Will EN 61000-3-2 Amendment 14 bring standards relief?

The reclassification of many products, the way limits are computed and how harmonics are measured are but a few of the changes.

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EN/IEC 61000-3-2[1] IS A MAINS frequency harmonic current emissions standard that has been the subject of considerable controversy. The recently published Amendment 14 to this standard makes many important changes and attempts to eliminate some of the controversy surrounding this standard. It changes the classification of many products, the way limits are computed for Class C and Class D, and the way that harmonics are measured and compared against the limits for all classes.

Although Amendment 14[2] is clearly advantageous to a large number of manufacturers, so far most test equipment manufacturers have not responded with product modifications that will allow testing to the new specifications. How the requirements have changed, how these changes will impact harmonic emissions testing, and what is expected from test equipment manufacturers are explained.

A BRIEF HISTORY OF HARMONICS STANDARDS

EN 60555-2:1987, in force until January 1, 2001, applied only to household appliances. EN 61000-3-2:1995 is the first generic requirement covering *all equipment* ≤ 16 A per phase and has a date of withdrawal of conflicting standards of January 1, 2001. This means that the prior standard with its restricted scope of household equipment could no longer be applied after that date, and that harmonic emissions testing is now required for a much broader range of equipment.

Until late last year, a number of companies that would have been affected by the standard lobbied vigorously to prevent its enforcement in 2001. While this didn't happen, work has been done to address some of the objections to this standard. EN/IEC 61000-3-2 Amendment 14[2] was approved by CENELEC in September 2000 and published in the official journal on December 14, 2000. Its publication gave relief to many products that were previously classified as Class D. It also removed some of the more controversial requirements of the standard, which had been subject to different interpretations.

HOW HARMONIC LIMITS WERE DERIVED

The IEC developed a Compatibility Standard (IEC 61000-2-2) that permits specific voltage distortion percentages for the public supply network. Similar to IEEE-Std-519, the compatibility percentages concern power quality at the HV – MV and LV levels. A portion of the overall distortion percentages are allocated to the LV level, and subsequently, to products which are directly connected to the Low Voltage (LV) public distribution system. These admissible contributions to voltage distortion levels by individual products formed the basis for the harmonics limits of Class-A type products per IEC/EN 60555.2 and its successor standard IEC 61000-3-2. Table 1 shows these compatibility levels, *i.e.*, permitted voltage distortion contribution at the 230 V to 50 Hz LV level.

The European Reference Impedance is given in IEC 60725, which was based on work done in the 1970s. The Reference Impedance values are set such that 95% of the network will have an impedance at or below the selected values. The result-

Harmonic Order	Distortion (%)
2	0.30
3	0.85
5	0.65
7	0.60
9	0.40
11	0.40
13	0.30
15 – 39	0.25
4 – 40	0.20

Table 1. Compatibility levels permitted under the new standard at the LV level.

ing impedance levels are given in Figure 1. Recent tests[3] show that the IEC-60725 resistive levels appear to be about correct, while the reactive component appears to have decreased somewhat (probably due to a shift from overhead to underground cabling). This standard is currently being revised and a change to the reference inductance value may be incorporated to reflect this trend.

The following example illustrates how the EN 60555.2 Class A harmonic limits were derived, using the compatibility levels and system impedance. The LV distribution network impedance at the 3rd harmonic (150 Hz) is $(0.4^2 + (3 \text{ x j } 0.25)^2)^{0.5} = 0.85$ ohm. The 0.85% (compatibility) permitted voltage distortion level for H3 means a maximum voltage distortion of 1.955 V (0.85% of 230 V). Hence, I_{H3} is allowed to be 1.955 / 0.85 = 2.3 A before 0.85% distortion for VH_3 is reached. The same calculations apply

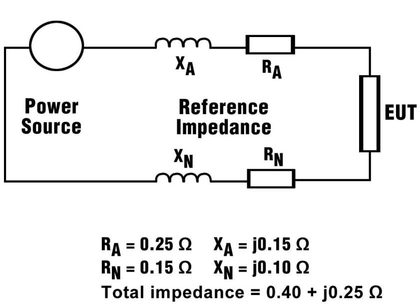

Figure 1. Impedance levels.

to the other harmonics, and they, in turn, form the limit set for Class A equipment. Class B involves portable equipment, intended for short time use, and the limits for these electrical products are simply 1.5 times higher than those for Class A. The limits for lighting products and other high volume consumer-type products (TVs) were set more stringently. Lighting products are defined as Class C.

Harmonic limits were defined for TVs in EN 60555-2. TV's are so-called "high impact" products. Not only are some 20 million sold every year in the European Community, but many TVs are also operated simultaneously during the same peak hours. Limits for TVs were based on the harmonics levels that a switch-mode power supply with an acceptable current conduction angle would exhibit. In EN 61000-3-2, this TV test class was extrapolated into a new Class D test class. Since the current waveform can be more or less defined by its conduction angle, the "special wave shape envelope" was defined as the identifying method to determine whether Class D limits are applied. However, because this special wave shape method is used to define what constitutes a Class D product, many "low impact products" are forced to be classified as Class D equipment as well.

CLASS D EQUIPMENT REDEFINED

According to Amendment 14, television receivers, personal computers, and their monitors less than or equal to 600 W are the only equipment considered to be Class D products. Gone is the Class D current waveform envelope requirement. This important change means that many products are no longer subject to the potentially significant added costs of complying with the stricter Class D limits. However, in the future, other high-impact products may be reclassified as Class D. High impact products are those products that have a significant impact on the public power supply system because of the number in use, duration of use, simultaneity of use, power consumption and harmonic spectrum.

Manufacturers of equipment that has been reclassified to Class A will want to adopt Amendment 14 immediately. However, in order to apply this Amendment, there are many other technical changes that must be implemented before compliance testing can be performed to all of its requirements. The following sections explain these requirements.

STEADY-STATE, TRANSITORY AND DYNAMIC LIMITS

The existing standard permits transitory harmonic currents to occasionally exceed the 100%, steady-state limit, provided that the harmonics never exceed 150% of the limit. In fact, the unit under test is allowed to exceed the 100% level for up to 10% of the test time. The test time for fluctuating loads is to be at least 2.5 minutes, *i.e.*, the harmonics can exceed the 100% limit for 15 seconds in every 150-second (2.5-min.) period. For longer test times, one can perform this test in 2.5-minute "time blocks" but another interpretation is to just take 10% of the overall test time. Thus, the testing method for fluctuating loads is somewhat subject to interpretation by the test equipment manufacturer.

The Class C limits are based on the EUT fundamental current and power factor. Class D limits are based on the EUT power. The existing standard does not make it clear whether these limits are based upon rated or measured values. Some test systems use the measured values to calculate dynamic limit values at every measurement window. Another interpretation is to take one EUT power measurement over an arbitrary period and calculate limits that will remain fixed throughout the entire test, regardless of changes in the EUT power conditions. Whether the Classes C and D limits were fixed or dynamic is also subject to interpretation.

Amendment 14 addresses these issues in two ways. First, the manufacturer is required to declare the product's rated power (the fundamental current and power factor (PF) for Class C). The manufacturer's ratings are used to calculate the Classes C and D limits which are fixed throughout the test. Second, the average harmonic level during the whole test must simply be below the limit, and individual values in each acquisition window (after 1.5-sec. filtering) must be below 150% of the limit. Also, note the extra allowance for the higher harmonics from H_{21} – H_{39} (See Partial Odd Harmonic Current.). The exact method to determine the "rated" power, fundamental current and PF, and how to measure these, is discussed in more detail below.

MEASURING "RATED" POWER, FUNDAMENTAL CURRENT AND PF

The process to measure the maximum averaged power is as follows; calculate the power for every acquisition window and pass this value through a 1.5-sec. smoothing filter. Take the maximum level of these 1.5-sec. smoothed values and compare it with the "rated power" (or fundamental current and power factor) and establish whether or not it is within ± 10% of the manufacturer's rating(s). If so, use the "rated power" for harmonic limit calculations and pass/fail comparison. If the measured value deviates by more than 10% from the rated value, use the measured value to compute the harmonics limits and perform the pass/fail test. It is extremely important to follow this procedure, as the peak level of the 1.5-sec. smoothed value will differ enormously from just the peak value for a given acquisition window! Obviously, it behooves the manufacturer to determine the "rated" values using the same methodology.

"Rated power" (current and PF) is used as the basis for the limit calculation of Class D (Class C). Thus, the amendment requires that an automated compliance test system must allow the user to enter this rated power or rated current. Also, the test system must verify the power (fundamental current and PF) because these "rated values" as declared by the manufacturer must be within ± 10% of the actual values. If not, the actually measured values are to be used for the limit calculation. The method to measure the actual power, fundamental current and PF differ from the "average method" used in existing test systems, and, of course, differ also from the "dynamic limit method."

For product testing per A14, especially for those products with fluctuating power, one must complete the whole test before the peak 1.5-sec. smoothed power (fundamental current and PF) can be determined, and before the limit calculation and Pass/Fail test can be finalized. Of course, intermediate results—based on either the "rated values" by the manufacturer or on peak levels observed thus far—can be given, but the official Pass/Fail decision cannot be made until the test is completed.

PARTIAL ODD HARMONIC CURRENT

A new quantity was introduced in the amendment in order to group together the contributions of the higher order harmonics. Individual higher order harmonics are allowed to exceed the limit by 50% so long as the partial odd harmonic current remains below its limit. The Partial Odd Harmonic Current is defined as the square root of the sum of squares of the odd harmonic currents of orders 21 to 39.

Partial Odd Harmonic Current =

$$\sqrt{\sum_{n=21,23}^{39} I_n^2} \qquad (1)$$

LIMITS AND PASS/FAIL CRITERIA

The harmonics current limits for all test classes are unchanged by the amendment. However, it is important to note the changes to the Pass/Fail criteria. The Pass/Fail criteria as listed in the standard are shown in Figure 2. Limits are not given for:

- Equipment with a rated power of ≤ 75 W, except for lighting equipment.
- Professional equipment with rated power > 1 kW.
- Symmetrically controlled heating elements with rated power ≤ 200 W.
- Dimmers for incandescent lamps with rated power ≤ 1 kW.

REPEATABILITY REQUIREMENTS

Another new requirement of A14 is that the measurement results must be repeatable. The test duration has to be sufficiently long to obtain better than ± 5% repeatability between successive tests. For products with a steady-state power level (quasi-stationary), this test time can be short, even less than a minute. For products with short power cycles (cycles < 2.5

The average value for the individual harmonic currents, taken over the entire test observation period, shall be less than or equal to the applicable limits.

For each harmonic order, all 1.5 sec. smoothed rms harmonic current values, as defined in 6.2.2, shall be less than or equal to 150% of the applicable limits.

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.

For the 21st and higher odd harmonics, the average values obtained for each individual odd harmonic over the full observation period, calculated from the 1.5-sec. smoothed values may exceed the applicable limits by 50% provided that the following conditions are met:

- The measured partial odd harmonic current does not exceed the partial odd harmonic current which can be calculated from the applicable limits.
- All 1.5-sec. smoothed individual harmonic values shall be less than or equal to 150% of the applicable limits.

Harmonic currents and power are ignored for the first 10 seconds when an equipment is brought into or taken out of operation.

Figure 2. Pass/fail criteria.

min.), the test should include at least 10 power cycles. For products with very long cycles, the manufacturer can provide information showing the worst case condition—highest Total Harmonic Current operating mode—in order to minimize test time. The implication is that for many products it will be necessary to test an EUT more than once in order to demonstrate that the repeatability requirement has been satisfied.

IMPACT OF THE FUTURE EN 61000-4-7 STANDARD

Requirements for measurement equipment are contained in the normative Annex B of EN 61000-3-2. Amendment 14 replaces the entire Annex B by a reference to EN 61000-4-7: 1993. A new version of this standard is being worked on which will have significant impact on the harmonic analysis methods. The important factors of the revised EN 61000-4-7 will be the move to a 200 ms measurement window and the inclusion of interharmonics in the harmonic level computation. Until EN61000-4-7 is released and its date of withdrawal for conflicting standards is reached (a process that could take several years), measurements using existing test equipment having 320 ms/16 cycles (266.7 ms for 60 Hz) acquisition windows will be permitted. The new 200 ms acquisition window better accommodates both 50 and 60 Hz systems, as 200 ms includes exactly 10 cycles of 50 Hz and 12 cycles of 60 Hz. Also, there are exactly fifteen such 200 ms periods in a 3-second averaging period which is commonly used in power quality analysis.

In the new EN 61000-4-7, interharmonics are "lumped in" with the (integer) harmonic subgroup level per a precisely specified algorithm. Although interharmonics may not necessarily have the cumulative effect as is the case with odd triplens (3rd, 9th, 15th, etc.), they do generate heat and adversely affect electrical gear. Hence the interharmonics are lumped into the adjacent integer harmonic level using the geometric averaging algorithm, similar to a rms calculation, as given in Equations 2 and 3 and as illustrated in Figure 3. This geometric average of the harmonic subgroup is filtered (using the 1.5 sec filter) and then compared against the applicable limits. Note that if the 16 cycle acquisition window were to be used, the algorithms would change somewhat, as the number of interharmonics from the FFT would differ. Figure 3 shows the algorithm for a 0.2-sec. acquisition period, and the graphical representation of this concept for a 50-Hz power system.

RMS VALUE OF A HARMONIC GROUP

The rms value of a harmonic group is defined as the square root of the sum of the squares of the amplitudes of a harmonic and the spectral components adjacent to it within the observation window, thus summing the energy contents of the neighboring lines with that of the harmonic proper.

See also Equations 2, 3 and Figure 3. The group harmonic order, $_{ng}$, is given by the harmonic n. C is the output component of the DFT for each 5-Hz interval.

$$C_{ng}^2 = \frac{c_{10ng-5}^2}{2} + \sum_{i=-4}^{4} c_{10ng+i}^2 + \frac{c_{10ng+5}^2}{2} \quad \{50\text{Hz system}\} \qquad (2)$$

$$C_{ng}^2 = \frac{c_{12ng-6}^2}{2} + \sum_{i=-5}^{5} c_{12ng+i}^2 + \frac{c_{12ng+6}^2}{2} \quad \{60\text{Hz system}\} \qquad (3)$$

CONCLUSION

Amendment 14 to EN 61000-3-2 reclassifies many Class D products to Class A. It also clears up the most controversial requirements of the standard. However, it also introduces new measurement and analysis methods that must be implemented in test systems before any of the benefits of A14 can be realized. A14 also leaves the door open to future changes whenever EN 61000-4-7 is revised. To keep pace with these changes, test systems must have a flexible architecture that can be easily modified. PC-based test systems that implement all of the analysis in the application software will be the easiest to upgrade.

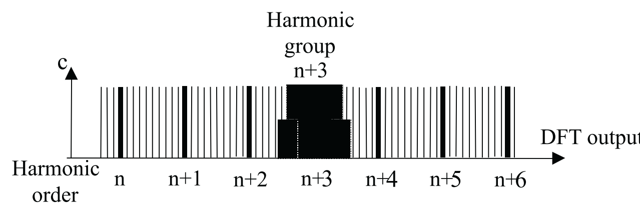

Figure 3. Harmonic group.

REFERENCES

1. EN 61000-3-2, Second Edition 2000-08, IEC. Geneva, Switzerland.
2. Amendment A14:2000 to EN 61000-3-2 :1995. OJ publication date 14-12-2000.
3. Mathieu van den Bergh. Low Voltage System Impedance Test. Oct. 2000.

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