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Voltage characteristics of electricity supplied by public distribution networks

By

Mr. Heinz Wanda
EN 50160

Voltage characteristics of electricity supplied by public distribution networks

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Scope

This European Standard defines, describes and specifies the main characteristics of the voltage at a network user's supply terminals in public low voltage medium and high voltage AC electricity networks under normal operating conditions.

This standard describes the limits or values within which the voltage characteristics can be expected to remain at any supply terminal in public European electricity networks and does not describe the average situation usually experienced by an individual network user.
Object

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

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

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

- The characteristics vary in a manner which is random in time, with reference to any specific supply terminal, and random in location, with reference to any given instant of time.

- Because of these variations, the values given in this standard for the characteristics can be expected to be exceeded on a small number of occasions.
Some of the phenomena affecting the voltage are particularly unpredictable, which make it very difficult to give useful definite values for the corresponding characteristics.

The values given in this standard for the voltage characteristics associated with such phenomena, e.g. voltage dips and voltage interruptions, shall be interpreted accordingly.
Normative references

- EN 61000-3-3 2008 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 61000-3-3:2008)
Normative references

- IEC/TR 61000-2-8 2002 Electromagnetic compatibility (EMC) – Part 2-8: Environment – Voltage dips and short interruptions on public electric power supply systems with statistical measurement results
- IEC/TR 61000-3-7 2008 Electromagnetic compatibility (EMC) – Part 3-7: Assessment of emission limits for fluctuating loads in MV and HV power systems
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4.1 General

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

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

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

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

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

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

NOTE In low voltage systems declared and nominal voltage are equal.
4.2 Continuous phenomena

4.2.1 Power frequency

- Under normal operating conditions the mean value of the fundamental frequency measured over 10 s shall be in a range of:
  - 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
4.2.2 Supply voltage variations

4.2.2.1 Requirements

- Under normal operating conditions excluding the periods with interruption, supply voltage variation should not exceed ± 10 % of the nominal voltage $U_n$.

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

Under normal operating conditions:

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

4.2.3.1 Single rapid voltage change

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

- If the voltage during a change crosses the voltage dip and/or the voltage swell threshold, the event is classified as a voltage dip and/or swell rather than a rapid voltage change.

- NOTE Reference can be made to EN 61000-2-2; some indicative values can be found in Annex B.
Flicker

- Impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time [IEV 161-08-13]

- NOTE Voltage fluctuation 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
Low-voltage supply characteristics

Figure 3 – Relative voltage change characteristic
Low-voltage supply characteristics

Analytical Method

\[ t_f = 2.3 \left( F \cdot d_{\text{max}} \right)^{3.2} \]

\[ P_{st} = \left( \Sigma t_f / T_p \right)^{1/3.2} \]
Low-voltage supply characteristics

Network voltage

Bulb model

Model of human reaction

Statistical operation on instantaneous flicker sensation

Figure 4 - The operations to determine the flicker severity $P_{ST}$
Low-voltage supply characteristics

Flicker perception characteristic $P_{st} = 1$
4.2.3.2 Flicker severity

Intensity of flicker annoyance evaluated by the following quantities:

- short term severity \((P_{st})\) measured over a period of ten minutes;
- long term severity \((P_{lt})\) calculated from a sequence of twelve \(P_{st}\)-values over a two hour interval,

according to the following expression

\[
P_{lt} = 3 \sqrt[12]{\sum_{i=1}^{12} \left( \frac{P_{st,i}^3}{12} \right)}
\]

Under normal operating conditions, during each period of one week the long term flicker severity caused by voltage fluctuation should be \(P_{lt} \leq 1\) for 95% of the time.
4.2.4 Supply voltage unbalance

- Under normal operating conditions, during each period of one week, 95% of the 10 min mean r.m.s. values of the negative phase sequence component (fundamental) of the supply voltage shall be within the range 0% to 2% of the positive phase sequence component (fundamental).

- NOTE 1 In some areas with partly single phase or two phase connected network users' installations, unbalances up to about 3% at three-phase supply terminals occur.

- NOTE 2 In this European Standard only values for the negative sequence component are given because this component is the relevant one for the possible interference of appliances connected to the system.
Low-voltage supply characteristics

Harmonic voltage

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

NOTE Application: Harmonic voltages can be evaluated:

- individually by their relative amplitude \( u_h \) which is the harmonic voltage related to the fundamental voltage \( u_1 \), where \( h \) is the order of the harmonic;
- globally, for example by the total harmonic distortion factor \( THD \), calculated using the following expression.

\[
THD = \sqrt{\sum_{h=2}^{40} (u_h)^2}
\]
Low-voltage supply characteristics

Harmonic voltage

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

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

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

**NOTE** The limitation to order 40 is conventional.
**Low-voltage supply characteristics**

Table 1 — Values of individual harmonic voltages at the supply terminals for orders up to 25 given in percent of the fundamental voltage $u_1$

<table>
<thead>
<tr>
<th>Odd harmonics</th>
<th>Even harmonics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Order</strong> $h$</td>
<td><strong>Relative amplitude $u_h$</strong></td>
</tr>
<tr>
<td>---------------</td>
<td>----------------</td>
</tr>
<tr>
<td>5</td>
<td>6,0 %</td>
</tr>
<tr>
<td>7</td>
<td>5,0 %</td>
</tr>
<tr>
<td>11</td>
<td>3,5 %</td>
</tr>
<tr>
<td>13</td>
<td>3,0 %</td>
</tr>
<tr>
<td>17</td>
<td>2,0 %</td>
</tr>
<tr>
<td>19</td>
<td>1,5 %</td>
</tr>
<tr>
<td>23</td>
<td>1,5 %</td>
</tr>
<tr>
<td>25</td>
<td>1,5 %</td>
</tr>
</tbody>
</table>

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

- sinusoidal voltage with a frequency not equal to an integer multiple of the fundamental
- NOTE Interharmonic voltages at closely adjacent frequencies can appear at the same time forming a wide band spectrum.

4.2.6 Interharmonic voltages

- The level of interharmonics is increasing due to the development of frequency converters and similar control equipment. Levels are under consideration, pending more experience.
- In certain cases interharmonics, even at low levels, give rise to flicker (see 4.2.3.2), or cause interference in ripple control systems.
Low-voltage supply characteristics

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 Classification: three types of signals in the public supply network can be classified:
  - ripple control signals: superimposed sinusoidal voltage signals in the frequency range 110 Hz to 3 000 Hz;
  - power-line-carrier signals: superimposed sinusoidal voltage signals in the frequency range 3 kHz to 148.5 kHz;
  - mains marking signals: superimposed short time alterations (transients) at selected points of the voltage waveform.
4.2.7 Mains signalling voltages

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

NOTE 1 Power line carrier signalling with frequencies in the range from 95 kHz to 148.5 kHz may be used in network users' installations. Though the use of the public LV network is not permitted for the transmission of signals between network users, voltages of these frequencies up to 1.4 V r.m.s. in the public LV network have to be taken into account. Because of the possibility of mutual influences of neighbouring network users’ signalling systems, the network user may need to apply protection or appropriate mitigation measures for his signalling installation.
Low-voltage supply characteristics

NOTE 2 For PLC purposes, in some networks also frequencies above 148.5 kHz are used.

Figure 1 — Voltage levels of signal frequencies in percent of $U_n$ used in public LV networks
4.3 Voltage events

4.3.1 Interruptions of the supply voltage

Interruptions are, by their nature, very unpredictable and variable from place to place and from time to time. For the time being, it is not possible to give fully representative statistical results of measurements of interruption frequency covering the whole of European networks. A reference for actual values recorded in European networks concerning interruptions is given in Annex B.
Low-voltage supply characteristics

**voltage swell = temporary power frequency overvoltage**

- temporary increase of the r.m.s. voltage at a point in the electrical supply system above a specified start threshold

- **NOTE 1** Application: for the purpose of this standard, the swell start threshold is equal to the 110 % of the reference voltage (see CLC/TR 50422, Clause 3, for more information)

- **NOTE 2** For the purpose of this standard, a voltage swell is a two dimensional electromagnetic disturbance, the level of which is determined by both voltage and time (duration).

- **NOTE 3** Voltage swells may appear between live conductors or between live conductors and earth. Depending on the neutral arrangement, faults to ground may also give rise to overvoltages between healthy phases and neutral.
Low-voltage supply characteristics

voltage dip

- temporary reduction of the r.m.s. voltage at a point in the electrical supply system below a specified start threshold

- NOTE 1 Application: for the purpose of this standard, the dip start threshold is equal to 90 % of the reference voltage.

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

- NOTE 3 For the purpose of this standard, a voltage dip is a two dimensional electromagnetic disturbance, the level of which is determined by both voltage and time (duration).
4.3.2 Supply voltage dips/swells

4.3.2.1 General

- Voltage dips are typically originated by faults occurring in the public network or in network users’ installations.
- Voltage swells are typically caused by switching operations and load disconnections.
- Both phenomena are unpredictable and largely random. 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.
4.3.2.2 Voltage dip/swell measurement and detection

If statistics are collected, voltage dips/swells shall be measured and detected according to EN 61000-4-30, using as reference the nominal supply voltage. The voltage dips/swells characteristics of interest for this standard are residual voltage (maximum r.m.s. voltage for swells) and duration.

On LV networks, for four-wire three phase systems, the line to neutral voltages shall be considered; for three-wire three phase systems the line to line voltages shall be considered; in the case of a single phase connection, the supply voltage (line to line or line to neutral, according to the network user connection) shall be considered.
Conventionally, the dip start threshold is equal to 90% of the nominal voltage; the start threshold for swells is equal to the 110% of the nominal voltage. The hysteresis is typically 2%; reference rules for hysteresis are given in 5.4.2.1 of EN 61000-4-30:2009.

NOTE For polyphase measurements, it is recommended that the number of phases affected by each event are detected and stored.
4.3.2.3 Voltage dips evaluation

- Evaluation of voltage dips shall be in accordance with EN 61000-4-30. The method of analyzing the voltage dips (post treatment) depends on the purpose of the evaluation.

- Typically, on LV networks:
  - if a three-phase system is considered, polyphase aggregation shall be applied; polyphase aggregation consists of defining an equivalent event characterized by a single duration and a single residual voltage;
  - time aggregation applies; time aggregation consists of defining an equivalent event in the case of multiple successive events; the method used for the aggregation of multiple events can be set according to the final use of data; some reference rules are given in IEC/TR 61000-2-8.
Figure 2 – Synchronization of aggregation intervals for Class A
4.3.2.4 Voltage dips classification

- If statistics are collected, voltage dips shall be classified according to the table 2. The figures to be put in the cells refer to the number of equivalent events (see in 4.3.2.3).

- NOTE For existing measurement equipment and/or monitoring systems, Table 2 is to be taken as a recommendation.

- Voltage dips are, by their nature, very unpredictable and variable from place to place and from time to time. For the time being, it is not possible to give fully representative statistical results of measurements of voltage dip frequency covering the whole of European networks. A reference for actual values recorded in the European networks concerning dips is given in Annex B.
Low-voltage supply characteristics

Table 2 — Classification of dips according to residual voltage and duration

<table>
<thead>
<tr>
<th>Residual voltage $u$ (%)</th>
<th>Duration $t$ (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$10 \leq t \leq 200$</td>
</tr>
<tr>
<td>90 &gt; $u \geq 80$</td>
<td>CELL A1</td>
</tr>
<tr>
<td>80 &gt; $u \geq 70$</td>
<td>CELL B1</td>
</tr>
<tr>
<td>70 &gt; $u \geq 40$</td>
<td>CELL C1</td>
</tr>
<tr>
<td>40 &gt; $u \geq 5$</td>
<td>CELL D1</td>
</tr>
<tr>
<td>5 &gt; $u$</td>
<td>CELL X1</td>
</tr>
</tbody>
</table>

Voltage dip residual voltage

Minimum value of r.m.s. voltage recorded during a voltage dip
Table 6 – Mixed networks: voltage dip incidence – maximum

<table>
<thead>
<tr>
<th>Residual voltage $u$ % of reference voltage</th>
<th>$10 \leq t &lt; 100$ ms</th>
<th>$100 \leq t &lt; 500$ ms</th>
<th>$0,5 \leq t &lt; 1$ s</th>
<th>$1 \leq t &lt; 3$ s</th>
<th>$3 \leq t &lt; 20$ s</th>
<th>$20 \leq t &lt; 60$ s</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 &gt; $u \geq 70$</td>
<td>111</td>
<td>99</td>
<td>20</td>
<td>8</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>70 &gt; $u \geq 40$</td>
<td>50</td>
<td>59</td>
<td>14</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>40 &gt; $u \geq 0$</td>
<td>5</td>
<td>26</td>
<td>11</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>$u = 0$ (interruptions)</td>
<td>5</td>
<td>25</td>
<td>104</td>
<td>10</td>
<td>15</td>
<td>24</td>
</tr>
</tbody>
</table>

Highest number of dips/site: 306
## Table 7 – Mixed networks: voltage dip incidence – mean

<table>
<thead>
<tr>
<th>Residual voltage $u$ % of reference voltage</th>
<th>$10 \leq t &lt; 100$ m</th>
<th>$100 \leq t &lt; 500$ m</th>
<th>$0,5 \leq t &lt; 1$ s</th>
<th>$1 \leq t &lt; 3$ s</th>
<th>$3 \leq t &lt; 20$ s</th>
<th>$20 \leq t &lt; 60$ s</th>
</tr>
</thead>
<tbody>
<tr>
<td>$90 &gt; u \geq 70$</td>
<td>26,8</td>
<td>27,6</td>
<td>3,4</td>
<td>1,2</td>
<td>0,3</td>
<td>0,02</td>
</tr>
<tr>
<td>$70 &gt; u \geq 40$</td>
<td>3,1</td>
<td>15,1</td>
<td>1,3</td>
<td>0,4</td>
<td>0,02</td>
<td>0</td>
</tr>
<tr>
<td>$40 &gt; u \geq 0$</td>
<td>0,4</td>
<td>6,5</td>
<td>1</td>
<td>0,4</td>
<td>0,1</td>
<td>0,02</td>
</tr>
<tr>
<td>$u = 0$ (interruptions)</td>
<td>0,3</td>
<td>3,5</td>
<td>7,4</td>
<td>1,2</td>
<td>1,1</td>
<td>2,1</td>
</tr>
</tbody>
</table>

Mean number of dips/site: 103
Table 8 – Mixed networks: voltage dip incidence – 95th percentile

<table>
<thead>
<tr>
<th>Residual voltage $u$ % of reference voltage</th>
<th>$10 \leq t &lt; 100$ ms</th>
<th>$100 \leq t &lt; 500$ ms</th>
<th>$0.5 \leq t &lt; 1$ s</th>
<th>$1 \leq t &lt; 3$ s</th>
<th>$3 \leq t &lt; 20$ s</th>
<th>$20 \leq t &lt; 60$ s</th>
</tr>
</thead>
<tbody>
<tr>
<td>$90 &gt; u \geq 70$</td>
<td>61</td>
<td>68</td>
<td>12</td>
<td>6</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>$70 &gt; u \geq 40$</td>
<td>8</td>
<td>38</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$40 &gt; u \geq 0$</td>
<td>2</td>
<td>20</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>$u = 0$ (interruptions)</td>
<td>0</td>
<td>18</td>
<td>26</td>
<td>5</td>
<td>4</td>
<td>9</td>
</tr>
</tbody>
</table>

95th percentile of dips/site: 256
It should be noted that, due to the measurement method adopted, measurement uncertainty affecting the results has to be taken into account: this is particularly relevant for shorter events. Measurement uncertainty is addressed in EN 61000-4-30.

Generally, the duration of a voltage dip depends on the protection strategy adopted on the network, which may differ from network to network depending on network structure and on neutral earthing. As a consequence, typical durations do not necessarily match the boundaries of the columns in Table 2.
4.3.2.5 Voltage swells evaluation

- Evaluation of voltage swells shall be in accordance with EN 61000-4-30. The method of analyzing the voltage swells (post treatment) depends on the purpose of the evaluation.

- Typically, on LV networks:
  - if a three phase system is considered, polyphase aggregation shall be applied; polyphase aggregation consists of defining an equivalent event characterized by a single duration and a single maximum r.m.s. voltage;
  - time aggregation applies; time aggregation consists of defining an equivalent event in the case of multiple successive events; the method used for the aggregation of multiple events can be set according to the final use of data; some reference rules are given in IEC/TR 61000-2-8.
4.3.2.6 Voltage swells classification

If statistics are collected, voltage swells shall be classified according to the following table. The figures to be put in the cells refer to the number of equivalent events (see 4.3.2.5)

NOTE 1 For existing measurement equipment and/or monitoring systems, Table 3 is to be taken as a recommendation.

NOTE 2 Typically, faults in the public LV network or in a network user's installation give rise to temporary power Frequency overvoltages between live conductors and earth; such overvoltages disappear when the fault is cleared. Some indicative values are given in Annex B.

NOTE 3 For the classification of swells between live conductors and earth, reference can be made to IEC 60364-4-44.
### Table 3 — Classification of swells according to maximum voltage and duration

<table>
<thead>
<tr>
<th>Swell voltage $u$ (%)</th>
<th>Duration $t$ (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$10 \leq t \leq 500$</td>
</tr>
<tr>
<td>$u \geq 120$</td>
<td>CELL S1</td>
</tr>
<tr>
<td>$120 &gt; u &gt; 110$</td>
<td>CELL T1</td>
</tr>
</tbody>
</table>
4.3.3 Transient overvoltages

Transient overvoltages at the supply terminals are generally caused by lightning (induced overvoltage) or by switching in the system.

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.
Low-voltage supply characteristics

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

NOTE 3 For withstanding transient overvoltages in the vast majority of cases, LV Installations and end users’ appliances are designed according to EN 60664-1. 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 over-voltages due to both lightning and switching.
Medium-voltage supply characteristics

5.1 General

Network users with demands exceeding the capacity of the LV network are generally connected to networks at nominal voltages above 1 kV. This clause applies to such electricity supplies at nominal voltages up to and including 36 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.
Medium-voltage supply characteristics

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

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

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

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

The magnitude of voltage is given by the declared supply voltage $U_c$. 
5.2 Continuous phenomena

5.2.1 Power frequency

- Under normal operating conditions the mean value of the fundamental frequency measured over 10 s shall be in a range of:
  - 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
5.2.2 Supply voltage variations

5.2.2.1 Requirements

- Under normal operating conditions, excluding the periods with interruptions, supply voltage variations should not exceed ± 10% of the declared voltage $U_c$.

- In cases of electricity supplies in networks not interconnected with transmission systems or for special remote network users, voltage variations should not exceed +10% / -15% of $U_c$. Network users should be informed of the conditions.
NOTE 1 The actual power consumption required by individual network users is not fully predictable, in terms of amount and simultaneity. As a consequence, networks are generally designed on a probabilistic basis. If, following a complaint, measurements carried out by the network operator according to 5.2.2.2 indicate that the magnitude of the supply voltage departs beyond the limits given in 5.2.2.2, causing negative consequences for the network user, the network operator should take remedial action in collaboration with the network user(s) depending on a risk assessment. Temporarily, for the time needed to solve the problem, voltage variations should be within the range $+ 10\% / - 15\%$ of $U_c$, unless otherwise agreed with the network users.
NOTE 2 Identification of what is a "special remote network user" can vary between countries, taking into account different characteristics of national electricity supply systems as, for instance, limitation of power on the supply terminal and/or power factor limits.
5.2.2.2 Test method

For performing voltage measurements if required, see EN 61000-4-30 with a measurement period of at least one week.

Under the conditions of 5.2.2.1, the following limits apply:
- at least 99 % of the 10 min mean r.m.s. values of the supply voltage shall be below the upper limits of +10% given in 5.2.2.1; and
- at least 99 % of the 10 min mean r.m.s. values of the supply voltage shall be above the lower limits of -10% given in 5.2.2.1; and
- none of the 10 min mean r.m.s. values of the supply voltage shall be outside the limits ± 15 % of $U_c$. 
Medium-voltage supply characteristic

- **NOTE 1** The percentages above are referred to a measuring period of one week (i.e. to 1 008 intervals of 10 min).
- **NOTE 2** For the evaluation of measurement results, care should to be taken of flagged intervals. The data flagged due to interruptions are excluded. The principles for the use of other flagged data are under consideration.
- **NOTE 3** For those particular cases where limits stricter than ±10% of $U_c$ are established, lower weekly percentiles (i.e. 95%) should be used.
5.2.3 Rapid voltage changes

5.2.3.1 Single rapid voltage change

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

If the voltage during a change crosses the voltage dip and/or the voltage swell threshold, the event is classified as a voltage dip and/or swell rather than a rapid voltage change.

NOTE Reference can be made to EN 61000-2-12; some indicative values can be found in Annex B.
5.2.3.2 Flicker severity

- Under normal operating conditions, during each period of one week the long term flicker severity $P_{lt}$ caused by voltage fluctuation should be less than or equal to 1 for 95% of the time.

- NOTE 1 This value was chosen on the assumption that the transfer coefficient between MV and LV system is 1. In practice, the transfer coefficients between MV levels and LV levels can be less than 1.

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

- NOTE 2 Guidance can be found in IEC/TR 61000-3-7.
5.2.4 Supply voltage unbalance

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

- NOTE 1 In some areas, unbalances up to about 3% at three-phase supply terminals occur.

- NOTE 2 In this European Standard only values for the negative sequence component are given because this component is the relevant one for the possible interference of appliances connected to the system.
5.2.5 Harmonic voltage

Under normal operating conditions, during each period of one week, 95 % of 10 min mean r.m.s. values of each individual harmonic voltage shall be less than or equal to the values given in Table 4. Resonances may cause higher voltages for an individual harmonic.

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

NOTE The limitation to order 40 is conventional. Depending on the type of voltage transformer used, the measurement of higher order harmonics may be not reliable; further information is given in EN 61000-4-30:2009, A.2.
## Medium-voltage supply characteristic

Table 4 — Values of individual harmonic voltages at the supply terminals for orders up to 25 given in percent of the fundamental voltage $u_1$

<table>
<thead>
<tr>
<th>Odd harmonics</th>
<th>Even harmonics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Not multiples of 3</strong></td>
<td><strong>Multiples of 3</strong></td>
</tr>
<tr>
<td>Order $h$</td>
<td>Relative amplitude $u_h$</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>5</td>
<td>6,0 %</td>
</tr>
<tr>
<td>7</td>
<td>5,0 %</td>
</tr>
<tr>
<td>11</td>
<td>3,5 %</td>
</tr>
<tr>
<td>13</td>
<td>3,0 %</td>
</tr>
<tr>
<td>17</td>
<td>2,0 %</td>
</tr>
<tr>
<td>19</td>
<td>1,5 %</td>
</tr>
<tr>
<td>23</td>
<td>1,5 %</td>
</tr>
<tr>
<td>25</td>
<td>1,5 %</td>
</tr>
</tbody>
</table>

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

---

* Depending on the network design, the value for the third harmonic order can be substantially lower.
5.2.6 Interharmonic voltage

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

In certain cases interharmonics, even at low levels, give rise to flicker (see 5.2.3.2) or cause interference with ripple control systems.
5.2.7 Mains signalling voltage

In some countries the public networks may be used by the network operators for the transmission of signals. For 99 % of a day the 3 s mean value of the signal voltages shall be less or equal to the values given in Figure 2.

NOTE 1 It is assumed that network users do not use the public MV network for signalling purposes.

NOTE 2 For PLC purposes, in some networks also frequencies above 148,5 kHz are used.
Medium-voltage supply characteristic

![Graph showing voltage levels in percent vs. frequency in kHz]

**Figure 2 — Voltage levels of signal frequencies in percent of $U_c$ used in public MV networks**
5.3 Voltage events

5.3.1 Interruptions of the supply voltage

Interruptions are, by their nature, very unpredictable and variable from place to place and from time to time. For the time being, it is not possible to give fully representative statistical results of measurements of interruption frequency covering the whole of European networks. A reference for actual values recorded in European networks concerning interruptions is given in Annex B.
5.3.2 Supply voltage dips/swells

5.3.2.1 General

- Voltage dips are typically originated by faults occurring in the public network or in the network users’ installations.
- Voltage swells are typically caused by switching operations and load disconnections.
- Both phenomena are unpredictable and largely random. 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.
Medium-voltage supply characteristic

5.3.2.2 Voltage dip/swell measurement and detection

If statistics are collected, voltage dips/swells shall be measured and detected according to EN 61000-4-30, using as reference the declared supply voltage. The voltage dips/swells characteristics of interest for this standard are residual voltage (maximum r.m.s. voltage for swells) and duration.

Typically, on MV networks, the line to line voltages shall be considered.

Conventionally, the dip threshold is equal to 90 % of the reference voltage; the threshold for swells is equal to the 110 % of the reference voltage. The hysteresis is typically 2 %; reference rules for hysteresis are given in 5.4.2.1 of EN 61000-4-30:2009.

NOTE For polyphase measurements, it is recommended that the number of phases affected by each event are detected and stored.
5.3.2.3 Voltage dips evaluation

- Evaluation of voltage dips shall be in accordance with EN 61000-4-30. The method of analyzing the voltage dips (post treatment) depends on the purpose of the evaluation.

- Typically, on MV networks:
  - polyphase aggregation is applied; polyphase aggregation consists in defining an equivalent event characterized by a single duration and a single residual voltage;
  - time aggregation applies; time aggregation consists of defining an equivalent event in the case of multiple successive events; the method used for aggregation of multiple events can be set according to the final use of data; some reference rules are given in IEC/TR 61000-2-8.
5.3.2.4 Voltage dips classification

- If statistics are collected, voltage dips shall be classified according to the following table. The figures to be put in the cells refer to the number of equivalent events (as defined in 5.3.2.3).

- NOTE For existing measurement equipment and/or monitoring systems, Table 5 is to be taken as a recommendation.
Medium-voltage supply characteristic

Voltage dips are, by their nature, very unpredictable and variable from place to place and from time to time. For the time being, it is not possible to give fully representative statistical results of measurements of voltage dip frequency covering the whole of European networks. A reference for actual values recorded in the European networks concerning dips is given in Annex B.

It should be noted that, due to the measurement method adopted, measurement uncertainty affecting the results has to be taken into account: this is particularly relevant for shorter events. Measurement uncertainty is addressed in EN 61000-4-30.
Medium-voltage supply characteristic

Generally, the duration of a voltage dip depends on the protection strategy adopted on the network, which may differ from network to network, depending on network structure and on neutral earthing. As a consequence, typical durations do not necessarily match the boundaries of the columns in Table 5.

Table 5 — Classification of dips according to residual voltage and duration

<table>
<thead>
<tr>
<th>Residual voltage ( u ) %</th>
<th>Duration ( t ) ms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( 10 \leq t \leq 200 )</td>
</tr>
<tr>
<td>90 &gt; ( u \geq 80 )</td>
<td>CELL A1</td>
</tr>
<tr>
<td>80 &gt; ( u \geq 70 )</td>
<td>CELL B1</td>
</tr>
<tr>
<td>70 &gt; ( u \geq 40 )</td>
<td>CELL C1</td>
</tr>
<tr>
<td>40 &gt; ( u \geq 5 )</td>
<td>CELL D1</td>
</tr>
<tr>
<td>5 &gt; ( u )</td>
<td>CELL X1</td>
</tr>
</tbody>
</table>
### Table 10 – Voltage dips and short interruptions on the MV system

<table>
<thead>
<tr>
<th>Residual voltage $u$ % of reference voltage</th>
<th>$50 \leq t &lt; 200$ ms</th>
<th>$200 \leq t &lt; 400$ ms</th>
<th>$400 \leq t &lt; 600$ ms</th>
<th>$0,6 \leq t &lt; 1$ s</th>
<th>$1 \leq t$ s</th>
</tr>
</thead>
<tbody>
<tr>
<td>$80 &gt; u \geq 75$</td>
<td>6.5 %</td>
<td>2.4 %</td>
<td>0.8 %</td>
<td>0.9 %</td>
<td>0 %</td>
</tr>
<tr>
<td>$75 &gt; u \geq 70$</td>
<td>2.7 %</td>
<td>1.4 %</td>
<td>1.1 %</td>
<td>1.3 %</td>
<td>0 %</td>
</tr>
<tr>
<td>$70 &gt; u \geq 50$</td>
<td>7.1 %</td>
<td>2.4 %</td>
<td>1.6 %</td>
<td>1.3 %</td>
<td>0 %</td>
</tr>
<tr>
<td>$50 &gt; u \geq 30$</td>
<td>2.2 %</td>
<td>1.8 %</td>
<td>0.6 %</td>
<td>0.6 %</td>
<td>0 %</td>
</tr>
<tr>
<td>$30 &gt; u$</td>
<td>5.7 %</td>
<td>2.4 %</td>
<td>0.8 %</td>
<td>0 %</td>
<td>0.2 %</td>
</tr>
<tr>
<td>Short interruptions</td>
<td>1.3 %</td>
<td>2.4 %</td>
<td>0.2 %</td>
<td>0 %</td>
<td>4.7 %</td>
</tr>
</tbody>
</table>
Table 11 – MV overhead networks: voltage dip incidence – maximum

<table>
<thead>
<tr>
<th>Residual voltage $u$</th>
<th>$20 \leq t &lt; 100$ ms</th>
<th>$100 \leq t &lt; 500$ ms</th>
<th>$0.5 \leq t &lt; 1$ s</th>
<th>$1 \leq t &lt; 3$ s</th>
<th>$3 \leq t &lt; 20$ s</th>
<th>$20 \leq t &lt; 60$ s</th>
<th>$60 \leq t &lt; 180$ s</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of reference voltage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$90 &gt; u \geq 85$</td>
<td>541</td>
<td>61</td>
<td>24</td>
<td>25</td>
<td>53</td>
<td>51</td>
<td>10</td>
</tr>
<tr>
<td>$85 &gt; u \geq 70$</td>
<td>1532</td>
<td>203</td>
<td>136</td>
<td>20</td>
<td>7</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>$70 &gt; u \geq 40$</td>
<td>1146</td>
<td>225</td>
<td>38</td>
<td>26</td>
<td>8</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>$40 &gt; u \geq 1$</td>
<td>97</td>
<td>424</td>
<td>31</td>
<td>28</td>
<td>5</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>$1 &gt; u \geq 0$ (interruptions)</td>
<td>2</td>
<td>20</td>
<td>7</td>
<td>27</td>
<td>27</td>
<td>6</td>
<td>10</td>
</tr>
</tbody>
</table>
## Table 12 – MV overhead networks: voltage dip incidence – 95\textsuperscript{th} percentile

<table>
<thead>
<tr>
<th>Residual voltage $u$ % of reference voltage</th>
<th>$20 \leq t &lt; 100$ ms</th>
<th>$100 \leq t &lt; 500$ ms</th>
<th>$0,5 \leq t &lt; 1$ s</th>
<th>$1 \leq t &lt; 3$ s</th>
<th>$3 \leq t &lt; 20$ s</th>
<th>$20 \leq t &lt; 60$ s</th>
<th>$60 \leq t &lt; 180$ s</th>
</tr>
</thead>
<tbody>
<tr>
<td>$90 &gt; u \geq 85$</td>
<td>150</td>
<td>37</td>
<td>9</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>$85 &gt; u \geq 70$</td>
<td>238</td>
<td>93</td>
<td>14</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$70 &gt; u \geq 40$</td>
<td>141</td>
<td>128</td>
<td>15</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$40 &gt; u \geq 1$</td>
<td>55</td>
<td>113</td>
<td>12</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$1 &gt; u \geq 0$ (interruptions)</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>6</td>
<td>7</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
5.3.2.5 Voltage swells evaluation

Evaluation of voltage swells shall be in accordance with EN 61000-4-30. The method of analyzing the voltage swells (post treatment) depends on the purpose of the evaluation.

Typically, on MV networks:

- polyphase aggregation shall be applied; polyphase aggregation consists in defining an equivalent event characterized by a single duration and a single maximum r.m.s. voltage;

- time aggregation applies; time aggregation consists in defining an equivalent event in the case of multiple successive events; the method used for aggregation of multiple events can be set according to the final use of data; some reference rules are given in IEC/TR 61000-2-8.
5.3.2.6 Voltage swells classification

- If statistics are collected, voltage swells shall be classified according to the following table. The figures to be put in the cells refer to the number of equivalent events (see 5.3.2.5).

- NOTE For existing measurement equipment and/or monitoring systems, Table 6 is to be taken as a recommendation.
NOTE Faults in the public distribution network, or in a network user's installation, give rise to temporary power frequency overvoltages between live conductors and earth; such overvoltages disappear when the fault is cleared. Some indicative values are given in Annex B.
5.3.3 Transient overvoltages

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

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

Network users with demands exceeding the capacity of the medium voltage network are generally supplied at nominal voltages above 36 kV. This clause applies to such electricity supplies at nominal voltages up to and including 150 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 some continuous phenomena limits are specified; for voltage events, only indicative values can be given at present (see Annex B).

The magnitude of voltage is given by the declared voltage $U_c$. 
High-voltage supply characteristics

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

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

– voltage events, i.e. sudden and significant deviations from normal or desired wave shape. Voltage events are typically due to unpredictable events (e.g. faults) or to external causes (e.g. weather conditions, third party actions).
High-voltage supply characteristics

6.2 Continuous phenomena

6.2.1 Power frequency

- Under normal operating conditions the mean value of the fundamental frequency measured over 10 s shall be in a range of:
  - 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
6.2.2 Supply voltage variations

As the number of network users supplied directly from HV networks is limited and normally subject to individual contracts, no limits for supply voltage variations are given in this standard.

Existing product standards for HV equipment should be considered.

6.2.3 Rapid voltage changes

6.2.3.1 Single rapid voltage change

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

If the voltage during a change crosses the voltage dip and/or the voltage swell threshold, the event is classified as a voltage dip and/or swell rather than a rapid voltage change.
6.2.3.2 Flicker severity

- Under normal operating conditions, during each period of one week the long term flicker severity $P_{lt}$ caused by voltage fluctuation should be less or equal to 1 for 95% of the time.

- NOTE 1 This value was chosen on the assumption that the transfer coefficient between HV and LV system is 1. In practice the transfer coefficients between HV levels and LV levels can be less than 1.

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

- NOTE 2 Guidance can be found in IEC/TR 61000-3-7.

- NOTE 3 In the case of related needs, an appropriate transition time has to be agreed upon with the relevant national authorities.
6.2.4 Supply voltage unbalance

Under normal operating conditions, during each period of one week, 95 % of the 10 min mean r.m.s. values of the negative phase sequence component of the supply voltage should be within the range 0 % to 2 % of the positive phase sequence component.

NOTE 1 In some areas, unbalances up to about 3 % at three-phase supply terminals occur.

NOTE 2 In this European Standard only values for the negative sequence component are given because this component is the relevant one for the possible interference of appliances connected to the system.

NOTE 3 The values given for supply voltage unbalance are only indicative; limits will be set on the basis of data made available by measurement campaigns.
6.2.5 Harmonic voltage

- Under normal operating conditions, during each period of one week, 95% of 10 min mean r.m.s. values of each individual harmonic voltage should be less than or equal to the indicative values given in Table 7. Resonances may cause higher voltages for an individual harmonic.

- NOTE 1 Limits for each individual harmonic voltage are under consideration.

- NOTE 2 The limit for the THD of the supply voltage (including all harmonics up to the order 40) is under consideration.

- NOTE 3 The limitation to order 40 is conventional. For measurement accuracy an appropriate type of voltage transformer should be used, particularly for the measurement of higher order harmonics; further information is given in EN 61000-4-30:2009, A.2.
## High-voltage supply characteristics

Table 7 — Indicative values of individual harmonic voltages at the supply terminals for orders up to 25 given in percent of the fundamental voltage $u_1$

<table>
<thead>
<tr>
<th>Odd harmonics</th>
<th>Even harmonics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not multiples of 3</td>
<td>Multiples of 3</td>
</tr>
<tr>
<td><strong>Order $h$</strong></td>
<td><strong>Relative amplitude $u_h$</strong></td>
</tr>
<tr>
<td>5</td>
<td>5 %</td>
</tr>
<tr>
<td>7</td>
<td>4 %</td>
</tr>
<tr>
<td>11</td>
<td>3 %</td>
</tr>
<tr>
<td>13</td>
<td>2,5 %</td>
</tr>
<tr>
<td>17</td>
<td>u.c.</td>
</tr>
<tr>
<td>19</td>
<td>u.c.</td>
</tr>
<tr>
<td>23</td>
<td>u.c.</td>
</tr>
<tr>
<td>25</td>
<td>u.c.</td>
</tr>
</tbody>
</table>

**NOTE 1** No values are considered for harmonics of order higher than 25, as they are usually small, but largely unpredictable due to resonance effects.

**NOTE 2** Harmonics not multiple of 3 of order higher than 13 are under consideration.

**NOTE 3** In some countries, limits for harmonics are already in place.

$^a$ Depending on the network design, the value for the third harmonic order can be substantially lower.
In the case of complaints, limits for harmonics in HV networks should be chosen on the base of MV network limits, suitably modified by a quantity \( D \) as resulting from the following formula:

\[
HV\text{-LIMIT} = MV\text{-LIMIT} - D
\]

\( D \) should be agreed between the HV network operator and the connected network user, if necessary in order to maintain harmonic levels of the connected network below the relevant limits.

NOTE 4 \( D \) can be chosen differently, depending on the use (harmonic transmission from HV public networks to HV public networks, from HV public networks to MV public networks or from HV public networks to network users).
High-voltage supply characteristics

6.2.6 Interharmonic voltage

- Due to the low resonance frequency of the HV network, no values are given for interharmonic voltage.

- NOTE Due to the very low resonant frequency in HV grids (200 Hz … 500 Hz), caused by high capacitances and inductances, interharmonics are of minor relevance in HV networks.

6.2.7 Mains signalling voltage

- Due to the low resonance frequency of the HV network, no values are given for mains signalling voltages.
High-voltage supply characteristics

6.3 Voltage events

6.3.1 Interruptions of the supply voltage

Interruptions are, by their nature, very unpredictable and variable from place to place and from time to time. For the time being, it is not possible to give fully representative statistical results of measurements of interruption frequency covering the whole of European networks. A reference for actual values recorded in the European networks concerning interruptions is given in Annex B.
High-voltage supply characteristics

6.3.2 Supply voltage dips/swells

6.3.2.1 General

- Voltage dips are typically originated by faults occurring in the public network or in the network users’ installations.
- Voltage swells are typically caused by switching operations and load disconnections.
- Both phenomena are unpredictable and largely random. 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.
6.3.2.2 Voltage dip/swell measurement and detection

- If statistics are collected, voltage dips/swells shall be measured and detected according to EN 61000-4-30, using as reference the declared supply voltage. The voltage dips/swells characteristics of interest for this standard are residual voltage (maximum r.m.s. voltage for swells) and duration.

- Typically, on HV networks, the line to line voltages shall be considered.

- Conventionally, the dip threshold is equal to 90 % of the reference voltage; the threshold for swells is equal to the 110 % of the reference voltage. The hysteresis is typically 2 %; reference rules for hysteresis are given in EN 61000-4-30:2009, 5.4.2.1.

- NOTE For polyphase measurements, it is recommended that the number of phases affected by each event is detected and stored.
6.3.2.3 Voltage dips evaluation

Evaluation of voltage dips shall be in accordance with EN 61000-4-30. The method of analyzing the voltage dips (post treatment) depends on the purpose of the evaluation.

Typically, on HV networks:
- polyphase aggregation is applied; polyphase aggregation consists of defining an equivalent event characterized by a single duration and a single residual voltage;
- time aggregation applies; time aggregation consists of defining an equivalent event in the case of multiple successive events; the method used for aggregation of multiple events can be set according to the final use of data; some reference rules are given in IEC/TR 61000-2-8.
6.3.2.4 Voltage dips classification

- If statistics are collected, voltage dips shall be classified according to the following table 8. The figures to be put in the cells refer to the number of equivalent events (see 6.3.2.3).

- NOTE For existing measurement equipment and/or monitoring systems, Table 8 should be taken as recommendation.

- Voltage dips are, by their nature, very unpredictable and variable from place to place and from time to time. For the time being, it is not possible to give fully representative statistical results of measurements of voltage dip frequency covering the whole of European networks.
High-voltage supply characteristics

Table 8 — Classification of dips according to residual voltage and duration

<table>
<thead>
<tr>
<th>Residual voltage $u$ (%)</th>
<th>$10 \leq t \leq 200$</th>
<th>$200 &lt; t \leq 500$</th>
<th>$500 &lt; t \leq 1,000$</th>
<th>$1,000 &lt; t \leq 5,000$</th>
<th>$5,000 &lt; t \leq 60,000$</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 &gt; $u \geq 80$</td>
<td>CELL A1</td>
<td>CELL A2</td>
<td>CELL A3</td>
<td>CELL A4</td>
<td>CELL A5</td>
</tr>
<tr>
<td>80 &gt; $u \geq 70$</td>
<td>CELL B1</td>
<td>CELL B2</td>
<td>CELL B3</td>
<td>CELL B4</td>
<td>CELL B5</td>
</tr>
<tr>
<td>70 &gt; $u \geq 40$</td>
<td>CELL C1</td>
<td>CELL C2</td>
<td>CELL C3</td>
<td>CELL C4</td>
<td>CELL C5</td>
</tr>
<tr>
<td>40 &gt; $u \geq 5$</td>
<td>CELL D1</td>
<td>CELL D2</td>
<td>CELL D3</td>
<td>CELL D4</td>
<td>CELL D5</td>
</tr>
<tr>
<td>5 &gt; $u$</td>
<td>CELL X1</td>
<td>CELL X2</td>
<td>CELL X3</td>
<td>CELL X4</td>
<td>CELL X5</td>
</tr>
</tbody>
</table>
### Table 9 – Voltage dips and short interruptions on the HV system

<table>
<thead>
<tr>
<th>Residual voltage $u$ % of reference voltage</th>
<th>50 ≤ $t$ &lt; 200 ms</th>
<th>200 ≤ $t$ &lt; 400 ms</th>
<th>400 ≤ $t$ &lt; 600 ms</th>
<th>0,6 ≤ $t$ &lt; 1 s</th>
<th>1 ≤ $t$ s</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 &gt; $u$ ≥ 75</td>
<td>7,4 %</td>
<td>2,7 %</td>
<td>0,6 %</td>
<td>0,8 %</td>
<td>0,6 %</td>
</tr>
<tr>
<td>75 &gt; $u$ ≥ 70</td>
<td>3,9 %</td>
<td>1,5 %</td>
<td>0,2 %</td>
<td>0,3 %</td>
<td>0 %</td>
</tr>
<tr>
<td>70 &gt; $u$ ≥ 50</td>
<td>4,7 %</td>
<td>2,5 %</td>
<td>0,2 %</td>
<td>0,4 %</td>
<td>0,4 %</td>
</tr>
<tr>
<td>50 &gt; $u$ ≥ 30</td>
<td>0,9 %</td>
<td>0,4 %</td>
<td>0,2 %</td>
<td>0,2 %</td>
<td>0 %</td>
</tr>
<tr>
<td>30 &gt; $u$</td>
<td>3,2 %</td>
<td>0,6 %</td>
<td>0,2 %</td>
<td>0 %</td>
<td>1,1 %</td>
</tr>
<tr>
<td>Short interruptions</td>
<td>0 %</td>
<td>0,3 %</td>
<td>0,1 %</td>
<td>0 %</td>
<td>3,5 %</td>
</tr>
</tbody>
</table>
Table 16 – HV (400 kV) networks: voltage dip incidence – maximum

<table>
<thead>
<tr>
<th>Residual voltage $u$ % of reference voltage</th>
<th>20 $\leq t &lt; 100$ ms</th>
<th>100 $\leq t &lt; 500$ ms</th>
<th>0,5 $\leq t &lt; 1$ s</th>
<th>1 $\leq t &lt; 3$ s</th>
<th>3 $\leq t &lt; 20$ s</th>
<th>20 $\leq t &lt; 60$ s</th>
<th>60 $\leq t &lt; 180$ s</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 $&gt; u \geq 85$</td>
<td>50</td>
<td>11</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>85 $&gt; u \geq 70$</td>
<td>61</td>
<td>15</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>70 $&gt; u \geq 40$</td>
<td>20</td>
<td>14</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>40 $&gt; u \geq 1$</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1 $&gt; u \geq 0$ (interruptions)</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
### Table 17 – HV (400 kV) networks: voltage dip incidence – mean

<table>
<thead>
<tr>
<th>Residual voltage $u$ % of reference voltage</th>
<th>$20 \leq t &lt; 100$ ms</th>
<th>$100 \leq t &lt; 500$ ms</th>
<th>$0,5 \leq t &lt; 1$ s</th>
<th>$1 \leq t &lt; 3$ s</th>
<th>$3 \leq t &lt; 20$ s</th>
<th>$20 \leq t &lt; 60$ s</th>
<th>$60 \leq t &lt; 180$ s</th>
</tr>
</thead>
<tbody>
<tr>
<td>$90 &gt; u \geq 85$</td>
<td>27.7</td>
<td>3.1</td>
<td>0.4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$85 &gt; u \geq 70$</td>
<td>30.2</td>
<td>7.6</td>
<td>0.3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$70 &gt; u \geq 40$</td>
<td>7.1</td>
<td>2.9</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$40 &gt; u \geq 1$</td>
<td>0.9</td>
<td>0.1</td>
<td>0</td>
<td>1.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$1 &gt; u \geq 0$ (interruptions)</td>
<td>0</td>
<td>0</td>
<td>0.2</td>
<td>0.6</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
High-voltage supply characteristics

- It should be noted that, due to the measurement method adopted, measurement uncertainty affecting the results has to be taken into account; this is particularly relevant for shorter events. Measurement uncertainty is addressed in EN 61000-4-30.

- Generally, the duration of a voltage dip depends on the protection strategy adopted on the network, which may differ from network to network, depending on network structure and on neutral earthing. As a consequence, typical durations do not necessarily match the boundaries of the columns in Table 8.
6.3.2.5 Voltage swells evaluation

Evaluation of voltage swells shall be in accordance with EN 61000-4-30. Post treatment aimed at swells evaluation depends on the intended purpose.

Typically, on HV networks:
- polyphase aggregation shall be applied; polyphase aggregation consists of defining an equivalent event characterized by a single duration and a single maximum r.m.s. voltage;
- time aggregation applies; time aggregation consists of defining an equivalent event in the case of multiple successive events. The method used for the aggregation of multiple events can be set according to the final use of data; some reference rules are given in IEC/TR 61000-2-8.
6.3.2.6 Voltage swells classification

- If statistics are collected, voltage swells shall be classified according to the following table. The figures to be put in the cells refer to the number of equivalent events (see 6.3.2.5) 14).

- NOTE For existing measurement equipment and/or monitoring systems, Table 9 is to be taken as a recommendation.

- A voltage swell generally occurs because of switching operations and load disconnections. Faults in the public electricity network or in a network user's installation give rise to temporary power frequency overvoltages between live conductors and earth; such overvoltages disappear when the fault is cleared.
Generally, temporary power frequency overvoltages in HV do not cause any concern to network users as normally any load is connected via transformers with different types of neutral earthing.
6.3.3 Transient overvoltages

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

NOTE The network users' insulation coordination scheme must be compatible with that adopted by the network operator.
Annex A (informative)

Special nature of electricity

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

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

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

- It should be noted that this question is directly addressed by other standards, already published or in preparation.

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

Indicative values for voltage events and single rapid voltage changes

B.1 General

- This annex is aimed at providing the reader with some information about indicative values currently available at a European level for some of the events defined and described in the standard. Some information is also given about the way of using values given in the standard, and about the way of collecting further measurement data, in order to allow for comparisons between different systems and to have homogeneous data at a European level.

- As many monitoring systems are in place in some countries, further information is available at a national level.
B.2 Long interruptions of the supply voltage

Under normal operating conditions, the annual frequency of voltage interruptions longer than three minutes 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 different countries, national interruption statistics exist giving indicative values. The CEER Benchmarking Reports on Quality of Supply give some statistics for a certain number of European countries and a review of applicable regulatory standards for long interruptions.
B.3 Short interruptions of the supply voltage

- The duration of most of the short interruptions may be less than some seconds. Indicative values, intended to provide readers with information on the range of magnitude which can be expected, can be found in IEC/TR 61000-2-8 (UNIPEDE statistics).

- When comparing statistical values for short interruptions, the following issues should be considered:
  - principles for aggregating events;
  - the possible exclusion of Very Short Interruptions (VSI) or transitory interruptions.

- In some documents, short interruptions are considered to have durations not exceeding 1 min. Sometimes control schemes are applied which need operating times of up to 3 min in order to avoid long voltage interruptions.
B.4 Voltage dips and swells

NOTE The swells treated in this clause are between live conductors
B.4.1 Use of Tables 2, 5 and 8

As detailed in product standards, voltage dips and swells, according to their severity, can impair the operation of equipment.

Classes 2 and 3 are defined in EN 61000-4-11 and in EN 61000-4-34

Although the cells of the Tables 2, 5 and 8 are not exactly coincident with the test levels table, it can be expected that equipment tested according to the relevant product standard should cope with voltage dips as indicated in the cells:

- A1, B1, A2, B2 for class 2;
- A1, B1, C1, A2, B2, A3, A4 for class 3.

Compatibility levels for industrial power networks are defined in EN 61000-2-4.
Annex B (informative)

Tables 2, 5 and 8 data can help the user to identify the expected performance of the network; in order to assess the probable behaviour of the equipment connected, its immunity has to be considered in accordance with such data.

The specification of immunity requirements (including tests specifications and performance criteria) is the responsibility of the product committees. Generic EMC standards (EN 61000-6-1 and EN 61000-6-2) apply to products operating in a particular environment for which no dedicated product family /product EMC standards exist. Nevertheless, and for information only, the performance criteria are reported below.
Annex B (informative)

Performance criterion A:
- The apparatus shall continue to operate as intended during and after the test. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer, when the apparatus is used as intended.
- The performance level may be replaced by a permissible loss of performance.

Performance criterion B:
- The apparatus shall continue to operate as intended after the test. No degradation of performance or loss of function is allowed below a performance level specified by the manufacturer, when the apparatus is used as intended.
- The performance level may be replaced by a permissible loss of performance. During the test, degradation of performance is however allowed. No change of actual operating state or stored data is allowed.
Annex B (informative)

Performance criterion C:

Temporary loss of function is allowed, provided the function is self-recoverable or can be restored by the operation of the controls.
B.4.3 Currently available indicative values

The vast majority of voltage dips has a duration less than 1 s and a residual voltage above 40 %. However, voltage dips with a smaller residual voltage and longer duration can occur infrequently. In some areas, voltage dips with a residual voltage between 90 % and 85 % of $U_c$ can occur very frequently as a result of the switching of loads in network users' installations.

Indicative values, which are intended to provide readers with information on the range of magnitude which can be expected, can be found in IEC/TR 61000-2-8 (UNIPEDE statistics).
B.4.4 Methods for reporting measurement data

The data relevant to voltage dips/swells should be presented according to the following guidelines.

The data collected should be homogeneous in terms of voltage levels. Within the same voltage level, distinction should be made between networks with prevailing underground cables or aerial lines. To cover all seasonal effects, the observation time should be at least one year.

The data should be collected in tables like 5 and 6; the following data shall be reported:

- average dips/swells incidence per bus per year;
- 90 % or 95 % dips/swells incidence per bus per year;
- maximum dips/swells incidence per bus per year.
B.5 Swells (temporary power frequency overvoltages) between live conductors and earth

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

For medium voltage systems, the expected value of such an overvoltage depends on the type of earthing of the system. In systems with a solidly or impedance earthed neutral the overvoltage shall generally not exceed $1,7 \ U_c$. In isolated or resonant earthed systems the overvoltage shall generally not exceed $2,0 \ U_c$. The type of earthing will be indicated by the network operator.

Indicative values about overvoltages on distribution networks can be found in IEC/TR 61000-2-14. More information for LV systems can be found in IEC/TR 62066.
Annex B (informative)

B.6 Magnitude of rapid voltage changes

- For low voltage, under normal operating conditions, rapid voltage changes generally do not exceed 5 % $U_n$, but changes of up to 10 % $U_n$ with a short duration of the sustained level might occur some times per day under some circumstances.

- For medium voltage, under normal operating conditions, rapid voltage changes generally do not exceed 4 % $U_c$, but changes of up to 6 % $U_c$ with a short duration of the sustained level might occur some times per day under some circumstances.

- These indicative values apply to the phenomenon of rapid voltage changes as defined in 3.14.

- At a national level, additional values may be available, but in some cases they are referred to another definition of rapid voltage change ($\Delta U_{\text{max}}$, see EN 61000-3-3:2008, 3.3 and Figure 2).

- In general, the frequency and magnitude of rapid voltage changes are related to the load variation by the users and to the short-circuit power level of the network.
Standards related to EN 50 160

- **EN 61 000-4-30 (2008) Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods**

- **IEC/TR 61 000-2-8 (2002) Electromagnetic compatibility (EMC) – Part 2-8: Environment – Voltage dips and short interruptions on public electric power supply systems with statistical measurement results**
This part of IEC 61000-4 defines the methods for measurement and interpretation of results for power quality parameters in 50/60 Hz a.c. power supply systems.

Measurement methods are described for each relevant parameter in terms that give reliable and repeatable results, regardless of the method's implementation. This standard addresses measurement methods for in situ measurements.

Measurement of parameters covered by this standard is limited to voltage phenomena that can be conducted in a power system. The power quality parameters considered in this standard are power frequency, magnitude of the supply voltage, flicker, supply voltage dips and swells, voltage interruptions, transient voltages, supply voltage unbalance, voltage harmonics and Interharmonics, mains signalling voltage and rapid voltage changes.
Depending on the purpose of the measurement, all or a subset of the phenomena on this list may be measured.

This standard gives measurement method and appropriate performance requirements, but does not set thresholds.

The effects of transducers inserted between the power system and the instrument are acknowledged but not addressed in detail in this standard. Precautions on installing monitors on live circuits are addressed.
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Annex C (informative) Guidance on instruments

Bibliography
This technical report describes the electromagnetic disturbance phenomena of voltage dips and short interruptions in terms of their sources, effects, remedial measures, methods of measurements, and measurements results (in so far as these are available). They are discussed primarily as phenomena observed on the networks of public electricity supply systems and having an effect on electrical equipment receiving its energy supply from these systems.

„Voltage sag“ is an alternative name for the phenomenon voltage dip.
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Thank you for your attention