

Electromagnetic Compatibility (EMC) Low-Frequency Standards

Summary

- IEC 61000-3-2:** Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)
- IEC 61000-3-4:** Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 16 A per phase

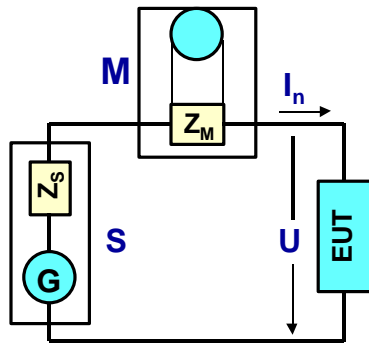
Standards on Low-Frequency Emission: IEC 61000-3-2

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

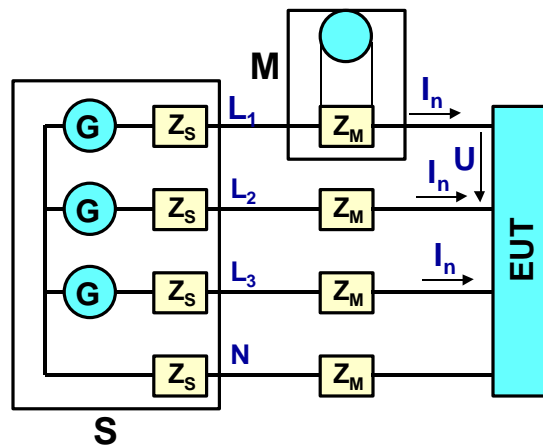
- Equipment to be connected to 220/380 V, 230/400 V and 240/415 V systems operating at 50 Hz or 60 Hz
- No limits for systems with nominal voltage less than 220 V (line-to-neutral)
- Four categories of equipment
- Absolute and/or relative limits (relative limits based on input power)

IEC 61000-3-2: Measurement Circuit

Single-phase equipment



Three-phase equipment



IEC 61000-3-2 Supply Source Requirements

Test voltage U at the EUT's terminals:

- **rated** voltage of the equipment. In the case of voltage range, use **230/400 V** for single-phase and three-phase supply
- voltage accuracy within $\pm 2\%$ of the nominal value
- frequency accuracy within $\pm 0.5\%$ of the nominal value
- displacement accuracy between each pair of phases of a three-phase source within $\pm 1.5^\circ$
- 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)

IEC 61000-3-2 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

Voltage drop on input impedance Z_M shall not exceed $0.15V_{peak}$

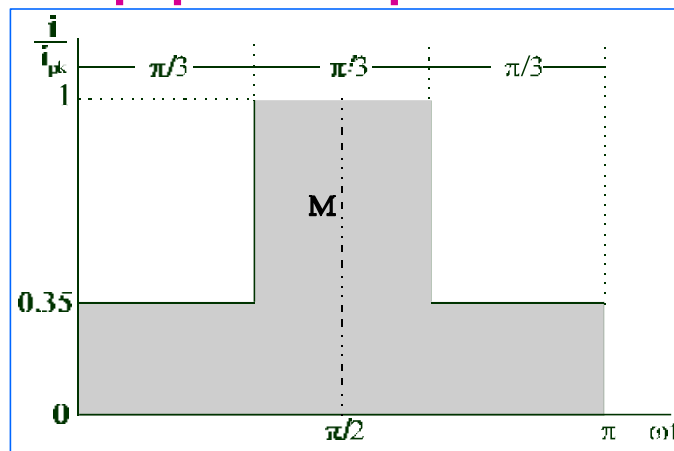
IEC 61000-3-2 Measurement Equipment Requirements

- Any type of wave analyzer may be used
 - (frequency-domain instrumentation using selective amplifier, heterodyne, multiple passive filters, spectrum analyzer tuned to the frequency to be measured, and time-domain instrumentation using digital filters or Discrete-Fourier-Transform DFT)
- Annex B of IEC 61000-3-2 reports requirements for measurement equipment

IEC 61000-3-2 Classification of Equipment

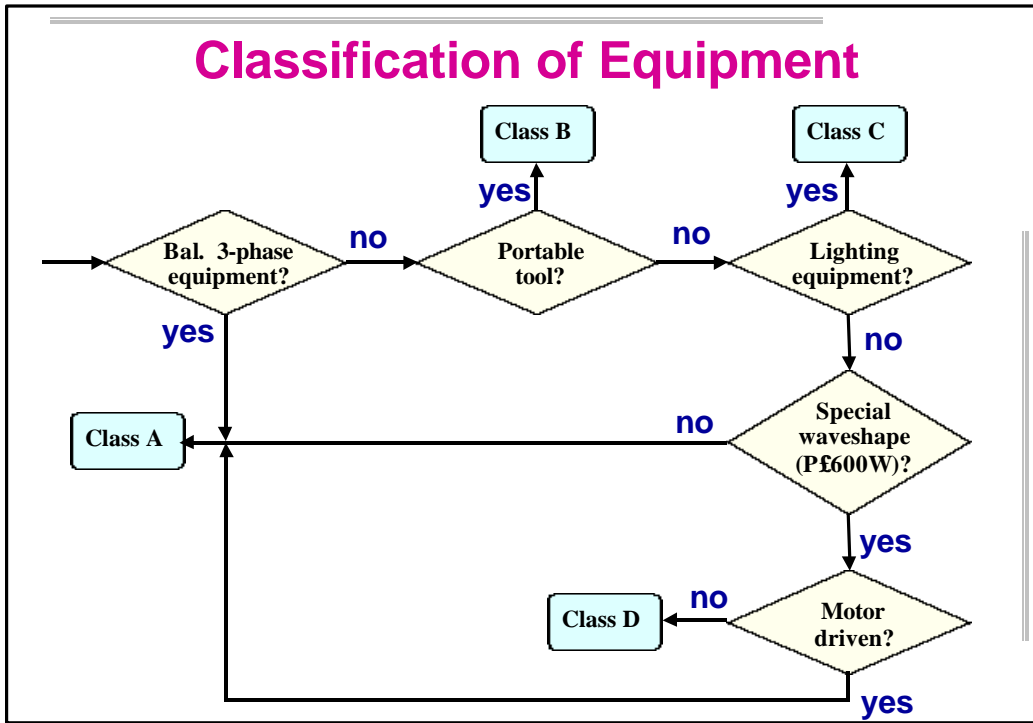
- **Class A:** balanced 3-phase equipment (r.m.s. line currents differing less than 20 %) and all other equipment, except those in the following classes
- **Class B:** portable tools
- **Class C:** lighting equipment including dimming devices with active input power above 25 W
- **Class D:** equipment 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

IEC 61000-3-2 Class D equipment: Special Wave Shape



Each half cycle of input current is within the envelope for at least 95% of the time

Classification of Equipment



IEC 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

IEC 61000-3-2 - Harmonic Limits

Class C > 25 W

Harmonic order n	Maximum value expressed as a percentage of the fundamental input current of the luminaries
2	2
3	$30 \lambda^*$
5	10
7	7
9	5
$11 \leq n \leq 39$	3

* λ is power factor

IEC 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 lamp class A limits shall be satisfied. Where phase control is used, the firing angle shall not exceed 145°
 - for discharge lamps class D limits apply

IEC 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

Harmonic Current Measurements

- **No limits apply for high power equipment (> 1 kW) for professional use (equipment for use in trades, professions, or industries not intended for sale to the general public)**
- **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**

Harmonic Current Measurements

- The limits are applicable to steady-state harmonic currents
- For transitory 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 transitory harmonic currents occurring during the testing of equipment or parts of equipment. For transitory **even** harmonic currents of order from **2 to 10** and transitory **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**

IEC 61000-3-2: Comments

- High crest-factor waveforms are penalized (Class D) in order to reduce peak-clipping effect. If line-voltage distortion will not improve in the future, the lower power limit of class D will be reduced from 75 W to 50 W
- 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
- Requirements for lamps above 25 W are severe, below 25 W there is presently no limit

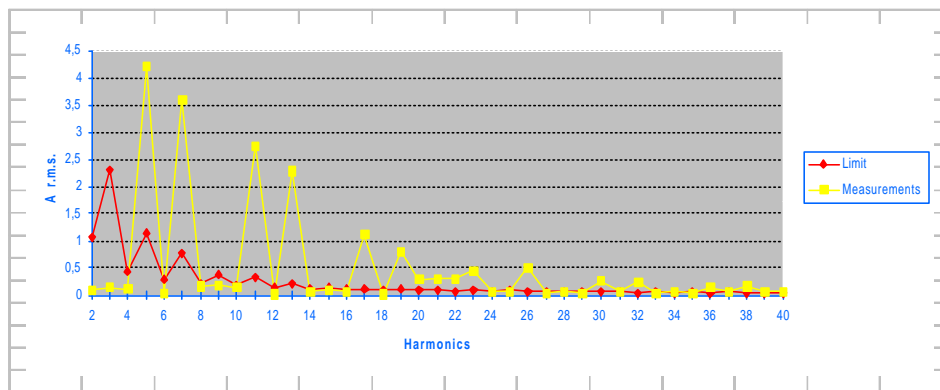
Test Conditions

- Particular test conditions are specified for the following equipment:
 - Television (TV) receiver (both colour and monochrome)
 - 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

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



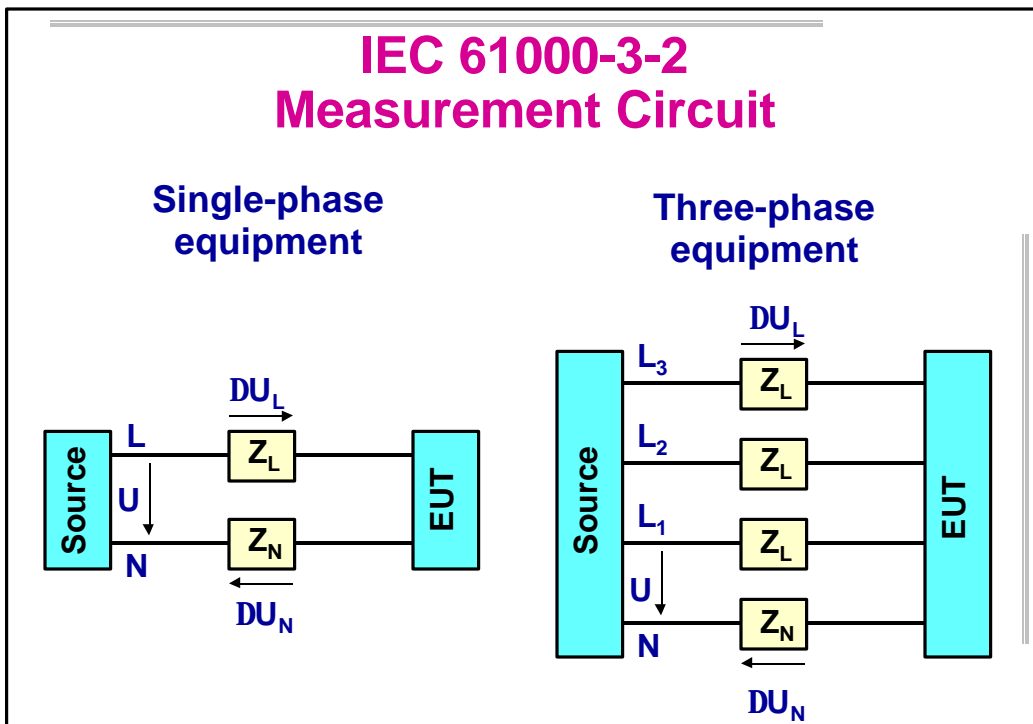
Technical Report on Low-Frequency Emission: IEC 61000-3-4

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

IEC 61000-3-4

- 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

IEC 61000-3-2 Measurement Circuit



IEC 61000-3-2 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 $\pm 2\%$ of the nominal value
- frequency accuracy within $\pm 0.5\%$ of the nominal value
- displacement accuracy between each pair of phases of a three-phase source within $\pm 1.5^\circ$
- 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 DU ($DU = DU_L + DU_N$ or $DU = 2DU_L$) shall not exceed $0.5 V_{\text{peak}}$

IEC 61000-3-2 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

IEC 61000-3-4: 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 (PWHHD):**

$$PWHHD = \sqrt{\sum_{n=14}^{40} \frac{a_n}{c_n} \frac{U_n}{U_1} \frac{1}{n^2}}$$

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

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

IEC 61000-3-4: 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 (interphase)

$$S_{\text{equ}} = U_p I_{\text{equ}} \quad \text{For single-phase equipment}$$

$$S_{\text{equ}} = U_i I_{\text{equ}} \quad \text{For interphase equipment}$$

$$S_{\text{equ}} = \sqrt{3} U_i I_{\text{equ}} \quad \text{For balanced three-phase equipment}$$

$$S_{\text{equ}} = 3 U_p I_{\text{equ_max}} \quad \text{For unbalanced three-phase equipment}$$

($I_{\text{equ_max}}$ is the maximum of the r.m.s. currents flowing in any one of the three phases)

IEC 61000-3-4: Definitions

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

$$R_{\text{sce}} = S_{\text{sc}} / (3 S_{\text{equ}}) \quad \text{For single-phase equipment}$$

$$R_{\text{sce}} = S_{\text{sc}} / (2 S_{\text{equ}}) \quad \text{For interphase equipment}$$

$$R_{\text{sce}} = S_{\text{sc}} / S_{\text{equ}} \quad \text{For all three-phase equipment}$$

IEC 61000-3-4: 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

IEC 61000-3-4: 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

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

IEC 61000-3-4: Connection Procedures

Stage 2 current emission values for single-phase, interphase 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

IEC 61000-3-4: 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

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 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, shall not exceed **1.5 times** the limit values given for the relevant stage
 - the limits apply to all other transitory 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**

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

Requirements for Simulation

- **Simulation performed using measured values of voltage spectrum and supply impedance. It is considered validated if the results from measurement and simulation do not differ of the highest following value:**
 - **either $\pm 5\%$ for each harmonic current measured**
 - **or $\pm 0.6\%$ 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 $\pm 25\%$**