Testing EN61000-3-2/3

Introduction

Any electrical or electronic equipment intended to be connected to the supply mains must meet many sets of EMC requirements at its mains lead: harmonic currents, flicker and voltage fluctuations, RF emissions and immunity (9kHz and above) as well as voltage dips, surges and transient tests. This article covers only the first two: harmonics and flicker & voltage variations for equipments taking up to 16 Amps, i.e. those which will be connected to a standard domestic mains outlet (higher power equipment is covered by different standards). These two measurements require specialised test equipment, and are usually combined in a single unit, such as the AC2000 produced by Laplace

Two layers of standards define the measurement methods and the performance levels required. All designers of electronic equipment need to be familiar with the performance requirements of EN61000-3-2 (Harmonics) and EN61000-3-3 (Flicker and voltage variations). Users are not generally familiar with the details of the underlying measurement method standards, so this article gives some information on the techniques involved.

These requirements have changed considerably as the standards have been amended and re-issued over the years; this makes it essential for the test equipment to provide an easy mechanism for its firmware to be updated, and that buyers choose equipment from a manufacturer willing to make the long term commitment to supporting customers by keeping the firmware up to date.

Harmonic Currents

EN61000-3-2 is the standard that defines permitted harmonic current limits; it categorises equipments into four classes (A, B, C and D) and imposes different harmonic current limits on each class. It also defines cases where no limits apply, but places prohibitions on some types of control method that apply to all equipment within its scope, even if they are not subject to limits. It was initially released in 1995, and substantially revised in 2000, particularly in its treatment of fluctuating harmonics and in the definition of class D.

Harmonic levels are checked using both the average and maximum values over the whole test interval. Any harmonic is allowed to fluctuate up to a maximum of 150% of its limit, provided that its average value is below 100% of the limit. In addition, some trade-off between harmonics is allowed for odd harmonics of order 21 to 39, based on a value called the Partial Odd Harmonic Current; this is the rms sum of all the odd harmonics between 21 and 39. This rms sum is compared to the Partial Odd Harmonic Limit, which is the rms sum of the limits for the same set of harmonics. If the actual POHC sum is less than the POHL sum, then the average value of any individual harmonic in this group may exceed 100% of its limit, again provided that no individual measurement exceeds 150% of limit throughout the test. Obviously one or more of the other harmonics must be correspondingly less than 100% of its limit, otherwise the POHC will not be less than 100% of the POHL.

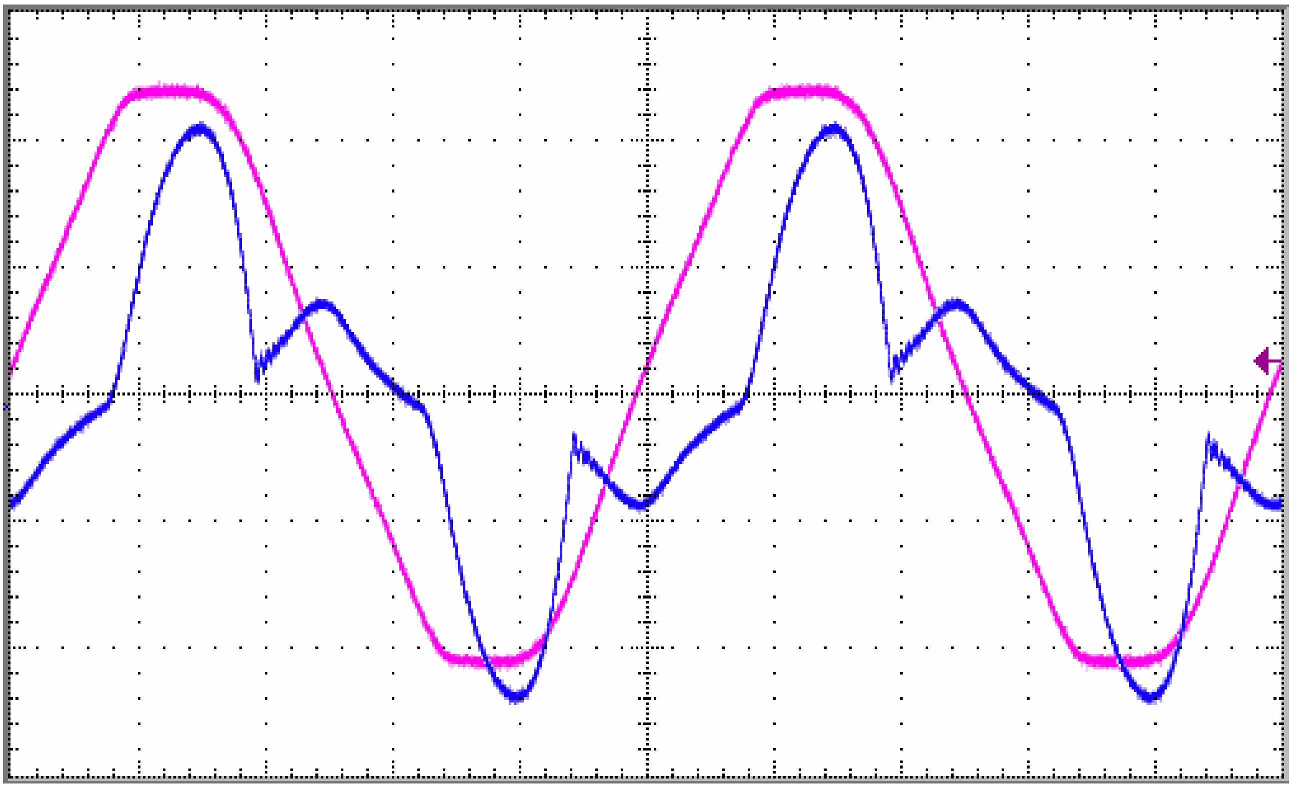
EN61000-4-7 is the standard that defines the requirements for test equipment to measure harmonic currents. This standard too has undergone substantial revision: the 1993 version covered both digital and analogue implementations (such as tuned level meters), while the present 2002 version anticipates an implementation based on digital signal processing techniques and extends the measurement complexity.

At the heart of the measurement is the Discrete Fourier Transform, which takes a sequence of samples of a waveform in the time domain and computes the frequency spectrum of the waveform, on the assumption that the signal repeats indefinitely. Much of the complexity of the standard arises to cover situations, known as fluctuating harmonics, where this assumption is untrue. The transform is taken across a number of cycles of the mains waveform – this is known as the window length. The present requirement is for a 200ms window – 10 cycles at 50Hz or 12 cycles at 60 Hz. The digital system is required to be synchronous; generally a phase locked loop links the sampling clock to an exact multiple of the mains frequency. Results are required up to the 40^{th} harmonic, and the well-known Nyquist criterion applies, so the sampling rate must be at least 80 points per cycle.

The standard demands that the instrument must sample continuously and perform transforms on all the data without any gaps. This imposes a burden of real-time availability on the processor, which is virtually impossible to achieve on a general-purpose computer running a desktop operating system. All compliance grade instruments will have Digital Signal Processor built in. It should also be noted, when comparing alternative solutions, that if a PC is used in the signal processing, then that PC becomes part of the instrument and must be included in the annual calibration cycle.

In order to reduce the processing burden, the DFT is usually implemented as a “Fast” Fourier Transform. There are many “fast” transform algorithms, the most commonly used one (properly called the Cooley-Tookey radix-2 algorithm) requires the number of samples in a window to be a power of 2 (512, 1024 etc.). It will be noted that if there are 10 mains cycles in a window, then meeting this requirement means that there is not an integer number of samples in each cycle. There are other “fast” algorithms, with different restrictions, which do allow an integer number of points per cycle; the AC2000A uses transforms based on the Prime Factor algorithm at 150 samples per cycle.

A major addition to the requirements, in the 2002 amendment, is the need to include spectral components at frequencies which fall between two harmonics (known as inter-harmonics in the standard). If a DFT is conducted over a window of 10 mains cycles, it gives spectral amplitudes at 10 points between the harmonic bins. Previously these components were ignored; now they must be added (by an rms sum of the magnitudes) into the amplitude of the nearest harmonic, before comparing that result to the limit, (half the amplitude of the mid-point bin is added to the harmonics on either side). Systems whose harmonic levels change over a time frame comparable to the window width cause sidebands on the harmonic signals, these are now included. Other systems may directly generate non-harmonic components – commutator noise from asynchronous motors is one example. A washing machine with an unbalanced spin load may produce such a waveform (it might also produce flicker, although generally the motor current is too small for this). Any such equipment will give different results when tested to the new methods.



The figure shows a typical mains voltage waveform as available at a normal socket outlet. The flat top distortion is clearly evident; this shows the effect on the supply network of harmonic currents caused by large numbers of electronic products taking a sharply peaked current waveform such as that illustrated.

Flicker and Voltage Fluctuations

EN61000-3-3 is standard that defines limits for two related effects, flicker and voltage fluctuations. Both are intended to ensure that equipments do not cause annoyance to neighbouring consumers connected to the same supply network by causing voltage changes across the shared source impedance of the network. The magnitude of these voltage changes depends on the both the network source impedance and on the changes in the current consumed by the unit under test.

Flicker is the impression of changes in the brightness of a lamp as perceived by a human observer. Many years ago surveys were conducted to establish the threshold of annoyance of the population; this lead to the definition of the perception unit. EN61000-4-15 (which has replaced IEC868) describes the complex processing sequence of AGC, demodulation, filtering, squaring and smoothing, and statistical classification by which the real-time voltage waveform is reduced to two simple numbers for the short and long term flicker severity indicators P_{st} and P_{lt}. As with harmonics, this continuous real-time processing burden requires a DSP in the instrument.

Assessing voltage fluctuations requires an examination of the history of the rms values of each half cycle over a period of time, categorising an interval as either a steady state or a voltage change, and comparing the magnitude and duration of the changes against the limits.

Both flicker and voltage fluctuations are caused by changes in the current consumed by a unit. These are most commonly step changes, perhaps causes by switching a heater on and off, but flicker at the frequencies of a few Hz (where the human perception is most acute) can be caused by changing loads on a motor, audio amplifiers or disco lighting. Photocopiers and laser printers (which have both motors and temperature controlled heaters) are an example of the type of product that may have difficulty passing the flicker test. Other sources, such as arc furnaces and many arc welders, generally take more than 16 Amps, and are covered by separate standards.

Supply Source and Reference Impedance

The standard environment for testing requires a perfect sine-wave mains source, with a defined source impedance called the reference impedance. This is intended to be representative of the actual characteristics of the supply mains at a domestic socket outlet; the reference value was derived from survey work many years ago. The voltage change produced by any given current change is directly proportional to the impedance value; therefore any error in the magnitude of this impedance translates directly into an error in the measured result. As the permitted overall error is 8%, the impedance must be quite precise. It is also necessary to allow for the resistance of any connecting leads, plugs and sockets.

Some laboratory standard mains generators have provision for simulating the reference impedance using their internal feedback loop, but such methods are subject to the limited bandwidth of that loop and it is possible for unforeseen interactions to occur.

Many laboratories do not have access to an expensive mains source but, because of waveform distortion and indeterminate source impedance, it is not possible to conduct these measurements by using the public mains supply in conjunction with the normal voltage sensing method. Therefore the AC2000A also implements an alternative current sensing technique that can be used without a laboratory grade mains supply. It measures the current consumed by the item under test and calculates the voltage drop across the reference impedance that this current would cause, using both the magnitude and rate of change of the current at each sampling point. The sampling rate must be high enough that a sufficiently accurate estimate of the rate of change of current can be calculated from the adjacent points. By subtracting this voltage drop (at each sampling point) from a notional pure sine-wave, the instrument can synthesise the waveform which would exist at the load side of the reference impedance under ideal measurement conditions. This synthesised waveform is then processed in exactly the same way as a measured voltage waveform.

This method yields results at least as accurate as the standard method (because the simulated reference impedance is exact), even with a distorted mains waveform and a substantial supply network impedance, provided that the behaviour of the equipment being tested is not significantly affected by these non-ideal conditions.

Inrush current

The 2001 amendment to EN61000-3-3 also introduced an explicit requirement to test the voltage fluctuation caused by manual switching events. This imposes a limit on the maximum peak half-cycle rms inrush current that a unit may take whenever it is switched on. This requirement arises from concerns among supply network operators about the difficulty of reconnecting a network after a supply failure.

These tests must be conducted by physically actuating the actual switch on the product under test; the use of electronic switches is not permitted. Because of the random phasing of the user's switch action with the mains waveform, a series of test must be performed to obtain a statistically valid average result. As equipments containing surge protection measures may take several minutes to cool down between tests, this is a time-consuming requirement.

Because of the nature of modern rectifier circuits, this test needs to be conducted on almost all electronic products.

The AC2000A Harmonics Flicker and Power Analyser from Laplace, combined with the AC1000A low distortion power source provides a complete solution for compliance quality measurements.

Other uses of the instrument

In addition to its EMC measurement capabilities, the AC2000A provides basic power meter measurements, such as rms and peak current, power, VA and power factor, as well as a visual display of the voltage and current waveforms on-screen, without any of the safety issues involved in using a standard oscilloscope for live mains measurements.

In production testing, a quick check of the waveform can easily show up manufacturing faults such as partially faulty bridge rectifiers, transformers with high magnetising current in a quick and safe way that allows manufacturers to dispatch their product confident that it is safe.

Another measurement provided is of instantaneous peak inrush current. There are no EMC standards limiting this, but it is a critical aspect determining the life expectancy of switch and relay contacts. Using the AC2000A, product designers can check that the ratings of the selected switch are not being exceeded.