# LOW FREQUENCY EMISSION STANDARDS

**EN 61000-3-2 : Harmonic Pollution**
**(IEC 1000-3-4: Technical Report)**
**EN 61000-3-3: Voltage Fluctuation & Flicker**
**(IEC 1000-3-5: Technical Report)**

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# Standard on Low-Frequency Emission: EN 61000-3-2

**Goal:** **limitation of harmonic components of the input current impressed on the public low-voltage supply system, for equipment with input current ≤ 16 A per phase**

- **Equipment to be connected to 220/380 V, 230/400 V and 240/415 V systems operating at 50 Hz or 60 Hz**
- **No limits for systems with nominal voltage less than 220 V (line-to-neutral)**
- **Four categories of equipment**
- **Absolute and/or relative limits**

***IEC 1000-3-2 extends the field of application of previous standard IEC 555-2, including also equipment for professional use with rated power < 1 kW***

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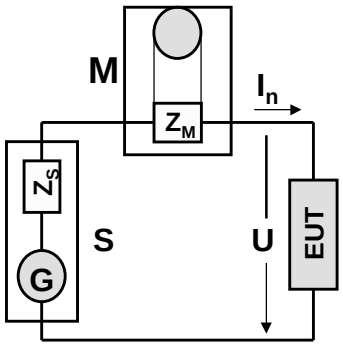
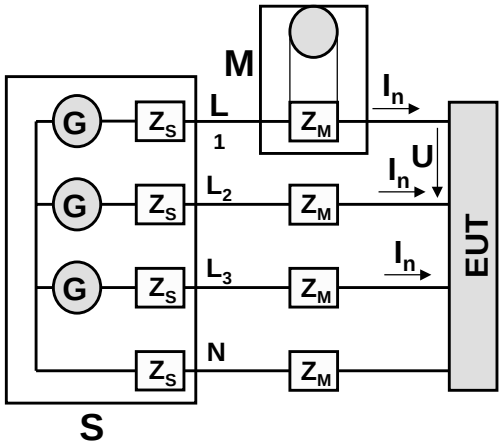
# EN 61000-3-2: Measurement Circuit

**Single-phase equipment**




**Three-phase equipment**

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# EN 61000-3-2 Supply Source Requirements

**Test voltage U at EUT's terminals:**

- **rated voltage of the equipment; in case of multiple voltage range, use 230/400 V for single-phase and three-phase supply**
- **voltage accuracy within ± 2 % of the nominal value**
- **frequency accuracy within ± 0.5 % of the nominal value**
- **displacement accuracy between each pair of phases of a three-phase source within ± 1.5°**
- **peak value of the test voltage shall be within 1.40 and 1.42 times its RMS value and shall be reached within 87° to 93° after the zero crossing (not applicable to class A and B equipment)**

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# EN 61000-3-2
# Supply Source Requirements

**With EUT connected, relative harmonics of test voltage shall not exceed the following values:**

| Limits | Harmonic order |
|---|---|
| 0,9% | 3 |
| 0,4% | 5 |
| 0,3% | 7 |
| 0,2% | 9 |
| 0,2% | even, from 2 to 10 |
| 0,1% | from 11 to 40 |

**The voltage drop on input impedance $Z_M$ cannot exceed $0.15V_{peak}$**

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# EN 61000-3-2
# Classification of Equipment

- ***Class A:*** **balanced 3-phase equipment (r.m.s. line currents differing less than 20 %) and all other equipment, except those in the following classes**
- ***Class B:*** **portable tools**
- ***Class C:*** **lighting equipment including dimming devices**
- ***Class D:*** **equipment having an input current with a "special wave shape" and a fundamental active input power between 75 and 600 W; whatever the wave shape of their input current, Class B, Class C, and provisionally motor-driven equipment are not considered as Class D equipment**

**Limits for high-power equipment (> 1 kW) for professional use are still under consideration**

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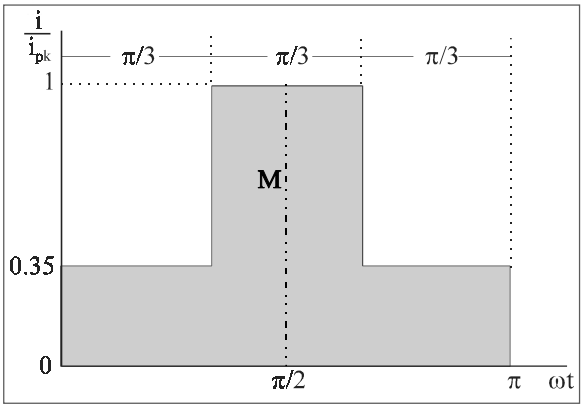
# EN 61000-3-2
## Class D equipment: Special Wave Shape




**An equipment is in class D if each half cycle of input current is within the envelope for at least 95% of time**

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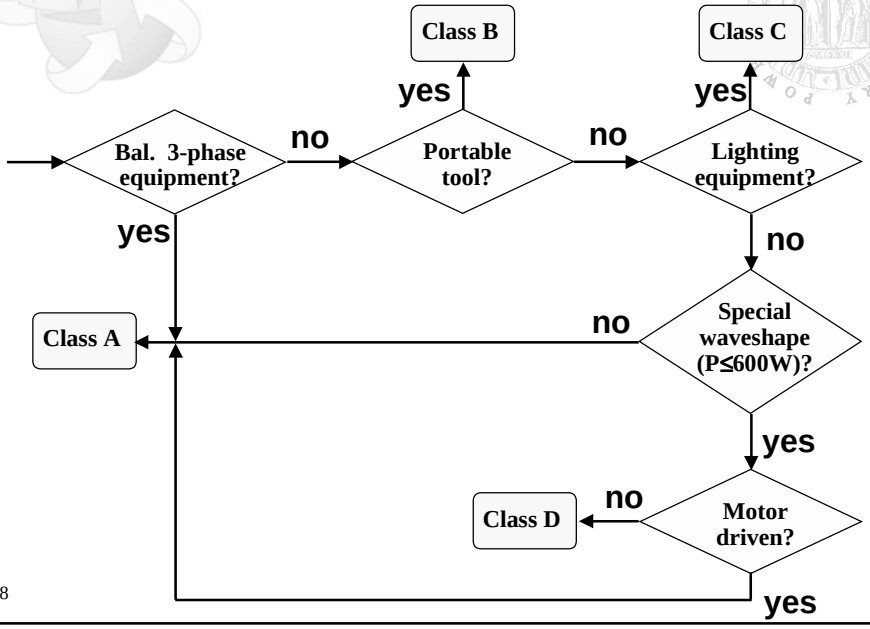
# Classification of Equipment

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# EN 61000-3-2 - Harmonic Limits

## Class A and Class B

| Harmonic order n | Class A max permissible harmonic current A | Class B max permissible harmonic current A |
|---|---|---|
| Odd harmonics | | |
| 3 | 2.30 | 3.45 |
| 5 | 1.14 | 1.71 |
| 7 | 0.77 | 1.155 |
| 9 | 0.40 | 0.60 |
| 11 | 0.33 | 0.495 |
| 13 | 0.21 | 0.315 |
| 15 <= n <= 39 | 2.25/n | 3.375/n |
| Even harmonics | | |
| 2 | 1.08 | 1.62 |
| 4 | 0.43 | 0.645 |
| 6 | 0.30 | 0.45 |
| 8 <= n <= 40 | 1.84/n | 2.76/n |

9 **No limits apply for equipment below 75 W input power**

# EN 61000-3-2 - Harmonic Limits

## Class C

| Harmonic order n | Maximum value expressed as a percentage of the fundamental input current of the luminaries |
|---|---|
| 2 | 2 |
| 3 | 30 λ* |
| 5 | 10 |
| 7 | 7 |
| 9 | 5 |
| 11 <= n <= 39 | 3 |

***λ is power factor**

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# EN 61000-3-2 - Lighting Equipment

- **Independent Dimming devices**
  - **shall comply with class A; where phase control is used on incandescent lamps, the firing angle shall not exceed 145°**
- **Built-in dimming devices**
  - **for incandescent lamps, class A limits shall be satisfied; where phase control is used, the firing angle shall not exceed 145°**
  - **for discharge lamps class C limits apply**

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# EN 61000-3-2 - Harmonic Limits

**Class D**
**(rated load condition)**

| **Harmonic order** n | **75 W < P < 600 W** mA/W | **P > 600 W** A |
|---|---|---|
| 3 | 3.4 | 2.30 |
| 5 | 1.9 | 1.14 |
| 7 | 1.0 | 0.77 |
| 9 | 0.5 | 0.40 |
| 11 | 0.35 | 0.22 |
| 13 | 0.296 | 0.21 |
| 15 <= n <= 391 | 3.85/n | 2.25/n |

**No limits apply for equipment below 75 W input power**

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## Harmonic Current Measurements

- For harmonics of the order above 19, if the current spectrum envelope shows a monotonic decrease of the increasing order harmonics, measurement can be restricted to the first 19 harmonics
- Harmonic currents less than 0.6 % of the input current measured under the test conditions, or less than 5 mA, whichever is greater, are disregarded

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## Harmonic Current Measurements

- The limits are applicable to steady-state harmonic currents
- For transient harmonic currents the following applies:
  - harmonic current lasting for no more than 10 s when a piece of equipment is brought into operation or is taken out of operation, manually or automatically, are disregarded
  - the limits apply to all other transient harmonic currents occurring during the testing of equipment or parts of equipment. For transient even harmonic currents of order from 2 to 10 and transient odd harmonic currents of order from 3 to 19, values up to 1.5 times the limits are allowed for each harmonic during a maximum of 10% of any observation period of 2.5 min

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# EN 61000-3-2: Comments

- **High crest-factor waveforms are penalized (Class D) in order to reduce peak-clipping effect**
- **Even harmonics are penalized in order to reduce asymmetry**
- **Below 600 W class A limits are less severe than Class D; consider changing the input current waveform**

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# Test Conditions

- **Particular test conditions are specified for following equipment:**
  - **Television (TV) receiver (both color and B&W)**
  - **Audio amplifiers**
  - **Video-cassette recorders**
  - **Lighting equipment**
  - **Incandescent lamp dimmers**
  - **Vacuum cleaners**
  - **Washing machines**
  - **Microwave ovens**
  - **Information technology equipment (ITE)**
  - **Induction hobs**
- **For other equipment, user's operation controls or automatic programs shall be set to produce the maximum harmonic components under normal operating conditions for each successive harmonic component in turn**

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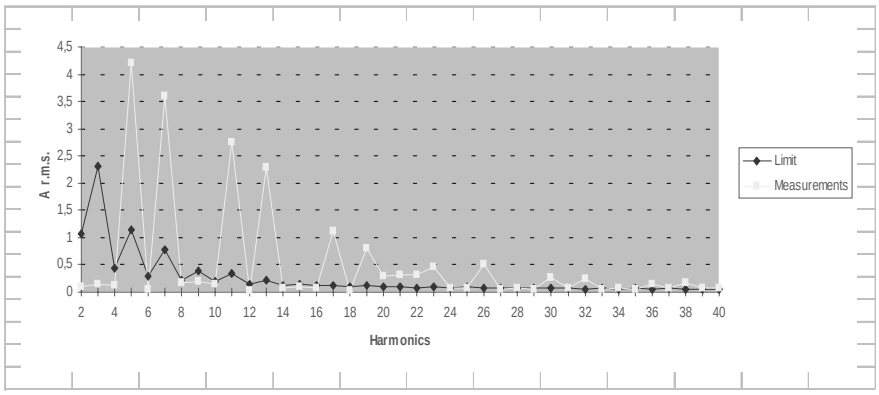
# Harmonic Pollution Tests

## Diode Rectifier supplying a Three-Phase Inverter

**Power: 3,500 W, Voltage: 400 V, 50 Hz, Switching frequency: 18 kHz**

**Class A**




**Harmonic emission of phase A**

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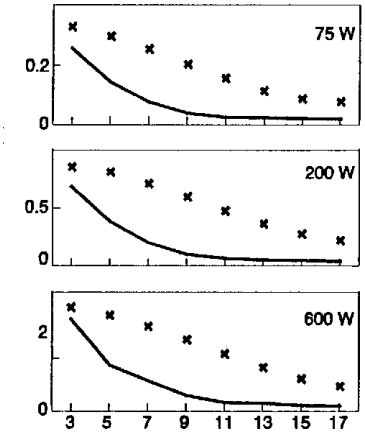
# EN 61000-3-2: Rectified Harmonic Currents and Class D Limits

**230 V, 50 Hz, 10% ripple**

**Harmonic number [A]**




**Rectified harmonic currents**

**x x x**

**Class D limit**

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# Recent Modifications
## (14/12/2000)

- **Class D applies only to the following apparatus:**
  - **Personal computers and monitors**
  - **Television receivers**
- **Measurement conditions shall test the maximum Total Harmonic Current (instead, previous standard required to find the maximum value for each harmonic)**

$$THC = \sqrt{\sum_{n=2}^{40} I_n^2}$$

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# Recent Modifications
## (14/12/2000)

- **Different measurement procedures**
- **With the exception of lighting equipment no limits will be applied for equipment of rated power of 75W or less**
- **Limits are introduced also for lighting equipment of rated power less than 25W**

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# Technical Report on Low-Frequency Emission: IEC 1000-3-4

**Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 16 A per phase**

**IT'S NOT A STANDARD !**
**It is proposed for provisional application, so that information and experience of its use in practice may be gathered**

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# IEC 1000-3-4

- **IEC 61000-3-4 extends the field of application of previous standard IEC 61000-3-2, for electrical and electronic equipment with a rated input current exceeding 16 A per phase**
- **Equipment to be connected to public low-voltage a.c. distribution systems of the following types:**
  - **nominal voltage up to 240 V, single-phase (two or three wires)**
  - **nominal voltage up to 600 V, three-phase (three or four wires)**
  - **nominal frequency 50 Hz or 60Hz**
- **Two methods for type tests are allowed:**
  - **direct measurement of emission**
  - **calculation of the emission by validated simulations**

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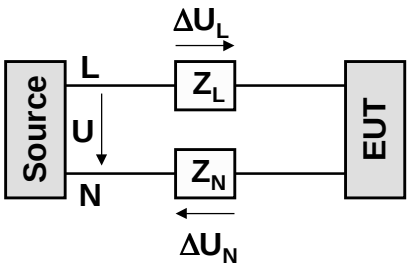
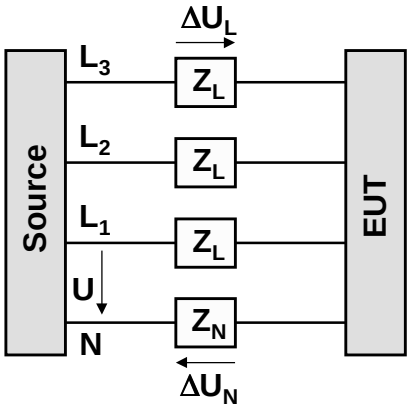
# IEC 1000-3-4
# Measurement Circuit

**Single-phase equipment**




**Three-phase equipment**

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# IEC 1000-3-4
# Supply Source Requirements

**Test voltage U at the source's terminals:**

- **rated voltage of the equipment. In the case of voltage range, use 230 V for single-phase or three-phase supply (400V line-line)**
- **voltage accuracy within ± 2 % of the nominal value**
- **frequency accuracy within ± 0.5 % of the nominal value**
- **displacement accuracy between each pair of phases of a three-phase source within ± 1.5°**
- **peak value of the test voltage shall be within 1.40 and 1.42 times its RMS value and shall be reached within 87° to 93° after the zero crossing**
- **voltage drop $\Delta U$ ($\Delta U = \Delta U_L + \Delta U_N$ or $\Delta U = 2\Delta U_L$) shall not exceed 0.5 $V_{peak}$**

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# IEC 1000-3-4
# Supply Source Requirements

**With EUT connected, the harmonic ratios of test voltage shall not exceed:**

| Limits | Harmonic order |
|---|---|
| 0,9% | 3 |
| 0,4% | 5 |
| 0,3% | 7 |
| 0,2% | 9 |
| 0,2% | even, from 2 to 10 |
| 0,1% | from 11 to 40 |

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# IEC 1000-3-4: Definitions

- **Point of common coupling (PCC): point in the public network which is closest to the consumer concerned and to which other consumers are or may be connected**
- **Partial weighted harmonic distortion (PWHD):**

$$PWHD = \sqrt{\sum_{n=14}^{40} n\left(\frac{I_n}{I_1}\right)^2}$$

- **Short-circuit power ($S_{sc}$): calculated from the nominal system voltage $U_{nom}$ and the impedance Z at the PCC**

$$S_{sc} = \frac{U_{nom}^2}{Z}$$

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# IEC 1000-3-4: Definitions

- **Rated apparent power ($S_{equ}$): calculated from the rated r.m.s. line current $I_{equ}$ of the piece of equipment and the rated voltage $U_p$ (single phase) or $U_i$ (inter-phase)**

| | |
|---|---|
| $S_{equ} = U_p I_{equ}$ | **For single-phase equipment** |
| $S_{equ} = U_i I_{equ}$ | **For inter-phase equipment** |
| $S_{equ} = \sqrt{3} U_i I_{equ}$ | **For balanced three-phase equipment** |
| $S_{equ} = 3 U_p I_{equ\_max}$ | **For unbalanced three-phase equipment ($I_{equ\_max}$ is the maximum of the r.m.s. currents flowing in any one of the three phases)** |

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# IEC 1000-3-4: Definitions

- **Short-circuit ratio ($R_{sce}$):**

| | |
|---|---|
| $R_{sce} = S_{sc} / (3 S_{equ})$ | **For single-phase equipment** |
| $R_{sce} = S_{sc} / (2 S_{equ})$ | **For inter-phase equipment** |
| $R_{sce} = S_{sc} / S_{equ}$ | **For all three-phase equipment** |

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# IEC 1000-3-4: Connection Procedures

- ***Stage 1 - Simplified Connection:*** **equipment complying with stage 1 limits can be connected at any point of the supply system provided the short-circuit ratio $R_{sce}$ is ≥ 33**
- ***Stage 2 - Connection based on Network and Equipment Data :*** **for equipment not complying with stage 1 limits, higher emission values may be allowed, provided the short-circuit ratio $R_{sce}$ is ≥ 33**
- ***Stage 3 - Connection based on the consumer's agreed power:*** **if the conditions of neither stage 1 nor stage 2 are fulfilled, or if the input current of the equipment exceeds 75 A, the supply authority may accept the connection of the equipment on the basis of the agreed active power of the consumer's installation. The local requirements of the power supply authority apply in this case**

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# IEC 1000-3-4: Connection Procedures

***Stage 1 current emission values for simplified connection of equipment*** **($S_{equ} \leq S_{sc} / 33$)**

| Harmonic number n | Admissible harmonic current $I_n/I_1$* % |
|---|---|
| 3 | 21.6 |
| 5 | 10.7 |
| 7 | 7.2 |
| 9 | 3.8 |
| 11 | 3.1 |
| 13 | 2 |
| 15 | 0.7 |
| 17 | 1.2 |
| 19 | 1.1 |

| Harmonic number n | Admissible harmonic current $I_n/I_1$* % |
|---|---|
| 21 | ≤ 0.6 |
| 23 | 0.9 |
| 25 | 0.8 |
| 27 | ≤ 0.6 |
| 29 | 0.7 |
| 31 | 0.7 |
| ≥ 33 | ≤ 0.6 |
| | |
| Even | ≤ 8/n or ≤ 0.6 |

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*** $I_1$ = rated fundamental current; $I_n$ = harmonic current component**

# IEC 1000-3-4: Connection Procedures

***Stage 2 current emission values for single-phase, inter-phase and unbalanced three-phase equipment***

| Minimal $R_{sce}$ | Admissible harmonic current distortion factors % | | Admissible individual harmonic current $I_n/I_1$* % | | | | | |
|---|---|---|---|---|---|---|---|---|
| | THD | PWHD | $I_3$ | $I_5$ | $I_7$ | $I_9$ | $I_{11}$ | $I_{13}$ |
| 66 | 25 | 25 | 23 | 11 | 8 | 6 | 5 | 4 |
| 120 | 29 | 29 | 25 | 12 | 10 | 7 | 6 | 5 |
| 175 | 33 | 33 | 29 | 14 | 11 | 8 | 7 | 6 |
| 250 | 39 | 39 | 34 | 18 | 12 | 10 | 8 | 7 |
| 350 | 46 | 46 | 40 | 24 | 15 | 12 | 9 | 8 |
| 450 | 51 | 51 | 40 | 30 | 20 | 14 | 12 | 10 |
| 600 | 57 | 57 | 40 | 30 | 20 | 14 | 12 | 10 |

NOTE 1 – The relative value of even harmonics shall not exceed 16/n %

NOTE 2 – Linear interpolation between successive $R_{sce}$ values is permitted

NOTE 3 – In the case of unbalanced three-phase equipment, these values apply to each phase

* $I_1$ = rated fundamental current; $I_n$ = harmonic current component

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# IEC 1000-3-4: Connection Procedures

***Stage 2 current emission values for balanced three-phase equipment***

| Minimal $R_{sce}$ | Admissible harmonic current distortion factors % | | Admissible individual harmonic current $I_n/I_1$* % | | | |
|---|---|---|---|---|---|---|
| | THD | PWHD | $I_5$ | $I_7$ | $I_{11}$ | $I_{13}$ |
| 66 | 16 | 25 | 14 | 11 | 10 | 8 |
| 120 | 18 | 29 | 16 | 12 | 11 | 8 |
| 175 | 25 | 33 | 20 | 14 | 12 | 8 |
| 250 | 35 | 39 | 30 | 18 | 13 | 8 |
| 350 | 48 | 46 | 40 | 25 | 15 | 10 |
| 450 | 58 | 51 | 50 | 35 | 20 | 15 |
| 600 | 70 | 57 | 60 | 40 | 25 | 18 |

NOTE 1 – The relative value of even harmonics shall not exceed 16/n %

NOTE 2 – Linear interpolation between successive $R_{sce}$ values is permitted

* $I_1$ = rated fundamental current; $I_n$ = harmonic current component

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# Harmonic Current Measurements

- **Limits for equipment as specified apply to line currents for all types of power connections and load**
- **Harmonic currents below 0.6 % of the input fundamental current are disregarded**
  - **harmonic currents lasting for no more than 10 s when a piece of equipment is brought into operation or is taken out of operation, manually or automatically, shall not exceed 1.5 times the limit values given for the relevant stage**
  - **the limits apply to all other transient harmonic currents occurring during the evaluation of equipment or parts of equipment. For even harmonic currents of order from 2 to 10 and odd harmonic currents of order from 3 to 19, values up to 1.5 times the limits are allowed for each harmonic during a maximum of 10% of any observation period of 2.5 min**

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# Requirements for Simulation

- **Assessment of current emission and the corresponding $R_{scemin}$ value can be made by computer simulation of the equipment considered**
  - **Measurement of the equipment under normal laboratory conditions (set-up as previously specified)**
  - **Supply voltage U shall have individual voltage harmonics not exceeding 70% of the compatibility levels given in IEC 61000-2-2. Its spectrum, as well as supply impedance (value at the fundamental frequency), shall be recorded**

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## Requirements for Simulation

- **Simulation is performed using measured values of voltage spectrum and supply impedance. It is considered validated if the results from measurement and simulation do not differ by the highest of following values:**
  - **either ± 5 % for each harmonic current measured**
  - **or ± 0.6 % of the fundamental current**
- **Validation of the simulation is considered to be valid if the same type of equipment is studied and if the rated input power differs from that of the tested EUT by no more than ± 25 %**

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## Low-Frequency Emission Standard EN 61000-3-3

**Goal: limitation of voltage fluctuation and flicker impressed in the public low-voltage supply system by equipment with input current ≤ 16 A per phase, for systems between 220 and 250 V line to neutral at 50 Hz**

**IEC 1000-3-3 standard extends the field of application of previous standard IEC 555-3 including the following equipment that were previously excluded:**

- **equipment for professional use**
- **equipment without automatic controls**
- **equipment causing voltage changes that occur less frequently than once per hour**
- **equipment causing voltage changes that occur more frequently than 1800 times per minute**
- **equipment with voltage changes caused by manual switching**

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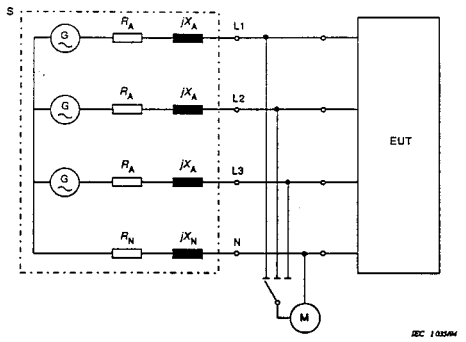
# EN 61000-3-3: Voltage Fluctuation

## Test Circuit

**Requirements**

- **total accuracy of measurement of the relative voltage change must be better than ± 8%**
- **precision of the total line impedance (EUT excluded) must be adequate to achieve the required total accuracy**
- **a special measurement method is foreseen if source impedance is not well defined**
- **THD of supply voltage must be ≤ 3%**
- **test voltage must be maintained within ± 2% of the nominal value**




**$R_A$ = 0,24 Ω, $jx_A$ = 0,15 Ω at 50 Hz**

**$R_N$ = 0,16 Ω, $jx_N$ = 0,10 Ω at 50 Hz**

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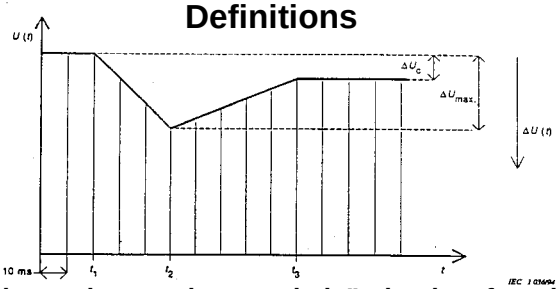
# EN 61000-3-3: Voltage Fluctuation

## Definitions




| | |
|---|---|
| **ΔU(t)** | **"voltage change characteristic": the time function of the change in the r.m.s. voltage between periods when the voltage is in a steady-state condition for at least 1 s** |
| **$\Delta U_{MAX}$** | **"maximum voltage change": the difference between maximum and minimum r.m.s. values of the voltage change characteristics** |
| **$\Delta U_C$** | **"steady-state voltage change": the difference between maximum and minimum r.m.s. values of the voltage change characteristics** |
| **Note:** | **Relative values d(t), $d_{MAX}$ and $d_C$ are obtained by dividing the previous voltages by $U_n$ (nominal voltage)** |

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# EN 61000-3-3: Voltage Fluctuation

## Limits

**The following limits apply:**

- **$d_C$ < 3 %**
- **$d_{MAX}$ < 4 %**
- **the value of d(t) during a voltage change shall not exceed 3% for more than 200 ms**

***If the voltage changes are caused by manual switching or occur less frequently than once per hour the above limits shall be increased by 33%***

**Note: Relative voltage change d(t) can be measured directly or derived from the rms current**

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# EN 61000-3-3: Flicker

***Flicker:*** **Impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time**

- **The flicker meter simulates the process of physiological visual perception and gives a reliable indication of the reaction of an observer to any type of flicker, independently of the source of disturbance.**
- **A statistical approach is applied**

**Short-term flicker indicator, $P_{st}$: flicker severity evaluated over a short period (10 minutes); $P_{st}$ = 1 is conventional threshold of irritability**

**Long-term flicker indicator, $P_{lt}$: flicker severity evaluated over a long period (2 hours) using successive $P_{st}$ values**

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

**It is generally necessary to assess the value of $P_{lt}$ for equipment which is normally operated for more than 30 min at a time**

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# EN 1000-3-3: Flicker

## Assessment of short-term flicker value $P_{st}$

| Types of voltage fluctuations | Methods of evaluating Pst |
|---|---|
| All voltage fluctuations (on line evaluation) | Direct measurement |
| All voltage fluctuations where U(t) is defined | Simulation<br>Direct measurement |
| Special shape of voltage change waveform with an occurrence rate less than 1 per second (*) | Analytical method<br>Simulation<br>Direct measurement |
| Rectangular voltage change at equal intervals | Use of Pst = 1 curve<br>Direct measurement |

**(*) ramp, step, double-step, rectangular, triangular and motor-start voltage characteristics**

**In case of doubt, the $P_{st}$ shall be measured using the reference method with a flicker meter.**

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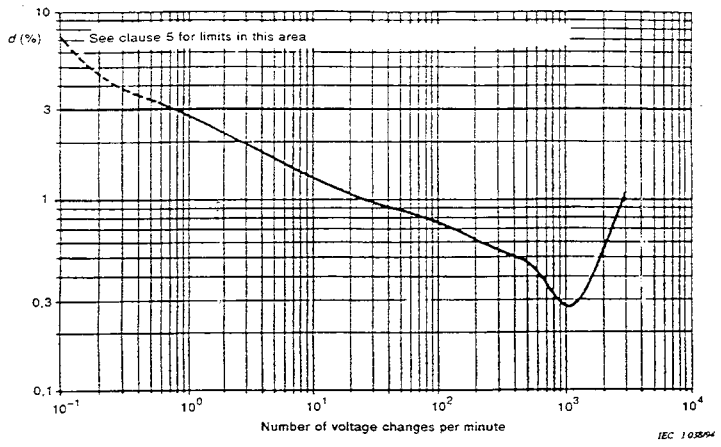
# EN 61000-3-3: Flicker

## Assessment of short-term flicker value,




**Curve for $P_{st}$ = 1 for rectangular equidistant voltage changes**

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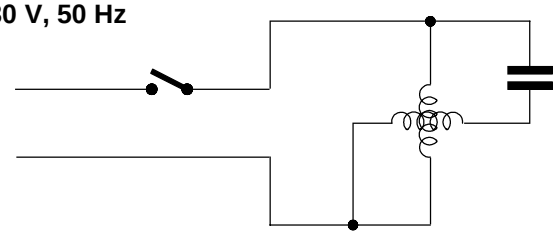
# Voltage Fluctuation Test

## Motor for Refrigerator

**Power: 500 W**

**Voltage: 230 V, 50 Hz**

**EUT scheme**



**$d_C$ = 0.9 %**

**$d_{MAX}$ = 4.16 %**

**d(t) > 3 % for 100 ms**

**Status: FAIL**

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# Voltage Fluctuation Test

## Motor for Refrigerator - Corrective Provisions

**1. <u>Decreasing transient current</u>**

- **Reactive current (steady-state conditions): Ir = 2.2 A**
- **By connecting a capacitor C = 30 μF at the input terminals, the maximum transient current reduces by 6 %, which is not enough**

**2. <u>Controlling supply voltage</u>**

- **A test with reduced supply voltage (0.85 $U_n$) shows $d_{MAX}$ = 3.85**
- **A supply voltage reduction can be achieved, during transient conditions, by using SCR regulators; in this case, however, attention must be paid to harmonic pollution**

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# Example: Equipment for Dental Technology

**Power: 700 W**

**Voltage: 230 V, 50 Hz**

**An automatic fan - used inside the EUT to suck up air - causes input transient currents**

| **Without any provisions:** | **Soft start of the fan (ramp V):** |
|---|---|
| **$d_C$ = -1.14 %** | **$d_C$ = -0.10 %** |
| **$d_{MAX}$ = 4.08 %** | **$d_{MAX}$ = 0.37 %** |
| **d(t) > 3 % for 70 ms** | **d(t) > 3 % for 0 ms** |
| **Status: FAIL** | **Status: PASS** |

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# Technical Report IEC 1000-3-5

**<u>Scope</u>: limitation of voltage fluctuation and flicker impressed on the public low-voltage supply system, for equipment with input current > 16 A per phase**

**Equipment with input current ≤ 75 A:**
- **calculation of maximum permissible system impedance**

**Equipment with input current > 75 A:**
- **a detailed system study is recommended**
- **the equipment shall be evaluated considering actual system impedance**

**IT'S NOT A STANDARD !**

**It is proposed for provisional application, so that information and experience of its use in practice may be gathered**

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# Technical Report IEC 1000-3-5

**Equipment with input current ≤ 75 A**

**The following steps are required:**

- **Measurement of the values $d_c$, $d_{MAX}$, $P_{st}$, $P_{lt}$ (an impedance lower than $Z_{ref}$ of IEC 1000-3-3 is foreseen)**
- **In case the values exceed the limits of IEC 1000-3-3: calculation of the maximum permissible system impedance**

**Manual switching:**

$$|Z_{sys}| = |Z_{ref}| \cdot 1{,}33 \cdot 4\% / d_{MAX}$$

$$|Z_{sys}| = |Z_{ref}| \cdot 1{,}33 \cdot 3\% / d_C$$

**In all other cases:**

$$|Z_{sys}| = |Z_{ref}| \cdot 4\% / d_{MAX}$$

$$|Z_{sys}| = |Z_{ref}| \cdot 3\% / d_C$$

$$|Z_{sys}| = |Z_{ref}| \cdot (1 / P_{st})^{3/2}$$

$$|Z_{sys}| = |Z_{ref}| \cdot (0{,}65 / P_{lt})^{3/2}$$

**The minimum among the computed $Z_{sys}$ is maximum permissible system impedance**

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**Go to Section 5**

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