics distortions, e.g. resonance condition, may cause a dielectric breakdown due to overvoltages.

Harmonics can lead to overloading. Subsequent overheating increases dielectric stress and the power loss.

– Capacitors for power factor correction often act as sinks for a particular order of harmonic currents. In this case, it can lead to capacitor overcurrent if no forethought is given at the designing stage.
– Non-sinusoidal power supplies result in a reduction of the torque of induction motors.
– Harmonics will increase the interference with telephone, ~~communication~~ communicating and analogue circuits.
– Excessive levels of harmonics can cause errors in the reading of induction type energy meters which are calibrated for pure sinusoidal AC power.
– High order harmonics cause voltage stresses.
– Harmonic currents flowing through power system networks can cause additional losses.

It is reported that the level of interharmonics in power supply systems is increasing due to the development of frequency converters and similar electronically controlled equipment. Harmonic voltages and interharmonic voltages, if not controlled, might lead (among other effects) to overloading or disturbance of equipment on the supply networks and in electricity users' installations.

In some cases, interharmonic voltages, even at low levels, can give rise to flicker, or cause interference in ripple control systems.

C.3 Voltage unbalance

Voltage unbalance is always a concern as it affects the transformers, electrical motors, and electrical generators.

– Voltage unbalance degrades the performance and shortens the life of a three-phase motor.
– Current unbalance caused by voltage unbalance ~~essentially~~ creates a counter-torque (resistive torque). That is, it tries to make the motor turn in the opposition direction. This will create heating.
– Voltage unbalance may also reduce the capacity of equipment such as motors or generators if not properly taken into consideration at the design stage (equipment is normally designed and rated to account for some degree of voltage unbalance normally present in any power system).

C.4 Voltage deviation

Large voltage deviations from the nominal values will shorten the life of electrical equipment, lower the stable limit of power system and increase the cost of network operation. Equipment operating under this condition will be malfunction, breakdown or damaged.

C.5 Frequency deviation

If frequency deviation exceeds the limit, ~~the~~ motors ~~shall be~~ are usually protected by means of stopping their operation. Sustained operation will alter the speed of motors and potentially create unsafe conditions for the processes in which they function.

Where frequency deviations occur frequently, such as islanded power systems, users may notice time drift with their analogue clocks.

C.6 Voltage fluctuation

Voltage fluctuations can cause a number of harmful technical effects such as data errors, memory loss, equipment shutdown, flicker, motors stalling and reduced motor life, resulting in disruption to production processes and substantial costs. However, considering the fact that voltage fluctuations are normally within 10 % magnitude, most of these above mentioned effects are more typical of voltage dips or swells.

C.7 Flicker

Flicker is considered to be an annoying problem for the network users. Most of the time, it does not have a high financial impact. However, at high levels it can cause inconvenience to people when frequent flickering of lights (different technology of lamps may have different sensitivity to voltage fluctuation) and computer screens occurs at their workplaces or homes.

C.8 Voltage dip (or voltage sag)

Motor drives, including variable speed drives, are particularly susceptible because the load still requires energy that is no longer available except from the inertia of the drive. In processes where several drives are involved, individual motor control units may sense the loss of voltage and shut down the drive at a different voltage level from its peers and at a different rate of deceleration, resulting in the complete loss of process control. Data processing and control equipment is also very sensitive to voltage dips and can suffer from data loss and extended downtime.

C.9 Transient overvoltages

Transient overvoltages can cause large dV/dt values that can damage or reduce the lifetime of variable speed drives.

Annex D
(informative)

Power quality issues related to distributed generation and micro-grids

D.1 General

Because of grid connected distributed generation (DG), the distribution network will eventually change from transmitting and allocating electrical energy to a new power exchange system, which includes power collection, transmission and storage. Consequently, it brings a series of problems including power quality issues.

DG is also the main power element making up micro-grids. The following PQ characterizations are always present in micro-grids.

D.2 Voltage deviation

Grid connected DG changes the distribution network power flow and can cause reverse power flow. This affects the distribution network voltage and may cause large voltage deviations. The deviation mainly depends on the network capability and location of grid connected DG. The closer the DG's location to the point of supply ~~terminal~~ node, the bigger the voltage change would be at the point of supply ~~terminals~~, and vice versa. Thus, some node voltages will be higher than the rated voltage or the bus line voltage because of improper application of the DG.

D.3 Harmonics

DGs such as photovoltaic cells (PV), wind power, fuel cells, power storage systems and gas turbines can be connected to the power system by power electronics devices.

– PV, fuel cells and storage systems generate direct current which needs an inverter to connect to the power system.
– Gas turbine generates high frequency alternating current, which needs AC/DC/AC or AC/AC frequency converters to connect to the power system.
– Advanced wind power connects to the power system by an AC/DC/AC converter, transforms AC voltage into DC voltage and then transforms the DC voltage into rated frequency AC voltage.

These devices convert electric power, control load and may cause grid voltage and current wave distortion leading to similar effects to that of adding a non-linear load to the power system.

D.4 DG magnetic bias (DC current injection)

In a DG system which connects to the grid through an inverter, if the parameters are unbalanced or trigger impulses that are asymmetrical, there may appear to be DC current in the inverters. Inflow of the DC current in the distribution transformers may cause the transformer's DC magnetic bias and consequently cause wave distortion and abnormal heating as a result. In order to attenuate this phenomenon, isolation transformers can be used, but the root problem of filtering and avoiding unequal firing should be corrected in the first place.

D.5 Voltage fluctuation and flicker

For renewable power generation systems like wind and photovoltaic, the unpredictable fluctuating source of electricity is the main reason leading to output electric power fluctuation. It can be increased by the use of maximum power point tracking (MPPT) control technology for improvement of efficiency of a DG system.

On the other hand, DG system operation is usually controlled by its property owner. This may cause the DG system to randomly start-up and stop operation. When some large capacity DG systems start or quit, the power output changes abruptly causing voltage fluctuations and flicker. This is more serious when the short-circuit capacity of the DG connection point is low.

D.6 High frequency conducted disturbances

Moreover, grid connected active infeed converters may be a source of high frequency conducted disturbances (e.g. in the range 2 kHz to 150 kHz) and interference cases with electronic devices, electricity meters and PLC systems for smart meter/grid have been reported.

Annex E
(informative)

Methods to maintain and improve power quality

E.1 General

The quality indices and the recommended values cover appropriately the vast majority of locations under acceptable economic conditions, despite the differences in situations, provided that:

- for mass-market products, emission requirements in standards such as IEC 61000-3-2, IEC 61000-3-3, IEC 61000-3-11 and/or IEC 61000-3-12 are regularly and appropriately updated to take into account the development of markets and changes in technologies;
- for large installations, emission levels are effectively controlled, e.g. through connection agreements;
- network operators make use of appropriate methodologies and engineering practices, e.g. based on planning levels and IEC TR 61000-3-6, IEC TR 61000-3-7, IEC TR 61000-3-13 and/or IEC TR 61000-3-14.

E.2 Voltage deviation

The deviation of supply voltage is mainly caused by voltage drops as a result of load current flowing through the system internal impedance.

Generally, voltage deviation requirements controlling operations are made by system operators, including:

– voltage regulation, including system aspects of active power flow control and reactive power flow optimizing, transformer taps adjusting, etc.

– reactive power compensation at distribution stations, including capacitor banks and reactors equipment, which are switched automatically according to the connected voltage.

On the other hand, the end users are required to comply with the power factor demand regulations made by (agreed with) system operators. Thus, reducing the reactive current draw from the supply system with reactive power compensation equipment is the main method for end users to meet voltage deviation requirements.

For large fluctuating end users, the following advanced equipment may be the best choice technically and economically:

– static Var compensator (SVC);

– magnetic controlling reactors (MCR);

– static synchronous compensators (STATCOM) or static Var generation (SVG).

E.3 Harmonics

Mitigating harmonics for the network user begins at the disturbance source. ~~The following process~~ One or more measures such as those listed below may be ~~the choice~~ selected according to the particular circumstances.

– Passive filters (LC filtering circuits)

This is the preferred industry choice as the equipment acts as the sink for certain harmonic current orders.

– Active power filters (APF)

Mostly used for harmonic current fluctuating situations, thus the response time is the key factor for characterizing their performance.

– Embedded solution

E.g., PWM (pulse width modulation) technology used in modern power electronic ~~communities~~ convertors.

E.4 Flicker

~~Similar with harmonics, mitigating flicker for the NETWORK USER begins at the disturbance source. It is always accomplished by controlling fluctuating power drawn by the disturbance load, e.g., electric arc furnace and elevator.~~

Similar with harmonics, mitigating flicker for the network is preferred at the disturbance source, however this may not always be possible, i.e. the best motor drive cannot mitigate the flicker caused by a motor which is too large for the service capacity. When possible, mitigation is accomplished by controlling fluctuating power drawn by the disturbance load, e.g., electric arc furnace, welding machine, pumps, rolling mills and elevator. When such is not possible, then power system service cable and/or transformer upgrade may be required. One or more measures such as those listed below may be selected according to the particular circumstances.

– use of higher voltage level supply as agreed between system operators and end users,
– static var compensators (SVC),
– static synchronous compensators (STATCOM) or static var generation (SVG),
– series reactors,
– upgrade of power system LV service cables and/or transformer,
– reconfiguration of MV power system to provide a stronger source,
– use of series capacitor in MV power system.

In cases where SVCs, STATCOMs, or SVGs are used, response time is the key factor for characterizing their performance.

E.5 Voltage unbalance

To decrease the degree of voltage unbalance~~, several actions can be taken~~ one or more measures such as those listed below may be selected according to the particular circumstances.

– The first and most basic solution is for the system operators to deploy or distribute the loads in such a way that the three phase loads become more balanced.
– For large unbalanced loads, as railway applications powered by single phase supplies, the use of higher voltage level supply is possible, with agreement between system operators and end users.
– For large unbalanced loads, the SVC technology has the result according to C.P.Steinmetz theory.
– For some of the railway applications powered by single phase supplies, special transformers, such as Scott and Steinmetz transformers~~, are to~~ can be used.
– In a three phases system, transposition of transmission lines may also be a solution to attenuate the negative sequence unbalance voltage.
– Feeder voltage regulators can be used to balance the voltages, e.g. line-neutral regulation can control zero-sequence unbalance, line-line regulation can control negative-sequence unbalance.

E.6 Voltage dip/swell/short time interruption

Voltage dips, swells and short time interruptions are important PQ problems affecting industrial and large commercial network users. As most of these events are caused by circuit faults, improving system operation management skills and constructing robust supply systems are always the fundamental procedure to decrease the effects of these unpredictable events. Improving protection system performance for reducing the duration of circuit faults is also possible to reduce voltage dips duration.

Another efficient method is an embedded solution to improve the sensitive load immunity for riding through these events. ~~For example, by the application of devices such as~~ One or more measures such as those listed below may be selected according to the particular circumstances:

- uninterruptible power supplies (UPS's),
- energy storage devices (super capacitors, SMES, etc.),
- and dynamic voltage restorers (DVR).

Annex F
(informative)

Relation between power quality and EMC

F.1 General

Power quality is related to EMC in a number of ways – especially because compliance with power quality requirements depends on the control of cumulative effect of electromagnetic emissions from all/multiple equipment and/or installations.

The values recommended in this document for power quality purposes are equal or very close to the compatibility levels in EMC standards (e.g. IEC 61000 (all parts)) but with a somewhat different meaning. In particular, they differ with respect to their point of application (see Figure F.1) and probability of being exceeded.

F.2 Differences between power quality and compatibility levels

According to IEC 61000-2-2 and IEC 61000-2-12, a compatibility level is a specified electromagnetic disturbance level used as a reference level in a specified environment for coordination in the setting of emission and immunity limits.

By convention, the compatibility level is chosen so that there is only a small probability that it will be exceeded by the actual disturbance level. According to IEC TR 61000-3-6, compatibility levels are generally based on the 95 % probability levels of entire systems, using statistical distributions which represent both time and space variations of disturbances. There is allowance for the fact that the network operator cannot control all points of a system at all times. Therefore, evaluation with respect to compatibility levels is made on a system-wide basis and not at specific locations.

This document defines the characteristics of electricity at the points of supply ~~terminals~~ of public networks. So, the recommended values for power quality indices apply at any point of public networks. Moreover, all weekly 95 % values should meet the recommended values. So, even if the power quality recommended values in this document are equal or very close to the compatibility levels defined in IEC 61000-2-2 and IEC 61000-2-12 for unbalance, harmonics and interharmonics, the criteria are far more severe.

NOTE 1 These differences can make power quality recommended values difficult to meet, in some situations. Hence, higher values than compatibility levels can better characterize the electricity at the point of supply of public networks (see example in Clause F.3).

NOTE 2 Figure F.2 shows the relation between disturbance levels.

While the power quality requirements in this document apply only to the ~~SUPPLY TERMINALS~~ point of supply, these requirements should be coordinated with those concerning the electromagnetic environment of electrical equipment, the utilization point of equipment and the point of common coupling.

The change in voltage characteristics between the network user's point of supply ~~terminals~~ and the equipment terminals/utilization point depends on installation rules and is impacted differently by particular phenomena/electromagnetic disturbances.

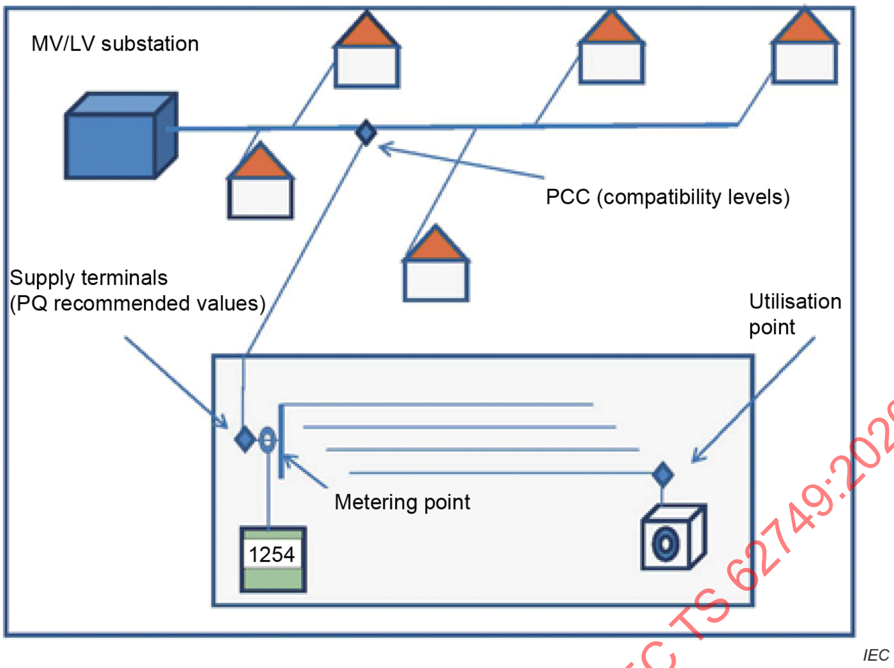


Figure F.1 – Application points in a LV system (example)

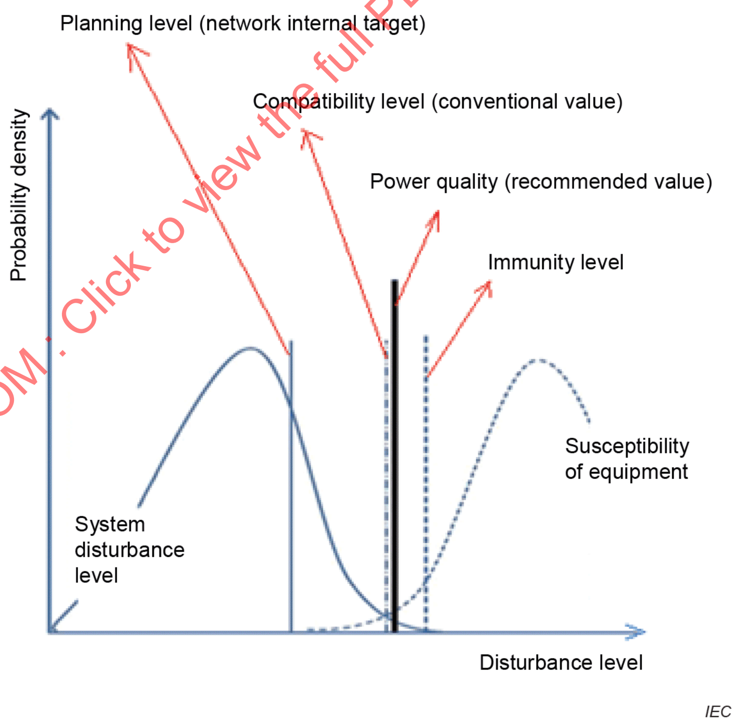


Figure F.2 – Relation between disturbance levels (schematic significance only)

F.3 Example of power quality level versus compatibility level

Suppose power quality monitoring devices installed at 30 LV points of supply recorded continuously the *THD* 10-minute RMS values of the supply voltage during a one week observation period. Hence, 1 008 *THD* values would be recorded at each monitored point of supply, totalling 30 240 recorded *THD* values on the LV system.

As evaluation with respect to compatibility level is made on a system-wide basis and not at specific locations, Figure F.3 gives the cumulative distribution of given 30 240 *THD* values. Results show that 95 % of the *THD* values fall under 7 %, which complies with the LV system compatibility level of 8 %.

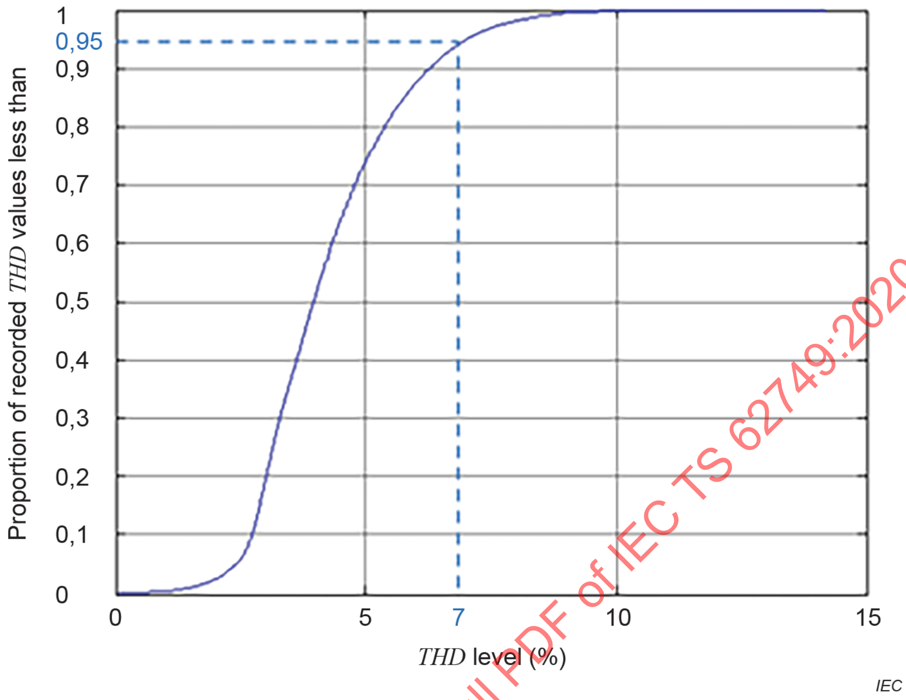


Figure F.3 – Cumulative distribution of all *THD* values recorded at 30 points of supply of the LV system, during one week

For evaluation with respect to power quality levels (or limits) characterizing the supply voltage, the weekly 95th percentile value is calculated at each monitored LV point of supply. Figure F.4 gives these statistical results and compares them with the LV compatibility level (8 %) and the 95th percentile value of all recorded *THD* values on the given LV system (7 %).

Shown as in Figure F.4, although 95 % of the *THD* values of the whole LV system is under compatibility level of 8 %, from PQ perspective, there are still 3 points of supply out of 8 %.

The above example intends to illustrate that although EMC and PQ look like using the same assessment method – percentile value to evaluate against the corresponding limits (compatibility levels for EMC /recommended values for PQ), but with the different meaning of x %. PQ assessment method is more stringent than that of EMC; thus, generally speaking, PQ recommended values may be higher than that of corresponding EMC compatibility levels.

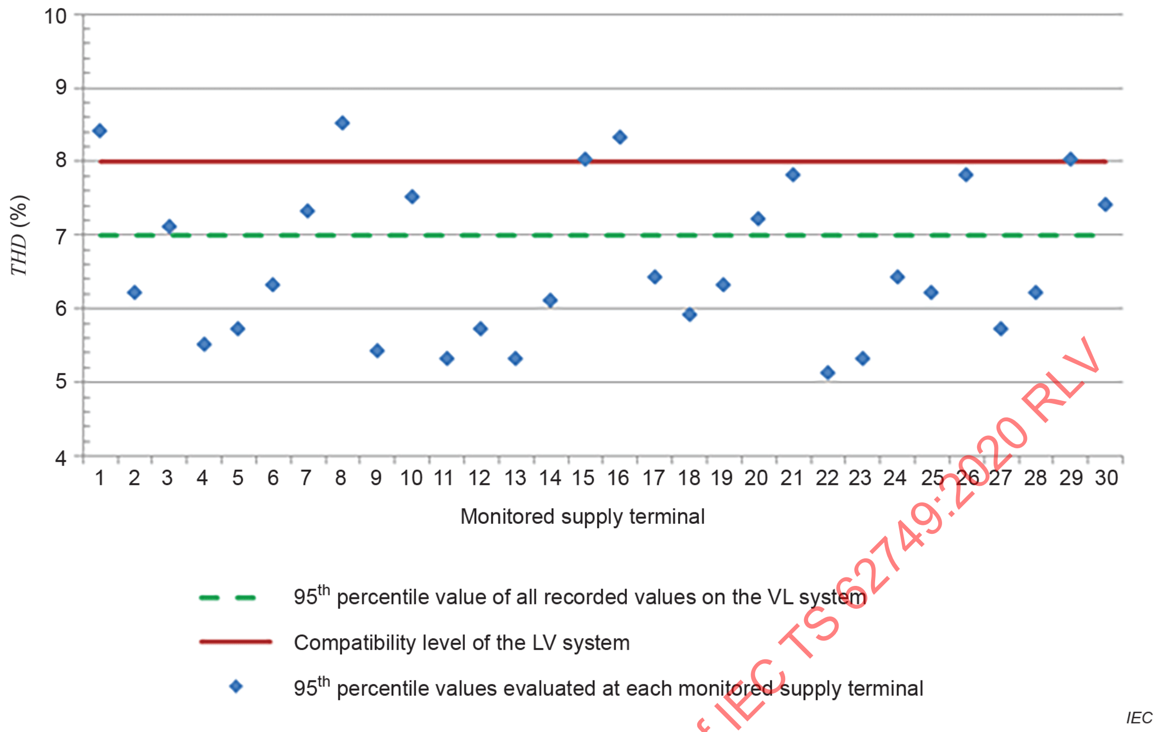


Figure F.4 – Weekly 95th percentile *THD* values evaluated at each monitored LV point of supply

Annex G
(informative)

Other phenomena

G.1 General

Annex G provides additional information about the particular parameters/characteristics of the supply voltage in the presence of mains communicating systems and/or equipment using switch-mode technology connected to the network, named as "other phenomena" in this document.

G.2 Level behaviour over time

It is to be distinguished between the following three aspects.

– Due to variation of loads connected to a network and/or some loads with switching technology, the impedance of the supply network is varying over time. Due to this variability of the grid impedance, the resulting voltages in the grid are varying in an unpredictable way.

– The level of voltages generated in the frequency range 2 kHz to 150 kHz is dependent on the cumulative effect of such equipment being connected to the grid at a given time, and on the action between such connected equipment and the grid impedance.

– Switch mode technologies as well as the transmission of modulated signals cause intermittent high-frequency voltages. Related transients or pulses may have an effect on PQ.

More detailed information about immunity requirements in the frequency range 2 kHz to 150 kHz is given in IEC 61000-4-16 and IEC 61000-4-19.

In addition to IEC 61000-4-30, representing the standard for PQ measurement, and with regard to the aforesaid, a time domain measurement would be also recommended beyond frequency domain measurement for comprehensively evaluating PQ related to voltage levels in the frequency range 2 kHz to 150 kHz.

G.3 Duration

Depending on

– the applied technology of equipment generating voltages in the frequency range 2 kHz to 150 kHz,

– which types of loads are connected to the grid at a given time,

the duration of voltages generated by these loads in the frequency range 2 kHz to 150 kHz can be from a few ms up to permanent.

G.4 Periodicity

Depending on

– the applied technology of equipment generating voltages in the frequency range 2 kHz to 150 kHz,

– which types of loads are connected to the grid at a given time,

some periodicity of voltages generated by these loads in the frequency range 2 kHz to 150 kHz may be given.

G.5 Bandwidth

Concerning the MCS, bandwidth of signal voltages depends on the MCS type (narrow-band, broadband) and the applied modulation system, and may cover some tens of kHz.

Concerning the general electrical equipment, bandwidth of voltages generated by such loads in the frequency range 2 kHz to 150 kHz depends on the choice of the switching frequency (some kHz to several tens of kHz), its multiples and the characteristics of applied embedded filters.

Annex H
(informative)

Role of stakeholders for power quality management – Coordination of the parties involved

H.1 General

In relation to the quality of the supply, three different relations are to be considered:

– Network operator – Network user,
– Network user – Equipment supplier
– Network operator – Equipment supplier.

H.2 Network operator – Network user

The quality of the supply involves two parties directly, the network operator and the network user.

– For the electricity delivered at the point of supply, it is up to the network operator to take all practical steps to ensure that its characteristics remain within such limits as are specified and to inform, if required, the network user of the levels that can occur in normal operating condition (the network user needs also to be aware that abnormal conditions occur occasionally). To fulfil the above responsibility, the network operator is also obliged to maintain reasonable control of the way in which all network users behave, and to provide each network user with such network information as may be necessary to enable him to use the supply and/or export power without disturbance to others.
– The responsibility of the network user is to behave in a way that avoids disturbing the operation of the network or the supply to other users and, insofar as such disturbance arises, to take all necessary steps to reduce it to an acceptable level. That responsibility of the network user includes providing the network operator with all information reasonably requested regarding the equipment that is or will be installed and the way in which it will be operated. Further, the network user has to comply with such conditions for its operation as may be specified by the network operator to prevent the emission of disturbance at an excessive level.

NOTE For practical reasons, this responsibility is fulfilled in this way only for relatively large loads and installations. In relation to other equipment, the quality of the supply, avoidance of disturbance and proper functioning of the networks and users' equipment are dependent on the proper implementation of the EMC process.

H.3 Network user – Equipment supplier

Under normal operating conditions, the network user uses/generates electricity by means of electrical equipment. The supplier of that equipment is indirectly involved in the relationship between network user and network operator.

– The equipment supplier guarantees that the equipment can perform the intended function, including avoidance of disturbance, and is suitable for the electromagnetic environment in which it is intended to operate, including the conditions that can arise in public electricity supplies.
– The equipment supplier is further responsible to provide the network user with such information about the characteristics of the equipment as may be required for transmission to the network operator or for the instruction of the customer.

NOTE Safety considerations in case of normal and abnormal conditions of the network are not dealt with in this document.

H.4 Network operator – Equipment supplier

Finally, at representative level, both network operators and equipment suppliers are involved in the EMC standardization process, in order to ensure that:

– emission limits are such as to prevent disturbance levels on electricity networks rising to values that would hinder or limit the proper functioning of electricity users' equipment or the proper operation of the electricity networks;

– equipment immunity levels are adequate to cope with the disturbances transmitted via the point of supply that can be found in practice.

NOTE While the concern of EMC is to secure the intended operation of equipment, it is clear that the consumer also requires that his equipment should not be damaged. If operation as intended is secured, that normally would be presumed to prevent damage also.

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TECHNICAL SPECIFICATION

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Assessment of power quality – Characteristics of electricity supplied by public networks

IEC TS 62749:2020-02(en)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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ASSESSMENT OF POWER QUALITY – CHARACTERISTICS OF ELECTRICITY SUPPLIED BY PUBLIC NETWORKS

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a Technical Specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical Specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62749, which is a technical specification, has been prepared by IEC technical committee 8: System aspects of electrical energy supply.

The text of this Technical Specification is based on the following documents:

Draft TS	Report on voting
8/1512/DTS	8/1524/RVDTS

Full information on the voting for the approval of this Technical Specification can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

This second edition cancels and replaces the first edition published in 2015. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) minimum number of remaining data for weekly analysis,
b) improvement of the compatibility between EN 50160 and IEC TS 62749,
c) further explanation of the conception of daily sliding window,
d) further explanation of the aggregation method used for events,
e) further explanation of the relation between Power Quality and EMC,
f) addition of a new definition of mains communicating system (MCS),
g) addition of a new Annex G: Other phenomena,
h) transfer of the main content of IEC TR 62510 to IEC TS 62749.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

The description of electricity is of fundamental importance within electricity supply systems. In the past, its characteristics depended less on its generation than on the way in which it was transported by networks and being used by the equipment of the multiple users. Faults or other events such as short-circuit and lightning strikes occurring within users' installations or public networks also disturb or degrade it.

Nowadays, Smart Grid construction and massive deployment of renewable energy sources increase the complexity of power quality management. For more information about power quality issues related to distributed generation and micro-grids, refer to Annex D.

NOTE For more information about role of stakeholders for power quality management, see Annex H.

There is a need for a common set of power quality (PQ) indices and measurement methods in order to allow different system operators to measure and report power quality in a consistent manner.

Regarding the limits or levels of power quality, the situation differs. Historically, the electrical systems in different countries/regions have been designed in different ways to cater for national/regional variations like different geographic, climatic or commercial conditions, etc. It is thus essential that any set of internationally agreed power quality limits or levels also recognize these differences, which depends namely on the system configuration, the transfer characteristics between the different voltage levels (attenuation or amplification), the actual disturbance levels on the system, etc.

Also, the quality of power is not absolute. Optimizing power quality should be carried out in a cost-effective manner to balance network user power quality requirements and willingness to pay for it with power quality supply costs.

Therefore, some of the objectives recommended hereafter allow for a range of values, or options, while still ensuring the coordination of disturbance levels between different parts of the system or voltage levels.

Then, the requirements to be applied can be expressed by the association of the IEC Power Quality framework from the normative part of this document and profiles. Examples of profiles are given in Annex A.

ASSESSMENT OF POWER QUALITY – CHARACTERISTICS OF ELECTRICITY SUPPLIED BY PUBLIC NETWORKS

1 Scope

This Technical Specification specifies the expected characteristics of electricity at the point of supply of public low, medium and high voltage, 50 Hz or 60 Hz, networks, as well as power quality assessment methods.

NOTE 1 The boundaries between the various voltage levels can be different for different countries/regions. In the context of this TS, the following terms for system voltage are used:

- low voltage (LV) refers to $U_N \leq 1$ kV;
- medium voltage (MV) refers to 1 kV $< U_N \leq 35$ kV;
- high voltage (HV) refers to 35 kV $< U_N \leq 230$ kV.

NOTE 2 Because of existing network structures, in some countries/regions, the boundary between medium and high voltage can be different.

This document applies to the phenomena listed in Table 1.

Table 1 – Classification of electromagnetic phenomena addressed by power quality indices

Continuous phenomena	Discontinuous phenomena – Events	Other phenomena
FREQUENCY DEVIATION	SUPPLY INTERRUPTION	MAINS COMMUNICATING VOLTAGES
SUPPLY VOLTAGE DEVIATION	VOLTAGE DIP	
VOLTAGE UNBALANCE	VOLTAGE SWELL	
HARMONIC VOLTAGE	TRANSIENT OVERVOLTAGE	
INTERHARMONIC VOLTAGE	RAPID VOLTAGE CHANGE	
FLICKER （VOLTAGE FLUCTUATION）		

NOTE 3 Specification of related measurement methods can be found in IEC 61000-4-30.

NOTE 4 Specification of the performance of related measuring instruments can be found in IEC 62586.

While power quality is related to EMC in a number of ways, especially because compliance with power quality requirements depends on the control of cumulative effect of electromagnetic emission from all/multiple equipment and/or installations, this document is not an EMC publication (see also Annex F).

2 Normative references

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

IEC 60038, *IEC standard voltages*

IEC 60364-4-44, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*

IEC 60364-5-53, *Low-voltage electrical installations – Part 5-53: Selection and erection of electrical equipment – Devices for protection for safety, isolation, switching, control and monitoring*

IEC 61000-2-2:2002, *Electromagnetic compatibility (EMC) – Part 2-2: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems*
IEC 61000-2-2:2002/AMD1:2017
IEC 61000-2-2:2002/AMD2:2018

IEC 61000-2-12, *Electromagnetic compatibility (EMC) – Part 2-12: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public medium-voltage power supply systems*

IEC TR 61000-2-14, *Electromagnetic compatibility (EMC) – Part 2-14: Environment – Overvoltages on public electricity distribution networks*

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

3 Terms and definitions

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

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

NOTE Terms are listed in alphabetical order.

3.1
code
collection of rules concerning rights and duties of the parties involved in a certain part of the electric power system

Note 1 to entry: For example: grid code, distribution code, code in electric power system.

[SOURCE: IEC 60050-617:2009, 617-03-03, modified – "code in electric power system" has been added in the Note to entry]

3.2
connection agreement
agreement entered between the system operator and a system user which governs the procedure and conditions for connection

[SOURCE: IEC 60050-617:2009, 617-04-03]

3.3
declared supply voltage
U_c
supply voltage agreed by the network operator and the network user

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

3.4
electricity
set of the phenomena associated with electric charges and electric currents

Note 1 to entry: In the context of electric power systems, electricity is often described as a product with particular characteristics.

[SOURCE: IEC 60050-121:1998, 121-11-76, modified – The note has been added]

3.5
electromagnetic environment
totality of electromagnetic phenomena existing at a given location

Note 1 to entry: In general, the electromagnetic environment is time-dependent and its description can need a statistical approach.

[SOURCE: IEC 60050-161:2018, 161-01-01]

3.6
electromagnetic disturbance
electromagnetic phenomenon that can degrade the performance of a device, equipment or system, or adversely affect living or inert matter

Note 1 to entry: An electromagnetic disturbance can be an electromagnetic noise, an unwanted signal or a change in the propagation medium itself.

Note 2 to entry: Electromagnetic disturbance in this TS refers to low frequency conducted phenomena.

[SOURCE: IEC 60050-161:2018, 161-01-05, modified – Note 2 to entry has been replaced and Note 3 to entry has been deleted]

3.7
electromagnetic compatibility
ability of equipment or a system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

[SOURCE: IEC 60050-161:2018, 161-01-07]

3.8
(electromagnetic) compatibility level
specified electromagnetic disturbance level used as a reference level for co-ordination in the setting of emission and immunity limits

Note 1 to entry: By convention, the compatibility level is chosen so that there is only a small probability that it will be exceeded by the actual disturbance level.

[SOURCE: IEC 60050-161:1990, 161-03-10, modified – Note has been shortened and Note 2 has been deleted]

3.9
flagged data
data that has been marked to indicate that its measurement or its aggregation may have been affected by interruptions, dips, or swells

[SOURCE: IEC 61000-4-30:2015, 3.5, modified – modified to better understand this term]

3.10
flicker
impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time

Note 1 to entry: Voltage fluctuation cause changes of the luminance of lamps which can create the visual phenomenon called flicker. Above a certain threshold, flicker becomes annoying. The annoyance grows very rapidly with the amplitude of the fluctuation. At certain repetition rates, even very small amplitudes can be annoying.

Note 2 to entry: For the time being, flicker is qualified based on incandescent lamp's behaviour.

[SOURCE: IEC 60050-161:1990, 161-08-13, modified – Notes to entry have been added]

3.11
flicker severity
intensity of flicker annoyance evaluated by the following quantities:

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

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

Note 1 to entry: For details of P_{st} and P_{lt}, see IEC 61000-4-15.

3.12
frequency deviation
difference between power supply frequency ($f_{H,1}$) and nominal frequency (f_N)

[SOURCE: IEC 60050-614:2016, 614-01-10, modified – "system frequency at a given instant and its nominal value" has been changed to "power supply frequency ($f_{H,1}$) and nominal frequency (f_N)"]

3.13
group total harmonic distortion
THDG (abbreviation)
$THDG_Y$ (symbol)
ratio of the RMS value of the harmonic groups ($Y_{g,h}$) to the RMS value of the group associated with the fundamental ($Y_{g,1}$):

$$THDG_Y = \sqrt{\sum_{h=2}^{h_{max}} \left(\frac{Y_{g,h}}{Y_{g,1}}\right)^2}$$

Note 1 to entry: The symbol Y is replaced, as required, by the symbol I for currents or by the symbol U for voltages.

[SOURCE: IEC 61000-4-7:2002/AMD1:2008, 3.3.2]

3.14
harmonic frequency
$f_{H,h}$
frequency which is an integer multiple of the power supply (fundamental) frequency

[SOURCE: IEC 61000-4-7: 2002/AMD1:2008, 3.2.1, modified – "fundamental frequency of the power system" has been changed to "power supply (fundamental) frequency", the formula and Note to entry have been removed]

3.15
harmonic order
h
(integer) ratio of a harmonic frequency ($f_{H,h}$) to the power supply frequency ($f_{H,1}$)

[SOURCE: IEC 60050-161:1990, 161-02-19, modified – "the integral number given by the ratio of the frequency of a harmonic to the fundamental frequency" has been changed to "(integer) ratio of a harmonic frequency ($f_{H,h}$) to the power supply frequency ($f_{H,1}$)"]

3.16
harmonic ratio
HR
ratio of individual harmonic order component (U_h or I_h) to the fundamental component (U_1 or I_1)

3.17
mains communicating system
MCS
system using mains power lines to transmit information signals, either on the public electricity distribution network or within installations of network users

[SOURCE: IEC 61000-2-2 :2002/AMD1:2017, 3.1.8, modified – "electrical" has been deleted]

3.18
mains communicating voltage
signal superimposed on the supply voltage for the purpose of transmission of information in the public supply network and to network users' premises

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

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

3.19
system operator
network operator
party responsible for safe and reliable operation of a part of the electric power system in a certain area and for connection to other parts of the electric power system

[SOURCE: IEC 60050-617:2009, 617-02-09]

3.20
nominal frequency
f_N
value of frequency used to designate or identify a system

3.21
nominal voltage
U_N
value of voltage used to designate or identify a system

Note 1 to entry: For example: nominal voltage of a system.

[SOURCE: IEC 60050-601:1985, 601-01-21, modified – the abbreviation has been added, "suitable approximate" from beginning of definition has been removed]

3.22
normal operating conditions
operating conditions of a public electricity supply system typically including all generation variations, load variations and reactive compensation or filter states (e.g. shunt capacitor states), planned outages and planned arrangements during maintenance and construction work, non-ideal operating conditions and normal contingencies under which the considered system has been designed to operate

Note 1 to entry: Normal system operating conditions typically exclude exceptional situations such as: conditions arising as a result of a fault or a combination of faults beyond that planned for under the system security standard, unavoidable circumstances (for example: force majeure, exceptional weather conditions and other natural disasters, acts by public authorities, industrial actions), cases where Network users significantly exceed their emission limits or do not comply with the connection requirements, and temporary generation or supply arrangements adopted to maintain supply to Network users during maintenance or construction work, where otherwise supply would be interrupted.

Note 2 to entry: For example: nominal operating conditions of a public electricity supply system.

[SOURCE: IEC TR 61000-3-6:2008, 3.15, modified –"of the system or of the disturbing installation" has been replaced by "of a public electricity supply system", "and planned" has been added to "arrangements", "or the disturbing installation" has been deleted and "the Note to entry has been slightly changed]

3.23
percentile value
$U_{x\%}$ (symbol)
value such that x percent (x %) of measurements are smaller than or equal to that value, over a given period

3.24
planning level
level of a particular disturbance in a particular environment, adopted as a reference value for the limits to be set for the emissions from the installations in a particular system, in order to co-ordinate those limits with all the limits adopted for equipment and installations intended to be connected to the power supply system

Note 1 to entry: Planning levels are considered internal quality objectives to be specified at a local level by those responsible for planning and operating the power supply system in the relevant area.

[SOURCE: IEC TR 61000-3-6:2008, 3.16]

3.25
point of common coupling
PCC
point in a public power supply network, electrically nearest to a particular load, at which other loads are, or may be, connected

Note 1 to entry: These loads can be either devices, equipment or systems, or distinct network user's installations.

[SOURCE: IEC 60050-161:1990,161-07-15, modified – "of a power supply network" has been changed to "in a public power supply network", In the first note, "customer's" has been changed to "user's" and Note 2 to entry has been deleted]

3.26
point of supply
supply terminal
point in a distribution or transmission network designated as such and contractually fixed, at which electric energy is exchanged between contractual partners

Note 1 to entry: Point of supply can be different from the boundary between the electricity supply system and the user's own installation or from the metering point.

[SOURCE: IEC 60050-617:2009, 617-04-02, modified – "or transmission" has been added after "distribution" and "may" has been changed to "can" in the Note to entry]

3.27
network user
party supplying electric power and energy to, or being supplied with electric power and energy from, a transmission system or a distribution system

Note 1 to entry: For example: power network user.

[SOURCE: IEC 60050-617:2009, 617-02-07, modified – The note to entry has been added]

3.28
power quality
characteristics of the electricity at a given point on an electrical system, evaluated against a set of reference technical parameters

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

Note 2 to entry: In the context of this Technical Specification, power quality refers to point of supply and focuses on defining the characteristics of the voltage and frequency.

[SOURCE: IEC 60050-617:2009, 617-01-05, modified – "electric current, voltage and frequencies" have been replaced by "electricity", In Note 1 to entry "electric power system" has been replaced by "network" and Note 2 to entry has been added]

3.29
power quality indices
technical parameters characterizing the quality of electricity, measured at a given point, relevant for the assessment of the quality of the electricity delivered by a network operator

3.30
profile
specification that supplements a standard by limiting options, in order to serve the needs of users in a geographic area or in an application domain

3.31
RMS value of a harmonic component
$Y_{\mathrm{H},h}$
RMS value of one of the components having a harmonic frequency in the analysis of a non-sinusoidal waveform. For brevity, such a component may be referred to simply as a 'harmonic'

Note 1 to entry: The symbol Y is replaced, as required by the symbol I for currents, by the symbol U for voltages.

Note 2 to entry: For more details, see IEC 61000-4-7:2002/AMD1:2008.

[SOURCE: IEC 61000-4-7:2002/AMD1:2008, 3.2.3, modified – The three notes have been replaced]

3.32
RMS value of a harmonic group
$Y_{g,h}$
square root of the sum of the squares of the RMS value of a harmonic and the spectral components adjacent to it within the time window, thus summing the energy contents of the neighboring components with that of the harmonic proper

Note 1 to entry: The symbol Y is replaced, as required by the symbol I for currents, by the symbol U for voltages.

Note 2 to entry: For more details, see IEC 61000-4-7:2002/AMD1:2008.

[SOURCE: IEC 61000-4-7: 2002/AMD1:2008, 3.2.4, modified – The end of the definition has been deleted]

3.33
RMS value of an interharmonic centred subgroup
$Y_{isg,h}$
RMS value of all interharmonic components in the interval between two consecutive harmonic frequencies, excluding frequency components directly adjacent to the harmonic frequencies

Note 1 to entry: The RMS value of the centred subgroup between the harmonic orders h and $h + 1$ is designated as $Y_{isg,h}$; for example, the centred subgroup between $h = 5$ and $h = 6$ is designated as $Y_{isg,5}$.

Note 2 to entry: For more details, see IEC 61000-4-7:2002/AMD1:2008.

[SOURCE: IEC 61000-4-7:2002/AMD1:2008, 3.4.3, modified – "spectral" has been replaced by "interharmonic", the end of the definition has been modified, Note 1 to entry has been modified and Note 2 to entry has been added]

3.34
RMS value of an interharmonic component
$Y_{C,i}$
RMS value of a spectral component of an electrical signal with a frequency between two consecutive harmonic frequencies

Note 1 to entry: For brevity, such a component may be referred to simply as an ‘interharmonic’.

Note 2 to entry: For more details, see IEC 61000-4-7:2002/AMD1:2008, 3.4.2.

[SOURCE: IEC 61000-4-7:2002/AMD1:2008, 3.4.2, modified – The second part of the definition has been changed, the second sentence of the definition has been changed to a Note to entry and Note 2 to entry has been replaced]

3.35
rapid voltage change
RVC
quick transition (that may last more than several cycles) in RMS voltage between two steady-state conditions while the voltage stays in-between the thresholds defined for voltage swells and dips (otherwise, it would be considered as a swell or a dip)

Note 1 to entry: For more information, see IEC 61000-4-30.

3.36
recommended values
value under which, or values within which, the voltage characteristics should remain in view of providing an acceptable quality of the electricity supply

Note 1 to entry: The characteristics of electricity agreed between network operator and a network user or set by national/regional regulatory authority can be locally optimized.

3.37
reference voltage
value specified as the base on which residual voltage, thresholds and other values are expressed in per unit or percentage terms

Note 1 to entry: For example: reference voltage for interruptions, voltage dips and voltage swells measurement and evaluation.

3.38
supply voltage
RMS value of the line-to-line or line-to-neutral voltage at a given time at the point of supply, measured over a given interval

3.39
time aggregation
combination of several sequential values of a given parameter (each determined over identical time intervals) to provide a value for a longer time interval

Note 1 to entry: In this document, 3 s value refers to IEC 61000-4-30 150/180-cycle interval aggregation value (150 cycles for 50 Hz nominal or 180 cycles for 60 Hz nominal); 10 min value and 2 h value are also defined in IEC 61000-4-30.

[SOURCE: IEC 61000-4-30:2015, 3.31, modified –Note 1 to entry has been modified]

3.40
total harmonic distortion
THD (abbreviation)
$\boldsymbol{THD_Y}$ (symbol)
ratio of the RMS value of the sum of all the harmonic components ($Y_{H,h}$) up to a specified order (h_{max}) to the RMS value of the fundamental component ($Y_{H,1}$):

$$THD_Y = \sqrt{\sum_{h=2}^{h_{max}} \left(\frac{Y_{H,h}}{Y_{H,1}} \right)^2}$$

Note 1 to entry: The symbol Y is replaced, as required, by the symbol I for currents or by the symbol U for voltages.

Note 2 to entry: For more information, see IEC 61000-4-30:2015, 5.8.1.

3.41
transient overvoltage
voltage surge
transient voltage wave propagating along a line or a circuit and characterized by a rapid increase followed by a slower decrease of the voltage

[SOURCE: IEC 60050-161:1990, 161-08-11]

3.42
voltage deviation
difference between supply voltage (U) and nominal voltage (U_N), often expressed by relative value

Note 1 to entry: In some circumstances, U_N may be replaced by U_c by contract or agreement.

3.43
voltage dip
sudden reduction of the voltage at a point in an electrical system followed by voltage recovery after a short period of time, usually from a few cycles to a few seconds

Note 1 to entry: The starting threshold of voltage dip generally is 90% of reference voltage.

[SOURCE: IEC 60050-161:1990, 161-08-10, modified – "from" has been changed to "usually from" and Note 1 to entry has been added]

3.44
voltage fluctuation
series of voltage changes or a cyclic variation of the supply voltage envelope

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

[SOURCE: IEC 60050-161:1990, 161-08-05, modified –"or a continuous variation of the RMS or peak value of the voltage" has been changed to "or a cyclic variation of the supply voltage envelope" and Note 1 to entry has been modified]

3.45
voltage short time interruption
disappearance of the supply voltage for a time interval whose duration is between two specified limits

Note 1 to entry: A short time interruption is considered to be a reduction of the supply voltage under the interruption threshold (usually 5 % or 10 % of the reference voltage), with the lower limit of the duration typically a few tenths of a second, and its upper limit typically in the order of 1 min (or, in some cases up to 3 or 5 min).

[SOURCE: IEC 60050-161:1990, 161-08-20, modified – Note 1 to entry has been modified]

3.46
voltage swell
sudden increase of the voltage at a point in an electrical system followed by voltage recovery after a short period of time, usually from a few cycles to a few seconds

Note 1 to entry: The starting threshold of voltage swell generally is 110% of reference voltage.

3.47
voltage unbalance
in a polyphase system, a condition in which the magnitudes of the phase voltages or the phase angles between consecutive phases are not all equal (fundamental component)

[SOURCE: IEC 60050-161:1990, 161-08-09, modified –"RMS values" has been replaced by "magnitudes" and "(fundamental component)" has been added]

3.48
voltage unbalance factor
in a three-phase system, the degree of unbalance expressed by the ratio (in per cent) of the RMS values of the negative sequence component (or the zero sequence component) to the positive sequence component of the fundamental component of the voltage

[SOURCE: IEC 60050-614:2016, 614-01-33, modified – addition of "voltage" to term, deletion of “or the electric current"]

4 Recommended values for power quality indices

4.1 General

Most of the recommendations for power quality at the point of supply are expressed as power quality indices that describe the manner in which the characteristics of electricity vary. Such variations may appear random in time, with reference to any specific point of supply, and random in location, with reference to any given instant of time. As such, the power quality indices are based on the occurrence of the applicable electromagnetic phenomena:

- 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,

- discontinuous phenomena or events, i.e. sudden and significant deviations from normal or desired wave shape which typically occur due to unpredictable events (e.g. faults) or external causes (e.g. weather conditions), and
- other phenomena, i.e. phenomena occurring in the presence of mains communicating systems (MCS) and/or equipment using switch-mode technology connected to the grid. For more information about other phenomena, see Annex G.

The power quality indices and the recommended values are intended to be used as technical reference for regulatory purposes (e.g. in network codes) or for contracts between network operator and network user (e.g. part of a connection agreement).

Power quality requirements combine the obligations of network operators with the requirements of equipment or installations on the electromagnetic environment. It is worth noting however, that the requirements of equipment or installations on the electromagnetic environment also include emission aspects that are addressed in other IEC standards (see Clause 2 and Annex F).

NOTE 1 Network operators are in charge of developing and operating the electricity supply system taking into account at the same time:

- provision of adequate conditions for equipment, installations or other networks connected to their network;
- avoidance of unnecessary costs.

NOTE 2 In many countries/regions, requirements concerning the essential characteristics of electricity at points of supply of public networks are set, or controlled, by National/Regional Regulatory Authorities.

In some cases, additional requirements or differences in requirements can be agreed by terms of a contract (usually a connection agreement) 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, or having power quality sensitive load. It may also arise in sparsely populated or difficult terrain, such as mountain regions, where distribution costs are high. In such an area, a network user may be willing to accept a connection, at lower cost, which does not entirely comply with the power quality standards.

NOTE 3 The quality indices and the recommended values appropriately cover the vast majority of locations under acceptable economic conditions, despite the differences in situations, provided that:

- for mass-market products, emission requirements in standards such as IEC 61000-3-2, IEC 61000-3-3, IEC 61000-3-11 and/or IEC 61000-3-12 are regularly and appropriately updated to take into account the development of markets and changes in technologies;
- for large installations, emission levels are effectively controlled, e.g. through connection agreement (Annex E lists some methods to improve power quality);
- network operators make use of appropriate methodologies and engineering practices, e.g. based on planning levels and IEC TR 61000-3-6, IEC TR 61000-3-7, IEC TR 61000-3-13 and/or IEC TR 61000-3-14.

Regarding phenomena that occur continuously over time, this document provides the recommended or indicative values applicable during normal operating conditions. It considers an observation period of at least one week, e.g. in order to take account for variation in loads.

Measurement of voltage characteristics requires an aggregation time interval for both actual calculation of the voltage and for comparability between results at different points in time. In the case of this document, the 10-minute interval proposed in IEC 61000-4-30 is used for most phenomena.

NOTE 4 In some countries/regions, aggregation time intervals less than 10-minute are used.

NOTE 5 Voltage fluctuation leading to long term flicker and mains communicating voltage has specific observation period and/or aggregation time intervals.

The versatility and adaptability of electricity are managed by assigning some probability factors to the recommended values for some power quality indices. Percentile values are then compared to the recommended values expected to be statistically fulfilled within the observation periods. The related probability should never be less than 95 %.

Flagging concept is used in this document according to IEC 61000-4-30. Unless otherwise indicated (e.g. for voltage deviation), the flagged data is excluded in the calculation of percentile values.

For the relevance of the result, care should be taken regarding the number of the excluded and missing (for any reasons) data, e.g. for the weekly assessment, if more than 10 % of data are excluded or missing, a specific treatment should be performed. Percent of flagged data should be observed to ensure relevant data are not missed by default flagging.

Network disturbances corresponding to discontinuous phenomena or events shown in Table 1 require a relatively long observation period. Depending on the frequency of their occurrence and the wanted level of statistical accuracy, this period can vary between a single season to several years. These phenomena are mostly unpredictable, which makes it very difficult to give useful definite values for the corresponding characteristics. The values given in this document for the voltage characteristics associated with such phenomena, i.e. voltage dips/swells, voltage interruptions and rapid voltage changes, shall be interpreted as indicative.

For all phenomena, the measurements are performed according to IEC 61000-4-30.

4.2 Frequency deviation

The frequency shall be maintained within a given deviation from the specified value, 50 Hz or 60 Hz, in order to maintain a stable power system operation.

NOTE 1 In different synchronous areas, different requirements can apply (generally originated from grid codes).

NOTE 2 For systems with no synchronous connection to an interconnected system (e.g. supply systems on certain islands or microgrids in islanding mode), specific requirements can apply.

4.3 Supply voltage deviation

4.3.1 General

Standard voltages are defined in IEC 60038.

4.3.2 Low voltage systems

For low voltage systems, recommended values are based on nominal voltage (U_N).

Data flagged by voltage dips and swells shall be included in the calculation of percentile values.

NOTE 1 In low voltage systems, declared and nominal voltage are equal.

NOTE 2 The nominal voltage U_N for public low voltage is either between line and neutral or between lines.

Under normal operating conditions, during each period of one week, the 10-minute RMS values of the voltage at the point of supply (U), excluding the periods of interruptions, should comply with the following conditions:

- voltage percentile $U_{\rho\,\%}$ does not exceed $U_N + 10\ \%$;
- voltage percentile $U_{\beta\,\%}$ is not lower than $U_N - 10\ \%$;

  ρ having a value in the range [99, 100] according to national/regional conditions,

  β having a value of 5 or in the range of [0, 1] according to national/regional conditions,

- and, if $\beta > 100 - \rho$, voltage percentile $U_{(100-\rho)\,\%}$ is not lower than $U_N - 15\ \%$.

NOTE 3 The limits of the supply voltage deviation are more restrictive in some countries/regions.

NOTE 4 In some countries/regions, the voltage range can be specified asymmetrically with regard to the nominal voltage, e.g. + 6 % ~ – 14 %.

NOTE 5 Voltage percentile $U_{100\ \%}$ is equal to the maximum value, voltage percentile $U_{0\ \%}$ is equal to the minimum value.

4.3.3 Medium voltage systems

Network users with demands exceeding the capacity of the LV network are generally supplied at nominal voltages above 1 kV. This subclause applies to such electricity supplies at nominal voltages up to and including 35 kV.

NOTE 1 Network users can also be supplied at this voltage level to satisfy special requirements or to mitigate conducted disturbances emitted by their equipment.

For medium voltage systems, recommended values are based on the declared voltage (U_c).

Data flagged by voltage dips and swells shall be included in the calculation of percentile values.

Under normal operating conditions, during each period of one week, the 10-minute RMS values of the voltage at the point of supply (U), excluding the periods of interruption, should comply with the following conditions:

- voltage percentile $U_{99\ \%}$ does not exceed U_c + 10 %;
- voltage percentile $U_{1\ \%}$ is not lower than U_c – 10 %;
- voltage percentile $U_{0\ \%}$ is not lower than U_c – 15 %.

NOTE 2 In some countries/regions, the voltage range can be specified asymmetrically with regard to the declared voltage.

NOTE 3 In some countries/regions, $U_{100\ \%}$ doesn't exceed U_c + 15 %.

NOTE 4 Voltage percentile $U_{100\ \%}$ is equal to the maximum value, voltage percentile $U_{0\ \%}$ is equal to the minimum value.

4.3.4 High voltage systems

This subclause applies to electricity supplies at nominal voltages above 35 kV and not exceeding 230 kV.

NOTE 1 Network users can also be supplied at this voltage level to satisfy special requirements or to mitigate conducted disturbances emitted by their equipment.

NOTE 2 The number of network users supplied directly from HV networks is limited and normally the supply voltage is subject to individual contract.

For high voltage systems, recommended values are based on the declared voltage (U_c).

Data flagged by voltage dips and swells shall be included in the calculation of percentile values.

Under normal operating conditions, during each period of one week, the 10-minute RMS values of the voltage at the point of supply (U), excluding the periods of interruption, should comply with the following conditions:

- voltage percentile $U_{99\ \%}$ does not exceed U_c + 10 %;
- voltage percentile $U_{1\%}$ is not lower than U_c – 10 %.

4.4 Voltage unbalance

Under normal operating conditions, during each period of one week, the 10-minute RMS value of voltage unbalance factor (negative sequence) should be less than or equal to the recommended value for 95 % of the time or more.

For three phase LV, MV, and HV supply system, the negative sequence voltage unbalance factor $\varepsilon(\%)$ recommended value is 2 %.

NOTE In some countries/regions with part single phase or two phase connected network user's installations, an unbalance up to 3 % at the three phase point of supply can occur.

4.5 Flicker

Under normal operating conditions, during each period of one week, the flicker severity P_{lt} should be less than or equal to the recommended values defined in Table 2 for 95 % of the time or more.

In the case of complaints, the HV and MV limits, and appropriate mitigation measures, shall be chosen in such a way that at LV, the P_{lt} values do not exceed 1.

Table 2 – Flicker severity P_{lt} recommended values

Voltage levels	P_{lt}
LV/MV	1,0
HV	1,0

NOTE 1 The recommended values are based on the effect of voltage fluctuation on classical incandescent lamps. Modern types of lamps can have different behaviour.

NOTE 2 These limits take into consideration the flicker attenuation from MV to LV and from HV to MV.

4.6 Harmonic and interharmonic voltage

4.6.1 General

Recommended or indicative values are given for individual harmonic voltages, namely harmonic ratio (*HR*), and for total harmonic distortion (*THD*).

Resonances may cause higher voltages for an individual harmonic, however these effects should be controlled whenever they may have an impact on the system or equipment (for main impact of poor power quality, refer to Annex C).

Recommended values (or limits) will be given hereafter for interharmonic voltages as well. However, these limits are not meant to control flicker effects or interference in ripple control systems.

4.6.2 Low voltage systems

4.6.2.1 Harmonic voltages

Under normal operating conditions, during each period of one week, the voltage percentile $U_{h95\ \%}$ of the 10-minute RMS values of each individual harmonic voltage should be less than or equal to the values given in Table 3.

Table 3 – Recommended values of individual harmonic voltages at the low voltage points of supply for orders up to 50 given in percent of the fundamental voltage U_1

Odd harmonics				Even harmonics	
Not multiples of 3		Multiples of 3 [a]			
Order h	$U_{h95\ \%}$ %	Order h	$U_{h95\ \%}$ %	Order h	$U_{h95\ \%}$ %
5	6,0	3	5,0 (6,0)	2	2,0
7	5,0	9	1,5 (3,5)	4	1,5
11	3,5	15	1, 0 (2, 0)	6 … 24	0,75
13	3,0	21	0,75 (1,5)		
17	2,0				
19	1,8				
23	1,5				
25	1,5				
$29 \le h \le 49$	$2{,}27 \times (17/h) - 0{,}27$	$27 \le h \le 45$	0,5	$26 \le h \le 50$	0,5

NOTE 1 Where national/regional circumstances make it appropriate, lower limits than the values given in Table 3 can be specified.

NOTE 2 Depending on the type of voltage transformer used, the measurement of high order harmonics could be not reliable; further information is given in IEC 61000-4-30:2015, A.3.3.

[a] Depending on the type of neutral grounding systems and transformer connections in some countries/regions, more triplen harmonics will flow in neutral conductors and could cause higher harmonic voltages. In these cases, the highest value in brackets in Table 3 should adequately characterize the system harmonic voltages.

The total harmonic distortion (*THD*) of the supply voltage for harmonic orders up to 50 should be less than or equal to 8 %.

NOTE In some countries/regions, orders up to 40, only, are used to calculate the *THD*, maintaining the same recommended value.

4.6.2.2 Interharmonic voltages

The same statistical approach and the same range of values (see Table 3) should apply to harmonic (centred) group voltages as to individual harmonic voltages from Subclause 4.6.2.1. The group total harmonic distortion (*THDG*) of the supply voltage should also be less than or equal to 8 %.

In addition, based on a prudent consideration suggested in IEC 61000-2-2, indicative values and indices should be as follows. Under normal operating conditions, during each period of one week, the interharmonic voltage percentile $U_{h95\ \%}$ of the 10-minute RMS values of each interharmonic centred subgroup voltage should be no higher than those of the adjacent harmonic voltage given in Table 3.

4.6.3 Medium voltage systems

4.6.3.1 Harmonic voltages

Under normal operating conditions, during each period of one week, the voltage percentile $U_{h95\ \%}$ of the 10-minute RMS values of each individual harmonic voltage should be less than or equal to the values given in Table 4.

Table 4 – Recommended values of individual harmonic voltages at the medium voltage points of supply for orders up to 50 given in percent of the fundamental voltage U_1

Odd harmonics				Even harmonics	
Not multiples of 3		Multiples of 3 [a]			
Order h	$U_{h95\ \%}$ %	Order h	$U_{h95\ \%}$ %	Order h	$U_{h95\ \%}$ %
5	6,0	3	5,0 (6,0)	2	2,0
7	5,0	9	1,5 (3,5)	4	1,5
11	3,5	15	1,0 (2,0)	6 ... 24	0,75
13	3,0	21	0,75 (1,5)		
17	2,0				
19	1,8				
23	1,5				
25	1,5				
$29 \leq h \leq 49$	$2,27 \times (17/h) - 0,27$	$27 \leq h \leq 45$	0,5	$26 \leq h \leq 50$	0,5

NOTE 1 Where national/regional circumstances make it appropriate, lower limits than the values given in Table 4 can be specified.

NOTE 2 Depending on the type of voltage transformer used, the measurement of high order harmonics could be not reliable; further information is given in IEC 61000-4-30:2015, A.3.3.

NOTE 3 When end-use equipment is not directly connected to the MV system, lower values for MV could be more appropriate to allow coordination of disturbance levels between low and medium voltage systems.

[a] Depending on the type of neutral grounding systems and transformer connections in some countries/regions, more triplen harmonics will flow in neutral conductors and could cause higher harmonic voltages. In these cases, the highest value in brackets in Table 4 should adequately characterize the system harmonic voltages.

The total harmonic distortion (*THD*) of the supply voltage for orders up to 50 should be less than or equal to 8 %.

NOTE In some countries/regions, orders up to 40, only, are used to calculate the *THD*, maintaining the same recommended value.

4.6.3.2 Interharmonic voltages

The same statistical approach and the same range of values (see Table 4) should apply to harmonic (centred) group voltages as to individual harmonic voltages from Subclause 4.6.3.1. The group total harmonic distortion (*THDG*) of the supply voltage should also be limited under the value of 8 %.

In addition, based on a prudent consideration suggested in IEC 61000-2-12, indicative values and indices should be as follows. Under normal operating conditions, during each period of one week, the interharmonic voltage percentile $U_{h95\ \%}$ of the 10-minute RMS values of each interharmonic centred subgroup voltage should be no higher than those of the adjacent harmonic voltage given in Table 4.

4.6.4 High voltage systems

4.6.4.1 Harmonic voltages

Under normal operating conditions, during each period of one week, the voltage percentile $U_{h95\ \%}$ of the 10-minute RMS values of each individual harmonic voltage should be less than or equal to the values given in Table 5.

It is worthwhile mentioning that for HV transmission systems, one must realize the different purpose of voltage quality objectives. In contrast to low or medium voltage systems, quality objectives for harmonics in HV transmission systems are generally not directly related to their impact on equipment as the end-use equipment is not directly connected at HV. Indeed, these indicative levels are well below the levels that could cause immediate disturbances on the equipment. The indicative values on transmission systems are aimed at coordinating disturbance levels between different parts of the system or different voltage levels and may serve as indication of holistic network problems which warrant consideration.

Consequently, the indicative values of individual harmonic voltages at the higher voltage level should not be higher than the value for the lower one (MV and LV).

Table 5 – Indicative values of individual harmonic voltages at the high voltage points of supply given in percent of the fundamental voltage U_1

Odd harmonics				Even harmonics	
Not multiples of 3		Multiples of 3			
Order h	U_h %	Order h	U_h %	Order h	U_h %
5	2,0 to 5,0	3	2,0 to 3,0	2	1,5 to 1,9
7	2,0 to 4,0	9	1,0 to 2,0	4	0,8 to 1,0
11	1,5 to 3,0			6 …12	0,5
13	1,5 to 2,5				

NOTE 1 Limits for individual harmonic voltage of order higher than 13 are not defined due especially to the limited accuracy of voltage transformers currently in use on HV systems. For measurement accuracy, an appropriate type of voltage transformer can be used, particularly for the measurement of higher order harmonics.

NOTE 2 Due to the wide range of voltage levels included in HV (35 kV to 230 kV) and where national/regional circumstances make it appropriate, limits for intermediate voltage levels can be specified within the range of values given in Table 5.

The total harmonic distortion (THD) of the supply voltage should be limited under a value within 3 % to 6 % (including harmonics for orders up to 50).

NOTE In some countries/regions, orders up to 40, only, are used to calculate the THD, maintaining the same recommended value.

4.6.4.2 Interharmonic voltages

The same statistical approach and the same range of values (see Table 5) should apply to harmonic (centred) group voltages as to individual harmonic voltages from Subclause 4.6.4.1. The group total harmonic distortion ($THDG$) of the supply voltage should also be limited under a value within 3 % to 6 %.

In addition, based on a prudent consideration suggested in IEC 61000-2-12, indicative values and indices should be as follows. Under normal operating conditions, during each period of one week, the interharmonic voltage percentile $U_{h95\ \%}$ of the 10-minute RMS values of each interharmonic centred subgroup voltage should be no higher than those of the adjacent harmonic voltage given in Table 5.

4.7 Voltage dip

Voltage dips typically originate from short circuits occurring in the public network or in network users' installations. The annual frequency varies greatly depending on the type of supply system and on the point of observation. Moreover, the distribution over the year can be very irregular.

The power quality characteristics of individual events are defined for each individual phase, by residual voltage and duration, despite the specific shape of the RMS voltage variation. Recommended values of voltage dips are still under consideration. More assessment methods are described in 5.2 and 5.3 hereafter.

Where assessments are performed or statistics are collected to be provided to network users or authorities, voltage dips should be classified according to Table 10.

For polyphase measurements, it is recommended that the number of phases affected by each event be detected and stored.

Generally, according to the network user connection, or the concrete situation, line to line or line to neutral voltage shall be considered.

4.8 Voltage swell

Frequently, voltage swell phenomenon may occur to be unpredictable and random. Depending upon the magnitude and duration, voltage swell may affect different types of load differently for the same voltage swell event. Recommended values of voltage swells are still under consideration. More assessment methods are described in 5.2 and 5.3 hereafter.

Where assessment is performed or statistics are collected to be provided to network users or authorities, voltage swells should be classified according to Table 10.

For polyphase measurements, it is recommended that the number of phases affected by each event be detected and stored.

Generally, according to the network user connection, or the concrete situation, line to line or line to neutral voltage shall be considered.

4.9 Voltage interruption

On single-phase systems, a voltage interruption begins when the residual voltage falls under interruption threshold.

On polyphase systems, a voltage interruption begins when the residual voltage of all phases falls under interruption threshold.

Interruption threshold is generally 5 % or 10 % of the reference voltage.

Even when referring only to normal operating conditions, the annual frequency of supply interruptions varies substantially between areas. This is due, amongst other things, to differences in system layout (e.g. cable systems versus overhead line systems), environmental or climatic conditions.

In most countries/regions, specific continuity of supply indices is established by regulators in order to facilitate the benchmarking of the performance of the network operators under their jurisdiction. The indices allow network operators to meet their obligation to routinely report continuity of supply performance.

In the context of this document, voltage short time interruptions are mostly addressed. The detection of short time voltage interruptions is referred to in IEC 61000-4-30 and more assessment methods are described in 5.2 and 5.3 hereafter.

Where assessment is performed or statistics are collected to be provided to network users or authorities, voltage short time interruption should be classified according to Table 10.

4.10 Mains communicating voltage

The public networks may be used by the network operators or network users for the transmission of signals. Three types of systems are considered by standards:

- ripple control systems that are used by electrical utilities in public supply networks, in the range of 100 Hz to 3 kHz, generally below 500 Hz, with signals up to 5 % of U_N under normal circumstances and up to 9 % of U_N in cases of resonance;
- power-line carrier systems used by electrical utilities in public supply networks, in the range 3 kHz to 95 kHz, with allowed signal levels up to 5 % of U_N. These signals are strongly attenuated in the network (>40 dB);
- signalling systems for end-user premises (residential or industrial) in the range of 95 kHz to 148,5 kHz in Europe (ITU region 1), with allowed signal levels up to 0,6 % of U_N or 5 % of U_N, respectively. In some countries/regions, the upper frequency is 500 kHz, with allowed signal levels between 2 mV to 0,6 mV.

Signal voltages recommended values in LV and MV are indicated in Figure 1. For 99 % of a day, the 3 s RMS value of signal voltages shall be less than or equal to the recommended values.

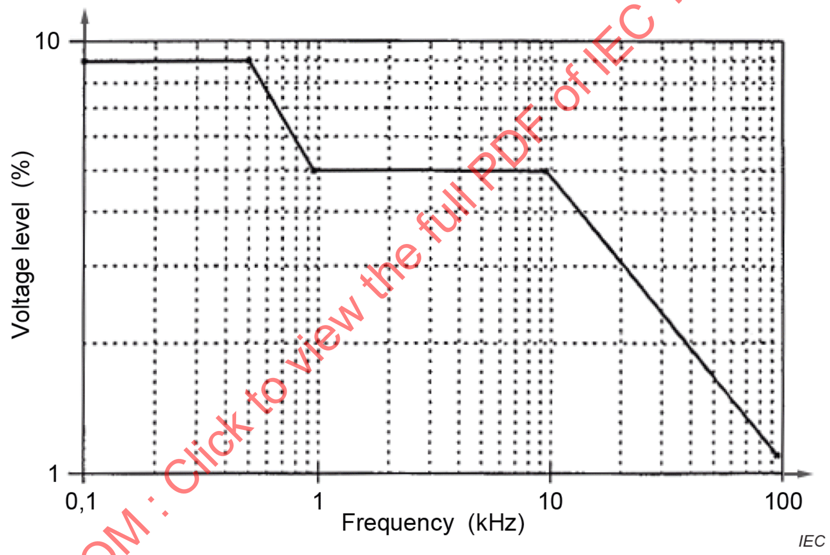

Figure 1 – Mains communicating voltages recommended values in percent of U_N used in public LV networks (or U_c in public MV networks)

NOTE 1 Due to the low resonance frequency of the HV network, no values are given for mains communicating voltages.

NOTE 2 The effective use of mains signalling is challenged by the presence of harmonic, interharmonic and high frequency conducted disturbances generated by power electronics (e.g. Active Infeed Converters). For compatibility levels for LV public network, refer to IEC 61000-2-2:2002/AMD1:2017, AMD2:2018 for MCS and NIE.

NOTE 3 Depending on the type of voltage transformer used, the measurement of high frequency mains communicating voltages can be not reliable; further information is given in IEC 61000-4-30:2015, A.3.3.

4.11 Rapid voltage change

Under normal operating conditions (excluding events), rapid voltage changes should not exceed indicative values.

Rapid voltage change indicative values are in the range of 3 %~5 % of U_N (U_c) for LV, MV and HV.

These values specifically refer to relative steady-state voltage changes aggregated over very-short time intervals, e.g. 150/180-cycle time intervals (all variations during these intervals are to be aggregated in the RMS value of the so-called steady-state voltage). They are based on the usual design criteria for reactive compensation equipment and motor starting, for example.

In some countries/regions, there are no RVC limits specified. Where national/regional circumstances make it appropriate, different limits may be specified than the values given in this document.

NOTE In this document, no values are given for the maximum voltage change (d_{max}) as defined in IEC 61000-3-3.

4.12 Transient overvoltage

4.12.1 Low voltage systems

Transient overvoltages at the points of supply of LV systems are generally caused by lightning (induced overvoltage) or by switching in the system or in the installation. More information on overvoltage can be found in IEC TR 61000-2-14.

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

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

For withstanding transient overvoltages in the vast majority of cases, where necessary (see IEC 60364-4-44), surge protective devices should be selected according to IEC 60364-5-53, to take account of the actual situations. This is assumed to cover also induced overvoltages due to both lightning and switching.

4.12.2 Medium and high voltage systems

Transient overvoltages in MV or HV supply systems are caused by switching or by lightning, directly or by induction. Switching overvoltages generally are lower in amplitude than lightning overvoltages, but they can have a shorter rise time and/or longer duration. More information on overvoltage can be found in IEC TR 61000-2-14.

The network users' insulation coordination scheme should be compatible with that adopted by the network operator.

5 Objectives and methods for power quality assessment

5.1 General

Generally, power quality assessments are made for:

- Network operator performance evaluation

  This evaluation is often required by either regulatory authorities or by the network users to value power quality against relevant standards, e.g. assessment for survey, complaint, verification of compliance with connection agreement, compliance with quality regulation, or benchmarking.

- Trouble shooting

  To diagnose power quality related problems such as system harmonic resonance, custom producing process abnormal interruption, equipment malfunction, etc., typically, raw unaggregated power quality measurement data are most useful for troubleshooting, as they permit any type of post-processing preferred.

In this case, emphasis should be focused on the measurement of current which is invaluable in determining sources/causes of power quality disturbances, since it can help to determine if the cause of the problem is up stream or downstream of the measuring instrument.

- System planning

  Power quality is an important aspect for the development of the network for system expansion or connection of new sensitive or disturbing installations (these could be either a load or a generator).

Attention shall be paid to the power quality assessment to ensure that the power quality evaluation process addresses the following 5 aspects explicitly:

- recommended or/indicative values;
- system conditions associated with recommended values;
- points on which power quality recommended values are applied;
- methods how power quality parameters are to be measured;
- methods by which assessment results come out from the large number of measurement field data. These methods are provided in 5.2 and 5.3 hereafter.

Although some types of disturbances are assumed to be continuous phenomena likely to be present on any point of supply, it is also important to keep in mind that these types of disturbances vary widely in time. Accordingly, any assessment approach used should carefully consider whether the time varying nature of these disturbances is properly addressed.

5.2 Site power quality assessment

5.2.1 General

For site power quality assessment, two kinds of methods are often used commonly depending on the concerning phenomena:

- statistical indices like percentile values, maximum or mean values over a certain period of time;
- event counting and tabulating.

5.2.2 Continuous phenomena

For continuous power quality phenomena assessment focusing on site, methods defined in Table 6 are recommended in this document.

Table 6 – Site power quality assessment methods

Phenomena	Minimum assessment period [a]	Assessment indices				Indicative value [d]
		not exceeding corresponding recommended values [b]			not exceeding k times corresponding recommended values [c]	
Supply voltage deviation	1 week	**Voltage**	**Low level**	**Upper level**	–	Max. upper level and low level supply voltage daily 3 s values with corresponding time stamp
		LV (see 4.3.2)	β % weekly 10-minute RMS values β = 5 or $\beta \in$ $\frac{-b\pm\sqrt{b^2-4ac}}{2a}$ [0, 1]	P % weekly 10-minute RMS values $\rho \in$[99, 100]		
			if $\beta > 100 - \rho$, $(100 - \rho)$ % weekly 10-minute RMS values			
		MV (see 4.3.3)	1 % weekly 10-minute RMS values	99 % weekly 10-minute RMS values		
			0 % weekly 10-minute RMS values			
		HV (see 4.3.4)	1 % weekly 10-minute RMS values	99 % weekly 10-minute RMS values		
Voltage unbalance	1 week	95 % weekly 10-minute RMS values (see 4.4)			99 % daily 3 s values	Max. daily 3 s values with corresponding time stamp
Flicker	1 week	95 % weekly 2 h P_{lt} values (see 4.5)			99 % daily 10-minute P_{st} values	Max. daily 10-minute P_{st} values with corresponding time stamp
Harmonics and inter-harmonics	1 week	95 % weekly 10-minute RMS values (see 4.6)			99 % daily 3 s values	Max. daily 3 s values with corresponding time stamp
Mains communicating voltage	1 day	99 % daily 3 s values (see 4.10)			–	Max. daily 3 s values with corresponding time stamp

[a] For long time measurement assessment, an assessed weekly value should be retained on a daily sliding basis; Figure 2 is an example. See also Annex B.

[b] Assessment for survey, complaint, verification of compliance with connection agreement, compliance with quality regulation, or benchmarking.

[c] Assessment for more detailed power quality during assessment period. The coefficient k shall be determined by long term measurement campaigns in several sites in order to proper characterize the voltage supplied with the power quality very short-time indices given in Table 6. The range of k for each phenomenon is between 1,25 to 2.

[d] Only for trouble shooting purpose. Here corresponding time stamp with appropriate time resolution is needed for further post analysis in case of incident occurring at the same time to find out the relationship between the incident and the power quality parameter indices.

NOTE 1 Flagging concept is used in this document according to IEC 61000-4-30. Unless otherwise indicated, e.g. for voltage deviation, the flagged data is excluded in the calculation of percentile values.

NOTE 2 Here in Table 6, 10-minute RMS values are referred to '10 min interval' values defined by IEC 61000-4-30; 3 s values are referred to '150/180-cycle interval' values (150 cycles for 50 Hz nominal or 180 cycles for 60 Hz nominal) defined by IEC 61000-4-30.

NOTE 3 Where national/regional circumstances make it appropriate, different aggregation intervals can be specified.

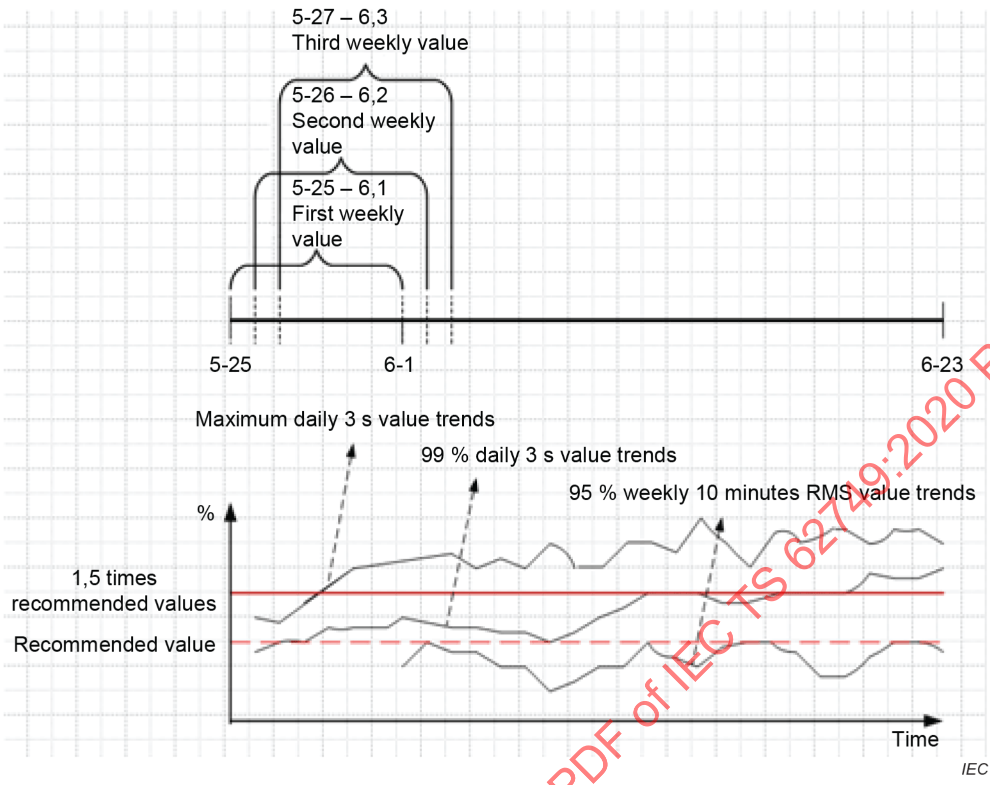

Figure 2 – Example for illustrating voltage *THD* assessment result trends

5.2.3 For discontinuous phenomena (single event)

For individual event evaluation, useful parameters can be tabulated during each event.

For evaluation of voltage dip and voltage swell, residual voltage and duration combined with the RMS voltage variation shape can be tabulated as shown in Table 7 and Figure 3 for example.

The measurement and detection methods for voltage swells, dips and short time interruptions should be in accordance with IEC 61000-4-30.

Table 7 – Example of single event assessment

Event attribution	Detailed characterization
Location	East station 10 kV busbar
Time stamp	2011-06-30 12 h:36 m:12.2150 s
Capturing threshold	80 %
Residual voltage	21 %
Time duration	81,9 ms
RMS variation shape	Upper part in Figure 3
Point on wave	Lower part in Figure 3

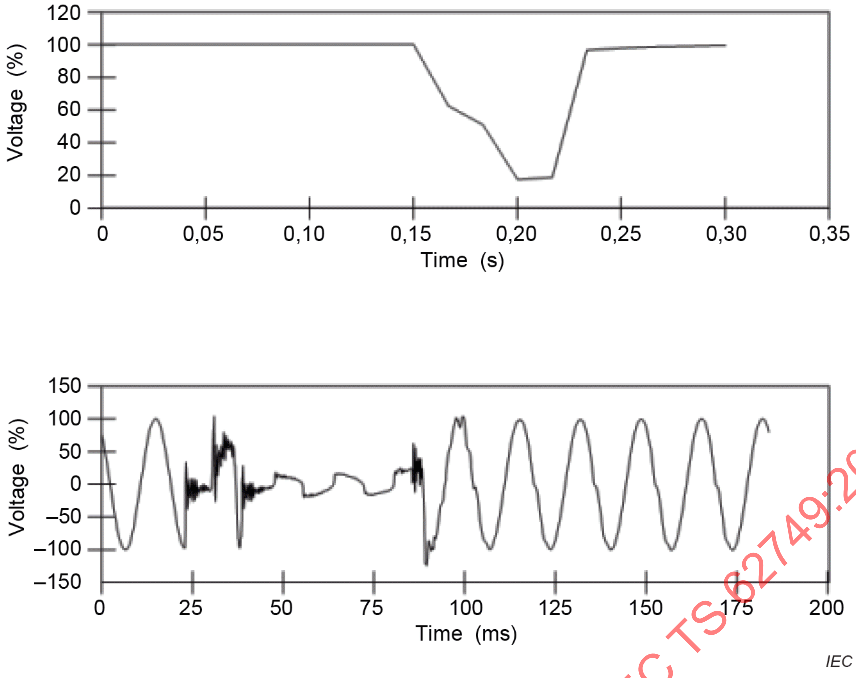

Figure 3 – Example showing information of single event assessment

5.3 System aspect power quality assessment

5.3.1 General

For system (sub-system/area) power quality assessment, weighting rules may be used applying both to statistical indices and events in order to get global results depending on the details of collection of single points.

NOTE For more information on weighting rules, see Bibliography [31].

5.3.2 For continuous phenomena

For system power quality indices, there are no corresponding recommended values, but the assessment based on site evaluation results can give very useful information for system power quality management.

Annex B gives an example of system aspect continuous disturbance evaluation.

5.3.3 For discontinuous phenomena (events)

5.3.3.1 General

For system aspect assessment of voltage dips, voltage swells and supply interruptions, the following *SARFI* methods combining with the magnitude-duration table (Table 10) can be used.

NOTE 1 Detailed information about *SARFI* methods is presented in IEEE 1564.

NOTE 2 For system aspect assessment of voltage dips, voltage swells and supply interruptions, several methods are also presented in CENELEC TR 50555.

Time aggregation method, in the case of multiple successive voltage dips, voltage swells and supply interruptions, should be used prior to the assessment. The time aggregation duration is defined as 1 minute in this document. Aggregation rules, if used, should be declared.

For more information about time aggregation methods, see Annex B.

5.3.3.2 SARFI method

SARFI is an acronym for System Average RMS Variation Frequency Index (*SARFI*). It is a power quality index that provides a count or rate of voltage dips, swells, and/or interruptions for a system. The size of the system is scalable: It can be defined as a single monitoring location, a single network user service, a feeder, a substation, groups of substations, or for an entire power delivery system.

SARFI-X corresponds to a count or rate of voltage dips, swells and/or interruptions below or above a voltage threshold. For example, *SARFI-70* considers voltage dips and interruptions that are below 0,70 per unit, or 70 % of the reference voltage. *SARFI-110* considers voltage swells that are above 1,1 per unit, or 110 % of the reference voltage.

In this document, a rate of 30 days (number of events/30 days) is recommended for assessment of voltage dips, swells and/or interruptions below or above a voltage threshold. If the measured period of the events would be longer than or shorter than 30 days, *SARFI-X* indices will be calculated accordingly.

The following is an example using the *SARFI-X* method. Table 8 presents a list of residual voltages with corresponding events duration at a single monitoring site and Table 9 gives *SARFI-X* indices coming out of Table 8. The observation period is from Jul-01-2000 to Oct-1-2000, total 92 days.

Table 8 – List of individual events measured at a single monitoring site

Time stamp	Residual voltage (%)	Event duration (ms)
Jul-01-2000 09:48:52	73	180
Jul-01-2000 09:50:16	73	180
Jul-07-2000 14:20:12	0	1 640
Jul-10-2000 15:55:23	13	2 000
Jul-21-2000 09:48:52	0	2 600
Aug-08-2000 07:35:02	49	680
Sep-02-2000 08:30:28	0	41 000
Sep-08-2000 10:30:40	59	800

Table 9 – *SARFI-X* indices coming out of Table 8

Index	Count	Events per 30 days
SARFI-90	8	2,61
SARFI-70	6	1,96
SARFI-50	5	1,63
SARFI-10	3	0,98

5.3.3.3 Magnitude-duration table

It is clear that when using the *SARFI* method, the event time duration information is missing. This will be remedied by using the magnitude-duration table described hereafter.

Magnitude-duration table format is shown as Table 10. The columns of the tables represent ranges of duration, while the rows represent ranges of residual voltage. Each cell in the table gives the number of events with the corresponding range of residual voltage and duration. The values in Table 10 are out of Table 8.

Table 10 – Magnitude-duration table format

Residual voltage *U* %	Duration *t* ms				
	10 ≤ *t* ≤ 200	**200 < *t* ≤ 500**	**500 < *t* ≤ 1 000**	**1 000 < *t* ≤ 5 000**	**5 000 < *t* ≤ 60 000**
$U \geq 120$	0	0	0	0	0
$120 > U > 110$	0	0	0	0	0
$90 > U \geq 80$	0	0	0	0	0
$80 > U \geq 70$	2	0	0	0	0
$70 > U \geq 40$	0	0	2	0	0
$40 > U \geq U_{ith}$	0	0	0	1	0
$U_{ith} > U$					
Voltage interruption	0	0	0	2	1

NOTE On a three phases system, voltage interruption begins when the U_{RMS} voltages of all three phases fall below the interruption threshold (U_{ith}). Refer to IEC 61000-4-30 for more information.

Annex A
(informative)

Examples of profiles for power quality specification

A.1 General

The following information is provided by experts from different countries/regions as examples.

NOTE Annex A is intended to address the flexibilities offered in this document, not to identify all the differences with applicable national/regional standards.

A.2 LV and MV public distribution networks in European countries

Table A.1 – Examples of profiles in European countries

LV and MV public distribution networks in European countries (applicable standard: EN 50160)	
4.2	For systems with synchronous connection to an interconnected system: – 50 Hz ± 1 % during 99,5 % of a year; – 50 Hz + 4 % / – 6 % during 100 % of the time. For systems with no synchronous connection to an interconnected system (e.g. supply systems on certain islands): – 50 Hz ± 2 % during 95 % of a week; – 50 Hz ± 15 % during 100 % of the time. European standard defines the frequency range for normal network conditions. During exceptional conditions, wider frequency tolerances may apply temporarily in order to maintain the continuity of electricity supply. NOTE The frequency assessment is based on 10 s values according to IEC 61000-4-30.
4.3.2	ρ = 100 β = 5
4.3.3	$U_{100\ \%}$ doesn't exceed U_c +15 %
4.4	–
4.5	–
4.6.2.1	*THD* is calculated with harmonic orders up to 40th only NOTE U_{19}, U_4 and $U_{6...24}$ in Table 3: see EN 50160 (Table 1)
4.6.2.2	–
4.7	–
4.8	–
4.9	Interruptions threshold = 5 % of reference voltage
4.10	–
4.11	No rapid voltage change limits are specified
4.12.1	–

A.3 LV, MV and HV power supply system in China

Table A.2 – Examples of profiles in China

<table>
<tr><th colspan="2">LV, MV and HV power supply system in China</th></tr>
<tr><td>4.2</td><td>For LV, MV, and HV power supply systems with synchronous connection to an interconnected system:
– 50 Hz ± 0,2 Hz

For systems with no synchronous connection to an interconnected system or for weaker systems:
– 50 Hz ± 0,5 Hz</td></tr>
<tr><td>4.3</td><td>ρ and β: not defined
For LV power supply systems:
– U_N ± 7 %

For MV and HV power supply systems:
– abs (plus deviation) + abs (minus deviation): 10 %

(abs: absolute value sign)</td></tr>
<tr><td>4.4</td><td>–</td></tr>
<tr><td>4.5</td><td>–</td></tr>
<tr><td>4.6.2.1, 4.6.3.1 and 4.6.4.1</td><td>– THD is calculated with harmonic orders up to 25th only
– Harmonics for LV, MV, and HV power supply systems:
<table>
<tr><th>Voltage</th><th>THD</th><th colspan="2">HR (%)</th></tr>
<tr><th>kV</th><th>%</th><th>Odd harmonics</th><th>Even harmonics</th></tr>
<tr><td>0,38</td><td>5,0</td><td>4,0</td><td>2,0</td></tr>
<tr><td>6</td><td rowspan="2">4,0</td><td rowspan="2">3,2</td><td rowspan="2">1,6</td></tr>
<tr><td>10</td></tr>
<tr><td>35</td><td rowspan="2">3,0</td><td rowspan="2">2,4</td><td rowspan="2">1,2</td></tr>
<tr><td>66</td></tr>
<tr><td>110</td><td>2,0</td><td>1,6</td><td>0,8</td></tr>
</table></td></tr>
<tr><td>4.6.2.2, 4.6.3.2 and 4.6.4.2</td><td>Interharmonics for LV, MV, and HV power supply systems:
<table>
<tr><th>Voltage</th><th><100 Hz</th><th>100 Hz ~ 800 Hz</th></tr>
<tr><td>$U_N \leq 1\,000$ V</td><td>0,2</td><td>0,5</td></tr>
<tr><td>$U_N > 1\,000$ V</td><td>0,16</td><td>0,4</td></tr>
</table>
NOTE Value here is for interharmonic ratio.</td></tr>
<tr><td>4.7</td><td>–</td></tr>
<tr><td>4.8</td><td>–</td></tr>
<tr><td>4.9</td><td>–</td></tr>
<tr><td>4.10</td><td>No mains communicating voltage limits are specified</td></tr>
<tr><td>4.11</td><td>No rapid voltage change limits are specified</td></tr>
<tr><td>4.12</td><td>See GB/T 18481</td></tr>
</table>