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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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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:

DTS	Report on voting
8/1363/DTS	8/1381/RVC

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

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site 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- withdrawn,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.

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INTRODUCTION

The description of ELECTRICITY is of fundamental importance within electricity supply systems. In general, its characteristics depend less on its generation than on the way in which it is 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.

There is a need for a common set of power quality 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.

This is why 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 Technical Specification and PROFILES. Examples of profiles are given in Annex A.

Nowadays, Smart Grid construction and massive deployment of renewable energy sources increase the complexity of power quality management.

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 of public low, medium and high voltage, 50 Hz or 60 Hz, networks.

NOTE 1 The boundaries between the various voltage levels may 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.

Most of the recommendations for power quality at the SUPPLY TERMINALS 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 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, and
- 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).

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 3 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 4 In many countries/regions, requirements concerning the essential characteristics of electricity at 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 5 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, 3-3, 3-11and/or 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, 3-7, 3-13 and/or 3-14.

This Technical Specification applies to the phenomena listed in Table 1.

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

Continuous phenomena	Discontinuous phenomena – Events
FREQUENCY DEVIATION	SUPPLY INTERRUPTION
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 6 Specification of related measurement methods can be found in IEC 61000-4-30, *EMC – Testing and measurement techniques – Power Quality measurement methods*.

NOTE 7 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 Technical Specification is not an EMC publication (see also Annex F).

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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, *Electrical installations of buildings – Part 5-53: Selection and erection of electrical equipment – Isolation, switching and control*

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

IEC 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, *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 purpose of this Technical Specification, the following terms and definitions apply.

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.

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

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

$\boldsymbol{U_c}$ (abbreviation)
supply voltage U_c 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.

3.5
electromagnetic compatibility
ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

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

3.6
(electromagnetic) compatibility level
specified electromagnetic disturbance level used as a reference level for coordination 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.

3.7
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 behavior.

[SOURCE: IEC 60050-161:1990, 161-08-13, modified (addition of Notes to entry)]

3.8
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 hour 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 Pst and Plt, see IEC 61000-4-15.

3.9
frequency deviation
difference between power supply frequency ($f_{H,1}$) and nominal frequency (f_N)

3.10
group total harmonic distortion
THDG (abbreviation)
***THDG*$_Y$**(symbol)

ratio of the r.m.s. value of the harmonic groups ($Y_{g,h}$) to the r.m.s. 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, 3.3]

3.11
harmonic frequency
$f_{H,h}$ (abbreviation)
frequency which is an integer multiple of the power supply (fundamental) frequency

[SOURCE: IEC 61000-4-7:2009, 3.2.1, modified (removal of formula and Note to entry)]

3.12
harmonic order
h (abbreviation)
(integer) ratio of a harmonic frequency ($f_{H,h}$) to the power supply frequency ($f_{H,1}$)

3.13
harmonic ratio
HR (abbreviation)
ratio of individual harmonic order component (U_h or I_h) to the fundamental component (U_1 or I_1)

3.14
mains signalling voltage
signal superimposed on the supply voltage for the purpose of transmission of information in the public supply network and to network users' premises

Note 1 to entry: 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.

3.15
network operator
system 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]

3.16
nominal frequency
f_N (abbreviation)
value of frequency used to designate or identify a system

3.17
nominal system voltage
***U*$_{N}$** (abbreviation)
value of voltage used to designate or identify a system

[SOURCE: IEC 60050-601:1985, 601-01-21, modified (addition of abbreviation, removal of "suitable approximate" from beginning of definition)]

3.18
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.

[SOURCE: IEC TR 61000-3-6:2008, 3.14, modified ("of a public electricity supply system" added to term and definition)]

3.19
percentile value
***U*$_{x\%}$** (symbol)
value such that × percent (x %) of measurements are smaller than or equal to that value, over a given period

3.20
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]

3.21
point of common coupling
PCC (abbreviation)
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")]

3.22
supply terminals
point in a distribution network designated as such and contractually fixed, at which electric energy is exchanged between contractual partners

Note 1 to entry: Supply terminals may 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 Note 1 to entry]

3.23
(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

[SOURCE: IEC 60050-617:2009, 617-02-07]

3.24
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 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" replaced by "electricity" and Note 2 to entry added)]

3.25
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

3.26
profile
specification that supplement a standard by limiting options, in order to serve the needs of users in a geographic area or in an application domain

3.27
r.m.s. value of a harmonic component
$\boldsymbol{Y}_{\mathbf{H,h}}$ (abbreviation)
r.m.s. 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.

[SOURCE: IEC 61000-4-7:2009, 3.2.3]

3.28
r.m.s. value of a harmonic group
$\mathbf{Y}_{\mathbf{g,h}}$ (abbreviation)
square root of the sum of the squares of the r.m.s. 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.

[SOURCE: IEC 61000-4-7:2009, 3.2.4]

3.29
r.m.s. value of an interharmonic centred subgroup
$\mathbf{Y}_{\mathbf{isg,h}}$ (abbreviation)
r.m.s. 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 r.m.s. 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.

[SOURCE: IEC 61000-4-7:2009, 3.4.4]

3.30
r.m.s. value of an interharmonic component
$\mathbf{Y_{C,i}}$ (abbreviation)
r.m.s. value of a spectral component of an electrical signal with a frequency between two consecutive harmonic frequencies

For brevity, such a component may be referred to simply as an 'interharmonic'.

Note 1 to entry: For more details, see IEC 61000-4-7:2009, 3.4.2.

3.31
rapid voltage change
RVC (abbreviation)
quick transition (that may last more than several cycles) in r.m.s. 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.

3.32
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.

3.33
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

3.34
supply voltage
r.m.s. value of the line-to-line or line-to-neutral voltage at a given time at the supply terminal, measured over a given interval

3.35
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 Technical Specification, 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 (modification of Note 1 to entry)]

3.36
total harmonic distortion
THD (abbreviation)
$\boldsymbol{THD_Y}$ (symbol)
ratio of the r.m.s. value of the sum of all the harmonic components ($Y_{H,h}$) up to a specified order (h_{max}) to the r.m.s. 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.

3.37
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]

3.38
voltage deviation
difference between supply voltage (U) to nominal voltage (U_N), often expressed by relative value

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

3.39

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 (addition of Note 1 to entry)]

3.40
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 of "supply voltage" and Note 1 to entry)]

3.41
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]

3.42
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.

3.43
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 ("r.m.s. values" replaced by "magnitudes")]

3.44
voltage unbalance factor
in a three-phase system, the degree of unbalance expressed by the ratio (in per cent) between the r.m.s. values of the negative sequence (or, rarely, of the zero sequence) component and the positive sequence component of voltage

[SOURCE: IEC 60050-604:1987, 604-01-30, modified (addition of "voltage" to term)]

4 Recommended values for power quality indices

4.1 General

Regarding phenomena that occur continuously over time, this Technical Specification 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 Technical Specification, the 10 minutes interval proposed in IEC 61000-4-30 is used for most phenomena.

NOTE 1 In some countries/regions, aggregation time intervals less than 10 minutes are used.

NOTE 2 Voltage fluctuation leading to Long Time Flicker and Mains Signalling 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 Technical Specification 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.

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 make it very difficult to give useful definite values for the corresponding characteristics. The values given in this Technical Specification 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 In different synchronous areas, different requirements may apply (generally originated from grid codes).

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.

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 r.m.s. values of the voltage at the 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

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

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

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

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 clause applies to such electricity supplies at nominal voltages up to and including 35 kV.

NOTE Network users may 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 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 r.m.s. values of the voltage at the 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 1 In some countries/regions, voltage range can be specified asymmetrically with regard to declared voltage.

NOTE 2 In some countries/regions, $U_{100\%}$ doesn't exceed $U_c + 15\ \%$

4.3.4 High voltage systems

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

NOTE 1 Network users may 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 supply voltage is subject to individual contract.

For high voltage systems, recommended values are based on 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 r.m.s. values of the voltage at the 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 value of negative sequence voltage unbalance factor should be less than or equal to the recommended value for 95 % of time or more.

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

NOTE In some countries/regions with part single phase or two phase connected network user's installations, unbalance up to 3 % at three phase supply terminals may 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 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 have different behavior.

NOTE 2 These limits take into consideration 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.

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 r.m.s. 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 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 (2, 0)	6 … 24	0,75
13	3,0	21	0,5 (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	26 ≤h≤ 50	0,25 × (10/h) + 0,25

[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 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 THD, maintaining the same recommended value.

4.6.2.2 Interharmonic voltages

The same statistical approach and same range of values (see Table 3) should apply to harmonic (centred) group voltages as to individual harmonic voltages from the previous section. 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 r.m.s. 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 r.m.s. 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 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 (2,0)	6 … 24	0,75
13	3,0	21	0,5 (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	26 ≤h≤ 50	0,25 × (10/h) + 0,25

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

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

NOTE 3 When end-use equipment is not directly connected to the MV system, lower values for MV may 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 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 THD, maintaining the same recommended value.

4.6.3.2 Interharmonic voltages

The same statistical approach and same range of values (see Table 4 should apply to harmonic (centred) group voltages as to individual harmonic voltages from the previous section. 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 r.m.s. 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 r.m.s. 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 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 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 – 5,0	3	2,0 – 3,0	2	1,5 – 1,9
7	2,0 – 4,0	9	1,0 – 2,0	4	0,8 – 1
11	1,5 – 3,0			6 ... 12	0,5
13	1,5 – 2,5				

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

NOTE 2 Due to the wide range of voltage levels included in HV (35-230 kV) and where national/regional circumstances make it appropriate, limits for intermediate voltage levels may 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 THD, maintaining the same recommended value.

4.6.4.2 Interharmonic voltages

The same statistical approach and same range of values (see Table 5) should apply to harmonic (centred) group voltages as to individual harmonic voltages from the previous section. 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 r.m.s. 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 r.m.s. voltage variation. 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 is 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 is 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 to, among other things, differences in system layout (e.g. cable systems versus overhead line systems), environmental and climatic conditions.

In most countries/regions, specific continuity of supply indices are established by regulators in order to facilitate 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 Technical Specification, voltage short time interruptions are mostly addressed. The detection of short time voltage interruptions are 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 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 – 0,6 mV.

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

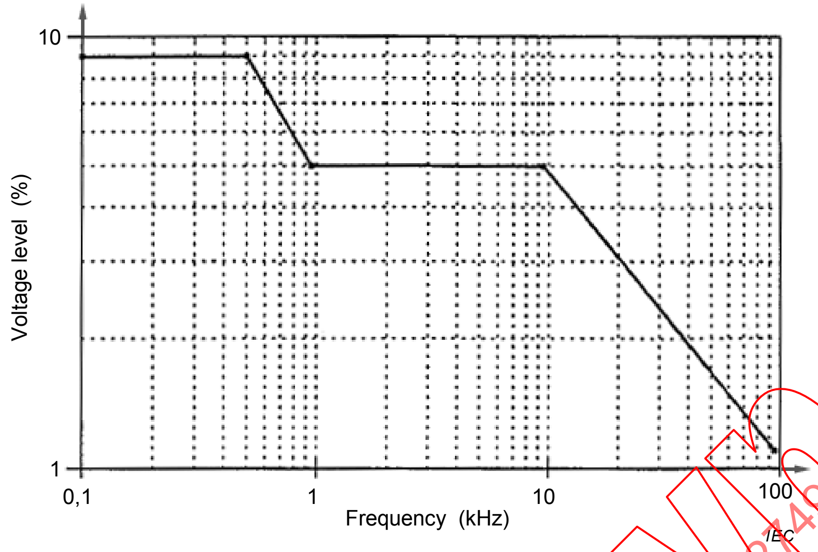

Figure 1 – Signal voltages recommended values in percent of U_N used in public LV networks (or U_c in public MV networks)

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

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 r.m.s. 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 Technical Specification.

NOTE In this Technical Specification, 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 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 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 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 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 Section 5.2 and 5.3 hereafter.

Although some types of disturbances are assumed to be continuous phenomena likely to be present on any 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 For continuous phenomena

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

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 r.m.s. values, β = 5 or β ∈ $\frac{-b\pm\sqrt{b^2-4ac}}{2a}$ [0, 1]	ρ % weekly 10 minute r.m.s. values. ρ ∈ [99, 100]		
			if β > 100 – ρ, (100 – ρ) % weekly 10 minute r.m.s. values.			
		MV (see 4.3.3)	1 % weekly 10 minute r.m.s. values.	99 % weekly 10 minute r.m.s. values		
			0 % weekly 10 minute r.m.s. values.			
		HV (see 4.3.4)	1 % weekly 10 minute r.m.s. values	99 % weekly 10 minute r.m.s. values.		
Voltage unbalance	1 week	95 % weekly 10 minute r.m.s. 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 r.m.s. values (see 4.6)			99 % daily 3 s values	Max. daily 3 s values with corresponding time stamp.

Phenomena	Minimum assessment period [a]	Assessment indices		Indicative value [d]
		not exceeding corresponding recommended values [b]	not exceeding *k* times corresponding recommended values [c]	
Mains signalling 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.

[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 PQ very short-time indices given in Table 6. The detailed value/or range of k for each phenomenon is under consideration.

[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 Technical Specification 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 r.m.s. 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.

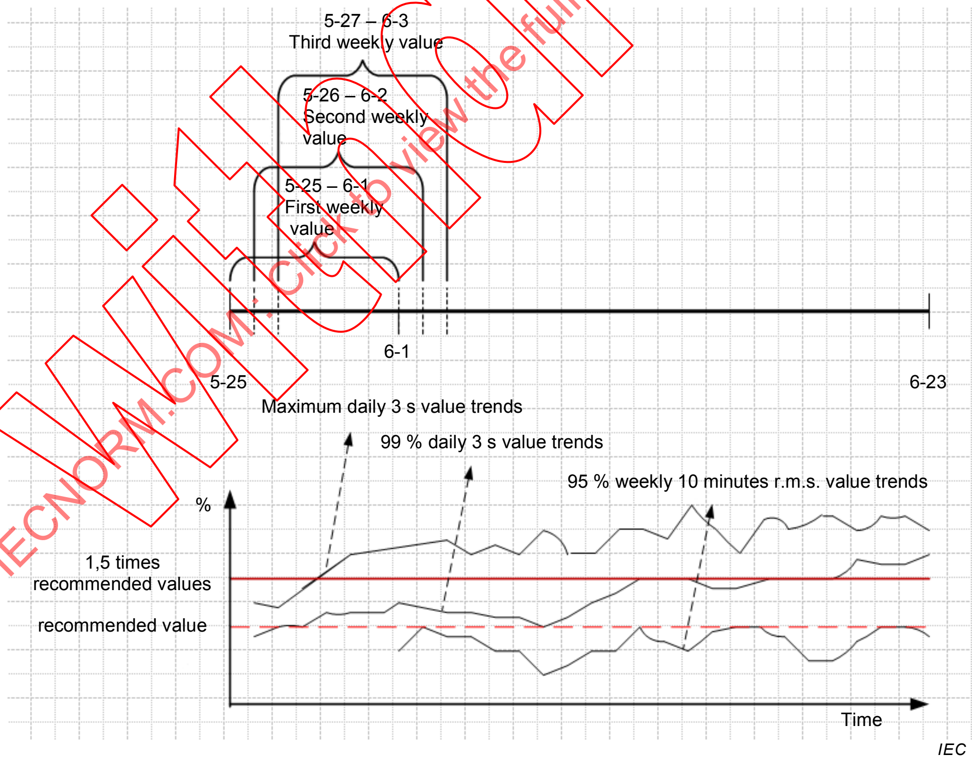

Figure 2 – An example for illustrating voltage THD assessment result trends

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.

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 Fig 3
Point on Wave	Lower part in Fig 3

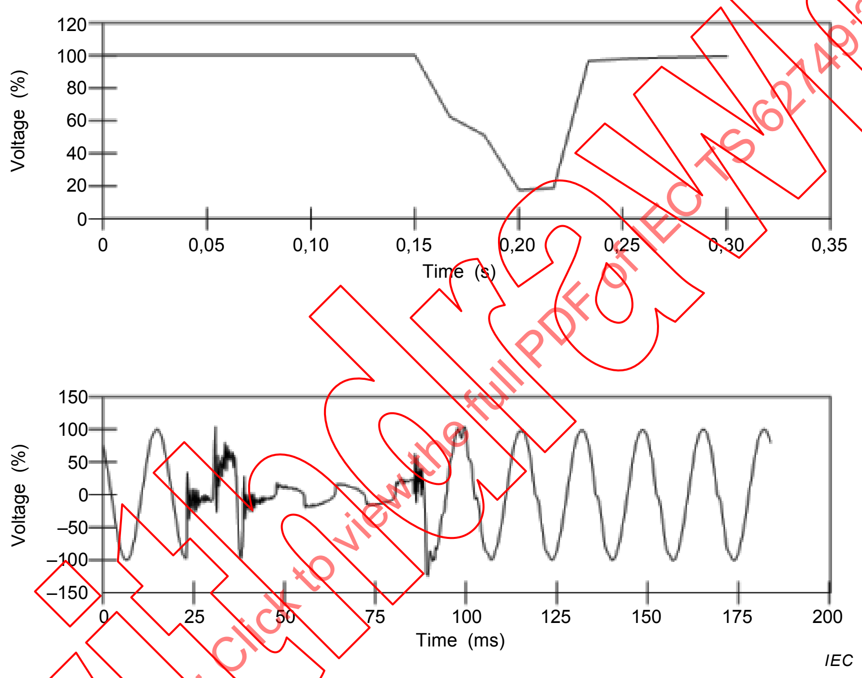

Figure 3 – An example showing information of single event assessment

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.

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, 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, several methods are also presented in CENELEC TR 50555, *Interruption indices*.

Time aggregation method, in the case of multiple successive events, should be used prior to the assessment. The time aggregation duration is defined as 1 minute in this Technical Specification, within which all events can be counted as one event whose magnitude and duration are those of the most severe observed during this interval.

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

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 Technical Specification, 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.

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	1640
Jul-10-2000 15:55:23	13	2000
Jul-21-2000 09:48:52	0	2600
Aug-08-2000 07:35:02	49	680
Sep-02-2000 08:30:28	0	41000
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. Each cell populates the total count summing each event matching the corresponding 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 ≤ *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 phase 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

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

NOTE This annex is intended to address the flexibilities offered in this TS, not to identify all the differences with applicable national/regional standards.

A.1 LV public distribution in European countries

LV public distribution 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. NOTE The frequency assessment is based on 10s values according to IEC 61000-4-30.
4.3.2	ρ = 100 β = 5
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.2 LV, MV and HV power supply system 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 ~ 800 Hz</th></tr>
<tr><td>U_N≤1000V</td><td>0,2</td><td>0,5</td></tr>
<tr><td>U_N>1000V</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 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.3 Example of a transmission system 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 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 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 ≤ h ≤ 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 ≤ h ≤ 49</td><td>1,2 × 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.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 to 50,25 Hz, while maintaining 49,85 to 50,15 Hz 99 % of the time over a 30 day period.
– For islanded systems, under normal conditions with no contingency or load event, the required frequency is: 49,5 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 230V 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 r.m.s</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, Un for at least a ½ cycle
(b) for poly-phase systems, falls below the interruption threshold of 10 % of the nominal voltage, Un 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)

Example on System Aspect Continuous Disturbance Evaluation

Firstly, two variables named Average Index $\bar{x}$ and Sample Standard Deviation s are defined by equations at B1 and B2.

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{B1}$$

$$s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}} \tag{B2}$$

$\bar{x}$ Site average value of one kind of disturbances, e.g., unbalance, flicker etc.

x_i The assessment result (percentile values) of individual site belonging to this system (area).

n Total number of monitoring sites covered in this system (area).

s Sample standard deviation.

Thus, Average Index $\bar{x}$ 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 be list here.					

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

Annex C
(informative)

Main Impact of Poor Power Quality

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' equipments will be impacted, and so will be the power system itself.

Power quality indices are described 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.1 Harmonic distortion

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

Harmonics can lead to overloading. Hence 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 over current if no forethought is given at the designing stage.
– Non-sinusoidal power supplies result in reduction of torque of induction motors.
– Harmonics will increase interference with telephone, communication and analogue circuits.
– Excessive levels of harmonics can cause errors in 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.2 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 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.3 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.4 Frequency deviation

If frequency deviation exceeds the limit, the motor shall be protected by means stopping the operation.

C.5 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.6 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 work-places or homes.

C.7 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 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.8 Transient overvoltages

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