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Calibration

A power engineer's guide to navigating the EMC directive

Application note

The EMC Directive introduces a mass of test and measurement requirements that many engineers actively try to avoid. Understanding the basics is no longer optional—and is nowhere near as difficult as you may have been led to believe.

Strangely for a profession that depends upon countless voluntary standards for its survival, the electronics industry always finds legislative demands tough going. There's no hiding place either—the global nature of today's commerce makes it impossible to ignore legislation and standards that originate in any of the key markets. No legislative demand to date has caused product designers more fear, uncertainty and doubt than the European Commission's EMC Directive 2004/108/EC (originally 89/336/EEC).

Under this directive, standards bodies in regions as diverse as the US, Australasia, and the Middle and Far East have broadly or even precisely followed the European Union's lead, whose definition of EMC is "the ability of an equipment to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment." Let's review the impact of the standards that the directive embraces for engineers working in the ac powerline, energy metering, and power-quality areas—where recent changes to the key harmonic pollution and voltage fluctuation measurements are crucially important. Please remember that this review is just that—it's no substitute for official standards documents or the expert interpretation that test houses apply on their client's behalf!

What is the EMC Directive?

To help promote free trade throughout the European Union, in 1985 the European Commission launched a program to harmonize national and international technical standards—the aim being to create uniform trading conditions for all member states. Recognizing the importance of electromagnetic compatibility for the ever-growing electrical and electronic equipment market, the Commission instructed CENELEC (the European Committee for Electrotechnical Standardization) to come up with standards to combat powerline and radio frequency interference—using where possible existing IEC standards. Established in 1906 as the standards-making body for the electrical industry, the International Electrotechnical Commission (IEC) has two main technical committees that are responsible for EMC—the CISPR (French for the International Special Committee on Radio Interference), and technical committee TC77 that's responsible for the IEC 61000 series.

IEC standards are voluntary until a regulatory authority adopts them, which in 61000's case is CENELEC. Standards acquire legal significance when they're published in the Official Journal of the European Community and acquire EN (European Normative) status. Notification of new standards and updates continually appears on Europa's website—see Useful Links at the conclusion of this document.. Accurate but turgid, this site covers everything from the shape of fruit and vegetables to the campaign against smoking, leaving most engineers to rely on trade magazines such as *Test & Measurement World* and specialist sources such as *Compliance Journal, Evaluation Engineering,* and *Metering International.*

The EMC Directive includes CISPR and IEC 61000 standards along with generic emissions and immunity standards that act as a catch-all for products where no specific standards apply. Among a seemingly endless string of numbers, generic standards include EN 50081, EN 55011, EN 55014, and EN 55022 for emissions and EN 50082 for immunity. It's a manufacturer's responsibility to ensure that any equipment sold or put into use within the European Union meets appropriate standards, without which assurance products cannot carry the CE mark—the Conformité Européenne health and safety product label—or legally be sold within this region. Other legislation that may apply includes the Low Voltage Directive and the Automotive EMC Directive that define which standards apply to particular product groups, as well as product-specific standards such as those for energy meters. Before considering individual specifications, it's essential to understand *power quality* and some key concepts that apply throughout this area.

Power quality and EN 50160

The concept of power quality ranges from a consumer's view of power delivery that's free from power outages to freedom from interference that may compromise, for example, broadcast reception. The standard that the European electricity supply industry uses to assess the quality of power delivery is EN 50160. This sets the voltage characteristics of the 230 V low-voltage supply level at ± 10 % of nominal voltage and 50 Hz ± 1 % for 95 % of the week. It also sets various limits for transient overvoltages, as well as voltage imbalances in three-phase systems as Table 1 shows.

While most countries have regulatory authorities that follow IEC specifications and guidelines for their electricity supplies, the US differs in having no federal regulatory body that's exclusively responsible for the nation's electricity supply—utilities are subject to the legislation that's effective within their state of residence, and publish their own quality-of-service statements that invariably include "best effort" clauses. The spate of blackouts across the US over the past few years has forced some major rethinking in that country's operating requirements, with the North American Electric Reliability Council recently publishing a series of operating standards that it strongly encourages utilities to adopt. Moreover, it has been in discussions with the Federal Energy Regulatory Commission in an attempt to secure the nation's bulk electricity supply, with many observers considering federal regulation to be inevitable.

	Voltage characteristics of electric supplies (EN50160)	
	LV (< 1kV)	MV (<35 kV)
Frequency	1% for 95% of week -6%/+4% for 100%	1% for 95% of week -6%/+4% for 100%
Voltage Magnitude	±10% for 95% of week, 10min rms	±10% for 95% of week, 10min rms
Rapid voltage changes	5% normal 10% infreq Plt <1 for 95% wk	4% normal 6% infreq Plt <1 for 95% wk
Temporary overvoltage	<1.5kV	170% (solidly or impedance earth) 200% (unearthed or resonant earth)
Transient overvoltage	Generally <6kV Occasionally higher	
Voltage unbalance	2% for 95% of week , 10min rms 3% in some locations	2% for 95% of week , 10min rms 3% in some locations

Table 1. EN 50160 sets limits for European electrical power availability.

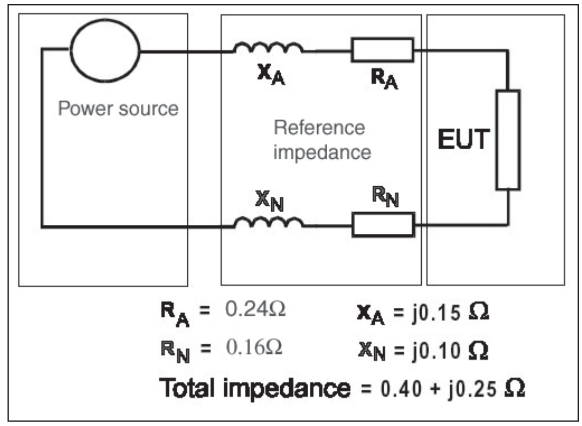

Figure 1. The European Reference Impedance according to IEC 60725.

Reactive power compromises supply-network stability

From an electricity provider's viewpoint, it's critically important to ensure that the supply network is always stable. Because capacitive and inductive loads cause reactive power flow that can compromise network stability, the electricity provider has to ensure that there's always enough power available to maintain stability under worst-case conditions, compromising efficient generation. Taken to extremes, a network that is supplying a poor power factor environment can trip out, creating local blackouts that can cascade throughout the network.

To understand these issues, remember that the ac powerline has finite impedance that varies from socket to socket. Figure 1 shows the European reference impedance according to IEC 60725 that's set with the objective of 95 % of the network's impedance being at or below these values. Dedicated power sources are available with programmable output impedance to simulate this and other models, which vary slightly across the world. In this instance, programming 400 mΩ and 800 µH approximates IEC 60725.

The interactions between the load and this impedance depend on the magnitude of the impedance and the load's current consumption profile. Resistive loads draw current in phase with the voltage waveform, and the resulting power waveform is a positive-going sinusoid at twice line frequency.

In contrast, a purely inductive load draws current 90° out-of-phase with the voltage waveform, and the power waveform is a sinewave of twice line frequency that centers on zero. That is, the inductor alternately absorbs and returns power to the line. Neglecting shunt capacitances, electric motors comprise a resistance in series with an inductance, so some percentage of the supply-line energy dissipates in the resistor that's doing real work while the balance alternates between absorption and return, moving the current waveform away from zero. This example of reactive power is just one of the effects that the electricity supply must accommodate.

Reactive power also creates electricity-metering issues, as traditional electromechanical meters don't accurately measure reactive loads and often undercharge. As a result, today's electronic electricity meters, or e-meters to signify energy metering, digitize the voltage and current waveforms to compute the true power flow. Illustrating several key concepts, e-meters typically measure instantaneous active power, which is the product of the current and voltage waveforms at any time, and then use algorithms to compute other terms. For example, one method to derive apparent power in Volt-Ampere (VA) units first computes both voltage and current root-mean-square (rms) values by squaring the instantaneous sample values, averaging some number of them, and square-rooting the average. The algorithm then multiplies the rms voltage and current values and expresses the result in VA, which represents the maximum amount of real power taken by the load.

To express the active average power in Watts, the real power flow in Joules per second, e-meters typically integrate the instantaneous active power samples over an integer number of powerline cycle periods for one second. Comparing the ratio of active-to-apparent power values yields power factor—PF = W/VA—that varies from unity for resistive loads to zero for a purely reactive load. E-meters often also compute reactive power in Volt-Amp-Reactive (VAR) units. One method uses the same sample group as the active power calculation, but phase-shifts either the voltage or the current signal by 90° relative to the other and then multiplies their instantaneous values. This approach allows a direct comparison between active and reactive power. Although all of these quantities are intrinsically linked, it's power factor that's of most concern to electronic product designers. Left uncorrected, the rectifier-capacitor frontend that appears in virtually all electronics creates nonlinear current flows that generate supply-line harmonic pollution—as Figure 2 shows.

The typical result to the ac line waveform is flat-topping, where the smooth curve around the sinewave's peak becomes compressed. For this reason, equipment increasingly employs active power-factor correction circuitry that cascades a switchmode boost converter ahead of the buck converter that supplies board-level voltages. By storing sufficient energy on an intermediate high-voltage rail, the boost converter decouples the load from drawing irregular current peaks from ac line, and—together with inductor-capacitor filtering—quashes other transients that would otherwise get back into the supply network.

IEC/EN 61000-3-2—classes and limits

While the CISPR standards tackle radio-frequency emissions, IEC/EN 61000 targets all non-CISPR and non product-specific EMC issues. These range from ac powerline EMC protection to radio frequency immunity testing, with a special focus on the low frequency interference that equipment can generate and distribute via the ac line port. The IEC standards follow this generic structure:

- Part One—introduction, fundamental principles, definitions & terminology
- Part Two—description and classification of the environment
- Part Three—emission limits and immunity limits
- Part Four—test and measurement techniques
- Part Five—installation and mitigation guidelines
- Part Six—generic emission and immunity standards
- Part Nine—miscellaneous

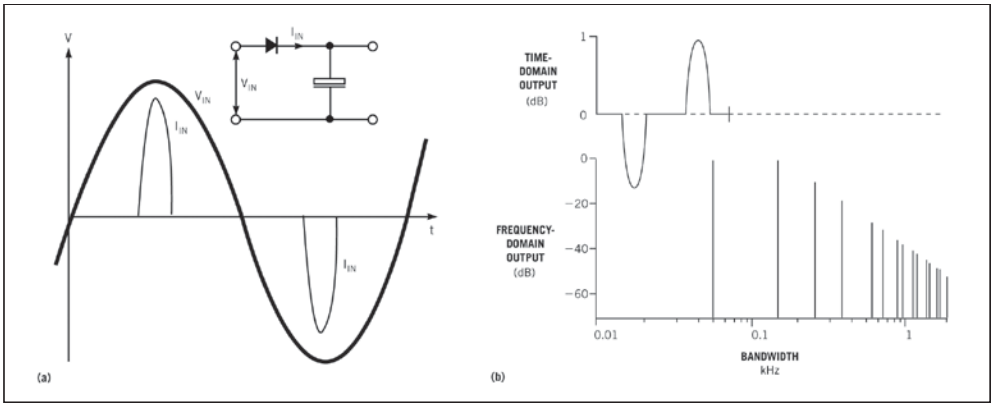

Figure 2. Diode-capacitor front-ends charge the input capacitor close to the peak of the sinewave (a), creating current harmonics that extend way beyond 1 kHz (b).

The 61000-3-2 standard specifies limits for the amount of harmonic powerline pollution that equipment that draws up to 16 A per phase can generate. Effective April 20, 2009, edition 3.2 is current (edition 3.0:2005 plus amendments of 2008 and 2009). Key changes from earlier editions include reclassifying Class D to comprise only PCs, monitors and TVs that draw 75 W to 600 W, together with new references to the IEC 61000-4-7 standard that provides guidance for making measurements on harmonics and interharmonics. 61000-3-2 divides equipment into four classes:

- Class A—balanced 3-phase equipment and anything not otherwise classified
- Class B—portable power tools
- Class C—all lighting equipment except incandescent lamp dimmers
- Class D—PCs, PC monitors, and TVs from 75 W to 600 W

Each class has its own harmonic current emission limits as Table 2 shows:

Harmonic number	Class A limits (A, rms)	Class B limits (A, rms)	Class C limits (% of fundamental)	Class D limits (mA/W)
2	1.08	1.62	2%	N/A
3	2.3	3.45	30 times power factor	3.4
4	0.43	0.65	N/A	N/A
5	1.14	1.71	10%	1.9
6	0.3	0.45	N/A	N/A
7	0.77	1.16	7%	1
8	0.23	0.35	N/A	N/A
9	0.4	0.6	5%	0.5
10	0.18	0.28	N/A	N/A
11	0.33	0.5	3%	0.35
12	0.15	0.23	N/A	N/A
13	0.21	0.32	3%	0.296
14 to 40 (even)	1.84/n	2.76/n	N/A	N/A
15 to 39 (odd)	2.25/n	3.338/n	3%	3.85/n

Table 2. IEC/EN 61000-3-2 emission limits for Classes A through D.

Flicker and IEC/EN 61000-3-3

Also affecting equipment that draws up to 16 A per phase, IEC/EN 61000-3-3 ed.2.0:2008 sets limits for the flicker that devices can cause and includes changes to some limits and measurement methods together with new references to IEC 61000-4-15, which describes the functional and design specifications for flickermeters. Also, IEC/EN 61000-3-11, ed1.0:2000 became effective from November 2003 to cover equipment or installations that 61000-3-3 doesn't address. This includes equipment with an input current of up to 75 A per phase and equipment that requires a conditional connection—that is, when reference impedance values lower than IEC 60725 are necessary to meet 61000-3-3's emissions limits.

So what is flicker? As long ago as the 1940s, consumers complained about periodic short-term variations in the supply voltage that modulate a light bulb's brightness, causing it to flicker like a candle in the breeze. Effectively a repetitive form of voltage dips or sags, these voltage fluctuations arise due to interactions between multiple loads on the local distribution network—with the worst offenders historically being heavy inductive loads such as electric arc furnaces, arc welders, and electric motors. Loads such as these draw significant turn-on currents and/or fluctuating currents in normal operation that create short-term voltage dips as current peaks flow through the supply-line's impedance. These current peaks create localised voltage fluctuations that—and typically unlike the effects of harmonic pollution—consumers directly perceive. For instance, a load that draws 10 A with a power factor of 0.7 creates a voltage drop of around 4.5 V across the IEC 60725 reference impedance. This drop is normally insignificant if it's static, but everyday loads such as laser copiers and printers with rapidly changing power demands can easily generate flicker.

Accordingly, flicker test equipment and test methods focus on modelling the human cognitive system, with measurement criteria that include perceptibility (P) and the short-term flicker indicator Pst, where Pst =1 is the conventional threshold of irritability. As research on 1,200 volunteers who were subjected to a flickering 230 V/60 W bulb reveals, amplitude fluctuation levels and repetition frequency are critical, with people being most sensitive to light fluctuations that occur with a repetition rate of 17.6 Hz. At this frequency, a voltage fluctuation of a mere 0.276 % represents Pst = 1 and is just as irritating as a 3 % fluctuation that repeats 0.8 times per minute. Plotting fluctuations up to 30 Hz when human perception drops sharply, Figure 3 plots amplitude and frequency fluctuations normalized to a constant irritation factor according to 61000-3-3.

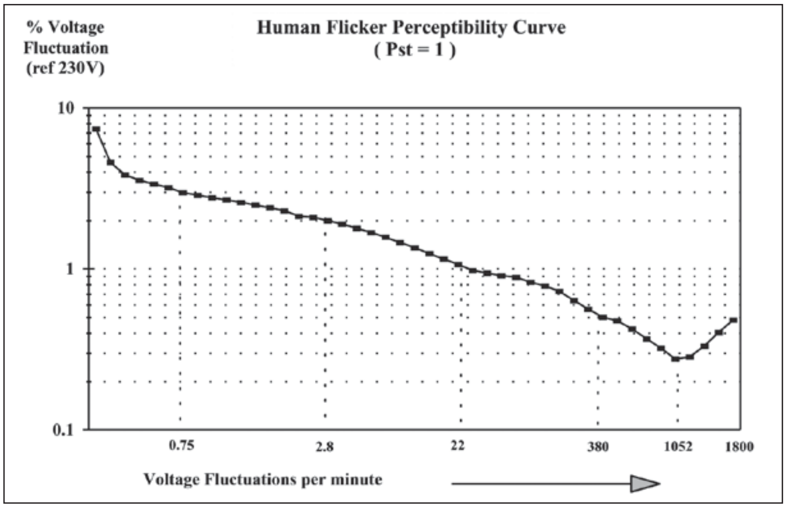

Figure 3. Human responses to flicker dictate IEC/EN 61000-3-3's test requirements.

Loads that draw significant turn-on currents and/or fluctuating currents during normal operation can create short-term voltage dips as current peaks flow through the supplyline's impedance. Repetitive voltage fluctuations can cause incandescent bulbs and fluorescent lamps to flicker, with effects that range from simply being irritating to triggering fits in people who are susceptible to photosensitive epilepsy.

As stated, flicker test equipment and test methods focus on modelling the human cognitive system, with measurement criteria that include perceptibility (P) and the short-term flicker indicator *Pst*, where Pst =1 is the conventional threshold of irritability. Figure 4 shows a simple example of flicker on the ac line waveform.

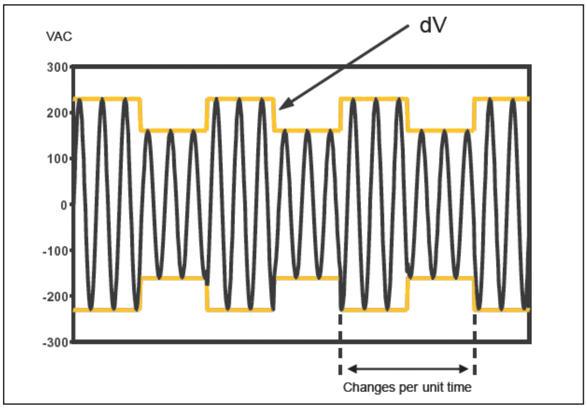

Figure 4. Rectangular amplitude modulation simulates simple flicker.

Implications for measurement

Electrical and electronic products that fall within the reach of European Union EMC or power-quality regulation and its regional equivalents must meet every applicable standard and comply with appropriate industry best practices. This implicitly means that any instrumentation that's used for initial compliance evaluation or to continually ensure compliance—typically at production test or final quality assurance—must be traceably calibrated to national standards and possess an acceptable test uncertainty ratio for the type of tests that it makes.

The IEC standards contain a great deal of information on test methods. Both IEC/EN 61000-3-2 and –3 include measurement requirements as well as annexes that prescribe type-test conditions for equipment such as TVs and washing machines. Additional key specifications that affect harmonics and flicker measurements appear within IEC/EN 61000-4-7 and IEC/EN 61000-4-15. Metrology for electro-mechanical active energy meters falls under IEC/EN 62053-11, with –21 and –22 applying to electronic meters in classes 2 through 0.2S. Power engineers also need to be familiar with the IEC/EN 61000-4-30 standard for electrical power quality measurements.

61000-3-2 and 61000-4-7

Compared with previous editions, Edition 3.2 of 61000-3-2 makes some important revisions to measurement methods, the first of which concerns data acquisition. The measurement windows have been revised from 320 msec (50 Hz) and 266.7 msec (60 Hz) to a uniform 200 msec rectangular window that's respectively and 10 and 12 line cycles long with ± 0.03 % worst-case accuracy. All measurements must be gap-free and the observation period must be long enough to ensure that results are repeatable within ± 5 %. There's a new method for measuring harmonics that measures the average level of each harmonic from the second to the fortieth order over the test's full duration, applying first-order filtering with a 1.5-second time constant to all the harmonic measurements before the final averaging stage. Results for each harmonic must lie below the respective limit for the equipment's class.

These changes substantially affect products that have fluctuating harmonic levels that result from changing power consumption levels. The original specification's allowances for fluctuating values of as much as 150 % of the limits for 10 % of measurement time are gone. Instead, the results from filtered harmonic measurements within each 200-msec window must be less than 150 % of the limit values. There's also an additional allowance for odd harmonics from the twenty-first through thirty-ninth instances, where individual harmonics can exceed their limits providing that the average value for the whole group is below the 100 % level. Because class C and D limits are proportional to power, manufacturers must state the power level of their equipment, which must be within ± 10 % of measured values.

In its original form, 61000-3-2's annex B specified various requirements for measurement equipment, such as total permissible error. Edition 3.2 replaces annex B with the new IEC/EN 61000-4-7 that provides a guide to measurements and measurement instrumentation for use in analysing harmonics. The guide describes a block-diagram level harmonic analyser that at first glance resembles a typical e-meter, with separate voltage and current inputs followed by sampling, conversion, and active power calculation modules—see

Figure 5: To obtain results that are reproducible and allow direct intercomparisons, the specification uses a simplified measurement approach that's based on a discrete-Fourier-transform (DFT) block with subsequent grouping and smoothing stages that shape the signal to suit the standard's compliance check. This signal processing chain measures the value of each harmonic up to the fortieth instance with 5-msec resolution within a 200-msec measurement window. It groups and smoothes harmonics and interharmonics that fall within each measurement window using a 1.5-sec filter. Because power is part of the limits calculation for class D, the active power calculation receives the same 1.5-sec filtering as the groups of harmonics. The instrument then compares the results for each harmonic group with the requisite limits for the class of equipment-under-test.

Table 3 shows the maximum allowable measurement error for single-frequency, steady-state signals for Class 1 instruments that are suitable for standards compliance work and Class 2 instruments for general-purpose use. The error terms relate to the limits that appear in 61000-3-2 that is, 5 % of the permissible limits or 0.15 % of the equipment-under-test's current rating, whichever is greater.

The instrument's normal measurement bandwidth is 2 kHz (50 Hz) or 2.5 kHz (60 Hz), above which anti-aliasing low-pass filters exclude higher frequency components from influencing results. Attenuation in the stop band must be >50 dB. The voltage supply to the equipment-under-test must also be quite pure to avoid influencing the results, with a worst-case value of 0.9 % for the third harmonic distortion falling to 0.1 % for the eleventh to fortieth orders. Other notable requirements include a maximum permissible voltage drop of 0.5 V across the current-sensing element and its wiring.

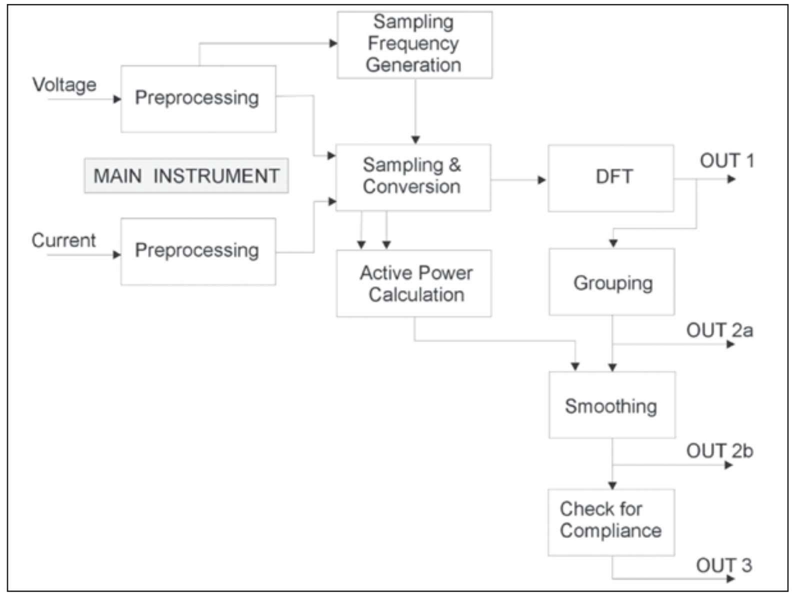

Figure 5. IEC/EN 61000-4-7's harmonic analyser block diagram.

Class	Measurement	Conditions	Maximum Error
I	Voltage	$U_m \geq 1\%\ U_{nom}$ $U_m < 1\%\ U_{nom}$	$5\%\ U_m$ $0{,}05\%\ U_m$
	Current	$I_m \geq 3\%\ I_{nom}$ $I_m < 3\%\ I_{nom}$	$\pm 5\%\ I_m$ $\pm 0{,}15\%\ I_{nom}$
	Power	$P_m < 150W$ $P_m > 150W$	$\pm 1{,}5$ W $\pm 1\%$ of P_m
II	Voltage	$U_m \geq 3\%\ U_{nom}$ $U_m < 3\%\ U_{nom}$	$5\%\ U_m$ $0{,}15\%\ U_m$
	Current	$I_m \geq 10\ \%\ I_{nom}$ $I_m < 10\ \%\ I_{nom}$	$\pm 5\%\ I_m$ $\pm 0{,}5\%\ I_{nom}$

U = V rms *m = measured value*
I = A rms *nom = nominal value*
P = W

Table 3. Maximum measurement error limits according to IEC/EN 61000-4-7.

61000-3-3 and 61000-4-15

To assess the equipment-under-test's ability to create flicker, it's necessary to monitor the voltage change over time at the equipment's ac line input port with the supply line having an impedance equivalent to the IEC 60725 reference values. The conventional device for making these measurements is a flickermeter, whose characteristics appear in IEC 61000-4-15—see Figure 6.

The model according to 61000-4-15 divides the flickermeter into five functional blocks. The first block scales the ac line input voltage to an internal reference level, enabling measurements to be independent of input level. There's also a signal generator for use as an on-site calibration checker. The next block is a demodulator that squares the input signal to recover the voltage fluctuation. Block three cascades two filters to remove dc and double-frequency ac line ripple from the demodulator's output and weight the instrument's frequency response. Block four comprises a squaring multiplier and a first-order filter that work with blocks two and three to simulate the human cognitive system's response to flickering lamps. The last block is the data processing subsystem that calculates the flicker level. Flickermeters calculate Pst using a Laplace transfer function that

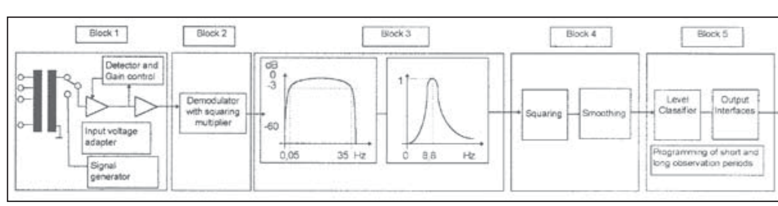

Figure 6. The standard flickermeter comprises five functional blocks.

evaluates individual rms voltage values measured over a series of equal rectangular intervals from turn-on, integrating over a 10-minute period—after which a Pst <1 result demonstrates compliance with the specification's limits. Equipment that's normally operated for more than 30 minutes at a time can take two hours or more to evaluate, with a maximum allowable long-term flicker indicator value *(Plt)* of 0.65 for measurements integrated over any two-hour period. Figure 7 shows the measurement parameters in an example test immediately following a power-cycle change.

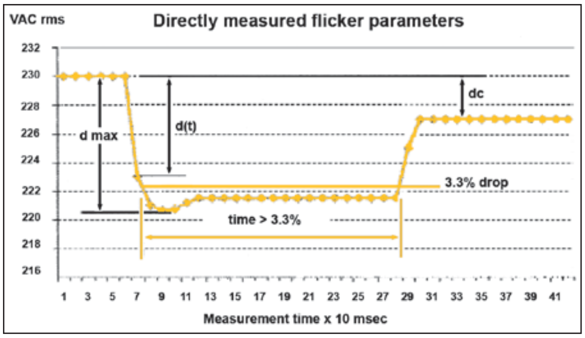

Figure 7. Flicker measurements assess the relative voltage change *d* over time.

Newly revised criteria include the relative voltage drop dc not exceeding 3.3 %; the transient value *d(t)* must not exceed 3.3 % for more than 500 msec; and the maximum relative voltage drop *d max* must not exceed 4% for equipment that continually cycles its power levels (additional qualification now allows 6 % to 7 % for inrush current into equipment that's switched on/off relatively infrequently, such as handheld tools). To avoid the random nature of mains phasing at equipment turn-on and the current peak variations that result, there's also a new procedure to establish d max that takes 24 readings, discards the lowest and highest values, and averages the remainder.

62053-11, -21, -22 and -23

The European standards that apply to energy meters appear within IEC/EN 62053, which specifies requirements for electromechanical meters (62053-11) and static meters that measure active energy—notably IEC/EN 62053-21 for meter classes 1 and 2, which replaces IEC 61036—and 62053-22 for class 0.2S and 0.5S active-energy meters. Reactive energy meters fall into 62053-23. If the meter measures more than one type of energy or contains other functionality—such as a time switch or a data communications interface—it must comply with the standards for those elements.

Replacing the general requirements of earlier standards, IEC/EN 62052-11 is today's reference for tests and test conditions that accompanies the IEC/EN 62053 series. Similarly, IEC/EN 62053-11, -21, -22, and -23 replace the earlier IEC 60521, 60687, 61036, and 61268 standards and describe the key tests and error limits for metrology. Table 4 annotates the error limits for the commonest meter classes 1 and 2 for measuring active energy according to 62053-21.

Value of current		Power factor	Percentage error limits for meters of class	
for direct connected meters	for transformer operated meters		1	2
$0.05\ I_b \leq I < 0.1\ I_b$	$0.02\ I_b \leq I < 0.05\ I_n$	1	± 1.5	± 2.5
$0.1\ I_b \leq I \leq I_{max}$	$0.05\ I_b \leq I \leq I_{max}$	1	± 1.0	± 2.0
$0.1\ I_b \leq I < 0.2\ I_b$	$0.05\ I_n \leq I < 0.1\ I_n$	0.5 inductive	± 1.5	± 2.5
		0.8 capacitive	± 1.5	–
$0.2\ I_b \leq I \leq I_{max}$	$0.1\ I_n \leq I \leq I_{max}$	0.5 inductive	± 1.0	± 2.0
		0.8 capacitive	± 1.0	–
When specially requested by the user:				±
From		0.25 inductive	± 3.5	±
$0.2\ I_b \leq I \leq I_b$	$0.1\ I_n \leq I \leq I_n$	0.5 capacitive	± 2.5	

Table 4. IEC/EN 62053-21 maximum error limits for Class 1 and Class 2 e-meters.

The specification differentiates between *direct connected* meters that use sense resistor current shunts and *transformer operated* meters that employ current transformers or transducers. In general, current shunts have better low-level linearity characteristics than current transformers, which the specification recognizes by applying measurement different bands of *Ib*—the meter's *basic current,* or nominal full-load value—to the respective sensor types. Meters must maintain rated accuracy for three power-factor conditions that represent typical installation environments. In addition, meters must maintain their accuracy within a small additional error percentage in the presence of *influence quantities* such as ambient temperature changes, voltage variations of ± 10 %, and frequency variations of ± 2 %. Figure 8 shows the functional measurement setup.

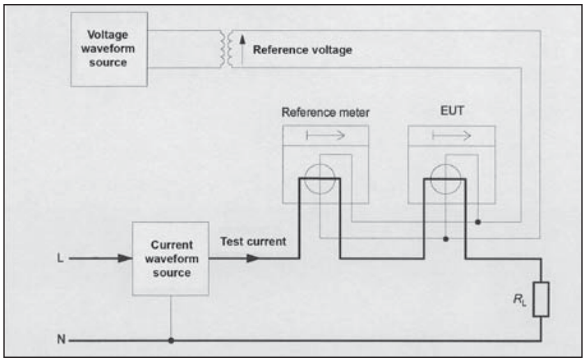

Figure 8. Functional setup for energy meter measurements.

While electromechanical meters only have to guarantee a measurement response to 10 % third-harmonic distortion in the current waveform, electronic meters have much more stringent requirements. Tests include harmonic components in the current and voltage channels; dc and even harmonics in the ac current channel; odd harmonics in the ac current channel; and sub-harmonics in the ac current channel. The test conditions for accuracy in the presence of harmonics specify nominal operating voltage, 50 % of nominal full-range current, and unity power factor at the fundamental ac line frequency. The interfering harmonic is fifth order at 10 % of nominal operating voltage and 40 % of the fundamental current, with a harmonic power factor of 1. The fundamental and harmonic voltages are in-phase at the positive going zero crossing. This results in fifth harmonic power level of 0.04 of the fundamental current for total active power of 1.04 of the fundamental value. Figure 9 shows one test waveform for sub-harmonics that applies to all electronic meters.

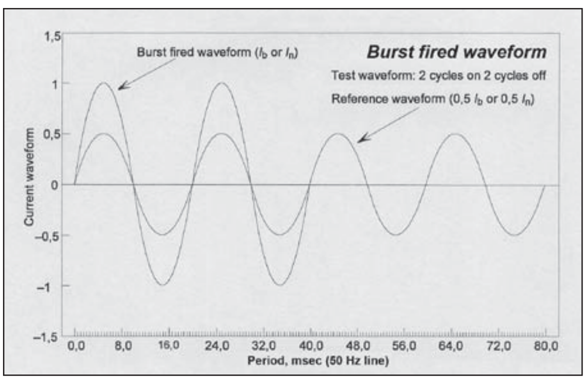

Figure 9. Example sub-harmonic current test waveforms for e-meters.

61000-4-30

IEC 61000-4-30 describes measurement and interpretation methods for power-quality parameters but doesn't set any limits—these already appear in other parts, such as 61000-3-2 and -3. The methods within 61000-4-30 tackle flicker and voltage and current harmonics and interharmonics measurements, together with assessing voltage and frequency stability—including phenomena such as voltage dips and swells, interruptions, and transients. Additional sections cover special measurements for applications that use the ac line supply line for signaling purposes.

There are two classes of measurement performance—class A, which applies to instruments that are used for reference measurements including standards compliance verification, and class B, which is used for applications such as troubleshooting. The specification points out that instruments may have different classes of performance for different measurement parameters. Class A instruments employ three time intervals to accumulate measurement data taken using the basic 200-msec ten or twelve-cycle measurement window—a three-second interval of 150 cycles for 50 Hz or 180 cycles for 60 Hz; a ten-minute interval; and a two-hour interval. There's also a 10-second period for making line frequency measurements. With the exception of flicker, the aggregation method for voltage and current measurements for each interval is rms. The aggregation period is continuous with no gaps between measurement windows. A flagging concept avoids accumulating unreliable values for supply stability, flicker, and harmonic measurements that can occur during voltage dips, swells, and interruptions. It's up to the user to decide how to evaluate flagged data. Notable class-A power-quality accuracy requirements include a maximum frequency measurement uncertainty of ± 0.01 Hz and voltage ≤ ± 0.1 % at nominal line values, along with the responses to harmonics and flicker that appear in 61000-4-7 and 61000-4-15. Further clauses describe the requisite performance characteristics for voltage dips and swells, interruptions, imbalances, and ac-line signaling.

Importantly, the specification imposes a range of influence quantities into the performance verification equation. This reflects the fact that many measurements can be degraded in the presence of other artifacts, such as three-phase voltage balance being disturbed by harmonic interference. To ensure that instruments measure correctly in the presence of multiple artifacts, 61000-4-30 dictates that measurement results for a parameter must be within their specified uncertainly when all other parameters lie within a permissible range. This means, for instance, that a class-A voltage measurement must maintain its ± 0.1 % uncertainty in the presence of harmonics, interharmonics, and flicker—placing exceptional

Influence quantities	Range of variation
Frequency	42,5 Hz – 57,5 Hz for 50 Hz systems 51 Hz – 69 Hz for 60 Hz systems
Voltage magnitude (steady-state)	0 % – 200 % of U_{din}
Flicker (P_{st})	0 – 20
Unbalance	0 % – 5 %
Harmonics (THD)	Twice the values in IEC 61000-2-4, class 3
Interharmonics (at any frequency)	Twice the values in IEC 61000-2-4, class 3
Mains signalling voltage	0 % – 9 % of U_{din}
Transient voltages according to IEC 61180	6 kV peak
Fast transients	4 kV peak
NOTE P_{st} shall be produced by periodic modulation.	

Table 5. 61000-4-30 demands parametric tests in the presence of multiple artifacts.

demands on the sources that are used to calibrate class-A instruments, which then require overall uncertainties of ≤ 0.02 % across a range of artifacts to ensure reliable results. Table 5 shows the influence quantities and their ranges for class-A performance.

For each measurement parameter, the test procedure first selects the parameter of interest—say voltage—then makes further measurements at five equally-spaced points throughout the range of this parameter while holding all other parameters constant within testing state 1—see Table 6. This check is therefore a linearity test, with voltage being checked at 0 %, 50 %, 100 %, 150 %, and 200 % of nominal full range. The procedure then advances to testing states 2 and 3, when the primary parameter of interest is subject to successive combinations of influence quantities—during which the instrument must maintain its accuracy within the specification's permissible uncertainties. For example, voltage readings must correctly report the sum of the fundamental and any harmonics, while harmonics mustn't disturb voltage imbalance measurements. These checks demand test sources that can freely combine reference test signals such as rms voltage, flicker, and harmonics:

Class B instruments must pass similar but less exacting multiple-artifact tests. Also, the manufacturer must state the respective measurement intervals and explain how the instrument acquires and reports its measurement data. The maximum voltage measurement uncertainty is ≤ ± 0.5 %, and again the manufacturer must state the uncertainty and measurement method for frequency readings.

Influence quantities	Testing state 1	Testing state 2	Testing state 3
Frequency	f_{nom} ± 0,5 Hz	f_{nom} – 1 Hz ± 0,5 Hz	f_{nom} + 1 Hz ± 0,5 Hz
Voltage magnitude	U_{din} ± 1 %	Determined by flicker, unbalance, harmonics, interharmonics (below)	Determined by flicker, unbalance, harmonics, interharmonics (below)
Flicker	P_{st} < 0,1	P_{st} = 1 ± 0,1 – rectangular modulation at 39 changes per minute	P_{st} = 4 ± 0,1 – rectangular modulation at 110 changes per minute NOTE This only applies to 10-min values. For other values, use P_{st} = 0 to 0,1
Unbalance	0 % to 0,5 % of U_{din}	0,73% ± 0,5 % of U_{din} Phase A 0,80% ± 0,5 % of U_{din} Phase B 0,87% ± 0,5 % of U_{din} Phase C all phase angles 120°	1,52% ± 0,5 % of U_{din} Phase A 1,40% ± 0,5 % of U_{din} Phase B 1,28% ± 0,5 % of U_{din} Phase C all phase angles 120°
Harmonics	0% to 3 % of U_{din}	10 % ± 3 % of U_{din} 3rd at 0° 5 % ± 3 % of U_{din} 5th at 0° 5 % ± 3 % of U_{din} 29th at 0°	10 % ± 3 % of U_{din} 7th at 180° 5 % ± 3 % of U_{din} 13th at 0° 5 % ± 3 % of U_{din} 25th at 0°
Interharmonics	0% to 0,5 % of U_{din}	1 % ± 0,5 % of U_{din} at 7,5 f_{nom}	1 % ± 0,5 % of U_{din} at 3,5 f_{nom}

Table 6. The parametric test states according to 61000-4-30

The measurement instruments directive

Effective from 30th October 2006, the European Measurement Instruments Directive (MID) enforces metrological controls for weighing and measuring instruments from gas, water, and electricity meters to automatic weighing equipment, exhaust gas analyzers, petrol pumps, taxi meters, and even wine and beer glasses. Like all such European legislation, a key objective is to stimulate competition by removing trade barriers and create a level playing field for manufacturers and consumers alike.

Applicable only to newly manufactured products, the MID details requirements that manufacturers must satisfy before instruments are offered for sale or put into use within the region. These requirements include generic essential requirements for all instruments, together with the instrument-specific essential requirements that appear in the various annexes to applicable standards. As before, notified bodies—test houses that are independent of national metrology organizations in European member states—are empowered to perform conformity testing, and the CE mark that results from successful testing is proof-of-conformity and valid throughout Europe. The necessary tests are those that European Normative standards prescribe for the equipment-under-test, and again as before, there are several routes to conformity—see *Changes Within 2004's EMC Directive*.

So, what's different? Principally, the MID encompasses various equipment that wasn't necessarily regulated in a number of member states. Any changes are therefore nationally dependent—for instance, the tightly regulated UK sees no necessity to introduce regulation for any instruments that aren't already regulated. From a manufacturer's viewpoint, the fact that equipment that was hitherto outside of harmonized standards—such as petrol pumps—can generate significant savings by requiring only one type test, rather than multiple tests for different target markets. The flexibility for manufacturers to perform their own conformity tests also particularly suits simple products, such as tape measures. For the vast majority of the electronics industry, it's unlikely that the MID will introduce any significant changes.

Changes within 2004's EMC Directive

With the EMC Directive's glut of self-referential material, it's hardly surprising that many engineers shy away from what they perceive as an impenetrable maze of dull documents. Recognizing confusion within the marketplace, the European Commission recently initiated its Simpler Legislation for the Internal Market (SLIM) project. One result is the new EMC Directive 2004/108/EC that supersedes 1989's original Directive 89/336/EEC. Effective as of July 20, 2007, equipment that complies with the original directive can appear on the market until July 20, 2009. The mission statement in Annex 1 of the new documentation reads: "Equipment shall be so designed and manufactured having regard to the state of art as to ensure the electromagnetic disturbance generated does not exceed the levels above which radio and telecommunication equipment or other equipment cannot operate as intended. It shall also have a level of immunity to electromagnetic disturbances to be expected in its intended use, which allows it to operate without unacceptable degradation of its intended use."

One significant change is that *fixed installations*—such as large machines and networks that may generate or be affected by electromagnetic interference—join finished commercially available apparatus in falling within the directive's scope. Where such equipment can take different configurations, the EMC assessment must account for any foreseeable configuration that could arise in normal use. The directive also says that components or subassemblies may fall within its scope if they are made available to end-users. Importantly, the new directive makes no changes to the standards that it references—the great majority of its changes are procedural. For instance, manufacturers now have two ways of demonstrating compliance for their products. The first is *internal production control*—or self-certification—when the manufacturer (or its authorized representative) is responsible for ensuring that products meet all of the directive's requirements, performing all necessary tests in accordance with harmonized EN standards. The second route employs a *notified body*—that is, an accredited test house—to assess the equipment in accordance with the manufacturer's instructions, typically performing tests that the manufacturer can't make.

Both routes require manufacturers to generate technical documentation that demonstrates the equipment's conformity, and to ensure that the production process guarantees adherence to the directive's requirements. Notified bodies will examine this documentation and when satisfied will issue a statement of compliance, which then accompanies the documentation file. Alternatively, manufacturers that elect for self-certification are exclusively responsible for every step on the compliance trail. In either case, the technical documentation will include a general description of the equipment, describe its design and manufacture, and present evidence that it complies with the appropriate harmonized standards. If harmonized standards have only been applied in part or not at all, the documentation must describe the steps taken to comply with the directive. This information must include design calculations, the EMC assessment, the examinations that were performed, and test reports.

The declaration of conformity that's necessary to gain the CE mark must now refer to the directive, identify the equipment, state its manufacturer or authorized representative within the European Union, and list which standards were used to claim compliance. An authorized company representative must sign and date the declaration. Although there's no compulsion to do so, the burden of acquiring a CE mark compels most organizations to engage specialist test houses to guide them through the conformity maze. You can conduct a search for "notified bodies," by country, in the EUR-LEX section of Europa at www.eur-lex.europa.eu/en/index.htm

Useful links

Compliance Engineering
www.ce-mag.com

Europa portal to the Official Journal of the EU
www.europa.eu/index_en.htm

Evaluation Engineering
http://evaluationengineering.com

European standards,
Electromagnetic-compatibility,
Directive 2004/108/EC
http://ec.europa.eu/enterprise/policies/european-standards/documents/harmonised-standards-legislation/list-references/electromagnetic-compatibility/index_en.htm

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