Harmonic Current International Standards and Measurement Techniques: Standard

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Recently, with the widespread use of devices equipped with high-efficiency switching power supplies, distortion is caused in the current waveform flowing in the power systems, resulting in frequent failures in high-voltage systems. Strict harmonic current regulations are imposed on electrical and electronic equipment to prevent such failures.

IEC61000-3-2 and IEC61000-3-12 are the international standards for harmonic currents. IEC61000-3-2 specifies the limits for harmonic currents for equipment with 16 A or less per phase and IEC61000-3-12 specifies the limits for equipment with greater than 16 A but not greater than 75 A per phase.

This paper describes the harmonic currents generated by electrical and electronic equipment and provides an overview of the international standards, IEC61000-3-2 and IEC61000-3-12.

1. Harmonics

Harmonics are sine waves whose frequencies are integral multiples of the fundamental wave, which is normally a 50 Hz or 60 Hz utility frequency sine wave, but not including the fundamental wave, itself. For example, where the fundamental wave (first order component) is 50 Hz, the third order component is 150 Hz and the fifth order component is 250 Hz. Each of the components is superposed on the other to form general distorted waveforms.

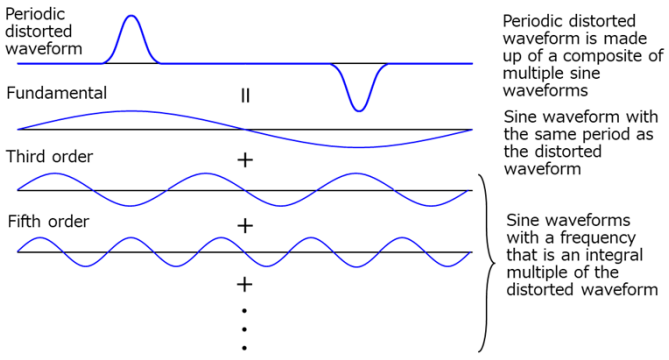

Figure 1. Principle of harmonics (Superposition theorem)

2. Background of harmonics regulations

Since most household appliances and OA equipment used in daily life employ a capacitor-input type high-efficiency switching power supply, harmonic current flows through commercial power supply lines. The effects of the harmonics cause various problems. The major problems include heating and the failure of power factor improving capacitors, phase adjustment reactors and their auxiliary equipment installed in power transmission facilities and electrical substations for high-voltage consumers.

Also, malfunctions of motor protection breakers used in large quantities in factories occurs frequently and noises are generated in home appliances such as televisions and radios. These problems are considered to be due to the eddy current and electromagnetic induction caused by harmonic currents and the distortion of voltage waveforms through the impedance of power supply wiring.

3. International standards for harmonic current

The international standards for harmonic current are IEC61000-3-2 for equipment of 16 A or less per phase and IEC61000-3-12 for equipment of greater than 16 A but not greater than 75 A per phase. IEC61000-3-2 defines four classes of equipment subject to the harmonic current regulations and specifies the limits for harmonic levels. In IEC61000-3-12, devices are classified into four types: equipment other than balanced three-phase equipment, balanced three-phase equipment, balanced three-phase equipment under specified conditions and balanced three-phase equipment under other specified conditions. Limits are specified for each type.

The next section provides an overview of IEC61000-3-2 and IEC61000-3-12.

4. IEC61000-3-2 limits for 16A or less per phase

Devices with current consumption of 16 A or less per phase are classified into class A, B, C, and D and the limits for harmonic currents up to 40th order are specified.

For each class, those limits are applicable to the average harmonic current and the maximum harmonic current over the set observation time. The average harmonic current has to be within the specified limits and the maximum harmonic current has to be within 1.5 times the specified limits.

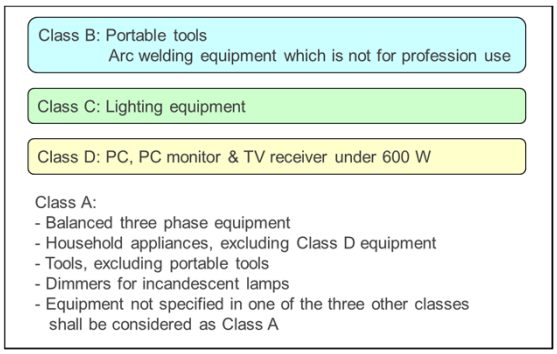

Figure 2. IEC61000-3-2 classification *1)

Table 1. Example of limits, limits for Class D *2)

Harmonic Order "h"	Maximum Allowance harmonic current per 1 W [mA/W]
3	3.4
5	1.9
7	1.0
9	0.5
11	0.35
13≦h≦39 Odd order only	3.85/h

The standard also provides the conditions where the regulations for upper limits can be partially alleviated. For example, as long as the partial odd harmonic currents (POHC) of order above and including 21 is less than the specified POHC limits, the odd harmonic currents of order above and including 21 is permitted to be up to 150% of the specified limits of each order.

$$POHC = \sqrt{\sum_{h=21,23}^{39} I_h{}^2} \qquad ①\ *3)$$

5. IEC61000-3-12 limits for more greater 16 A but not greater than 75 A

For equipment of greater than 16 A per phase, the current limits are determined by each harmonic up to the 13th order, the total harmonic current (THC) calculated from harmonic currents up to the 40th order, and the partial weighted harmonic current (PWHC) up to the 40th order.

$$THC = \sqrt{\sum_{h=2}^{40} I_h{}^2} \qquad ②\ *4)$$

$$PWHC = \sqrt{\sum_{h=14}^{40} h \cdot (I_h)^2} \qquad ③\ *5)$$

The terms used in the standard and their meanings are as follows. *6)

Ssc: Short Circuit Power
(the capacity of the system that a device is connected to, the strength of the system)

Sequ: Rated Apparent Power of the Equipment (calculated from the manufacturer-specified rated voltage and current)

Rsce: Short Circuit Ratio
(ratio of the strength of system (Ssc) to the rated apparent power (Sequ) of the equipment to be connected to it)

THC: Total Harmonic Current

PWHC: Partial Weighted Harmonic Current

For large equipment of 16 A or more per phase, the limit level is specified for each size of the short-circuit ratio, Rsce, which indicates the strength of the system that the equipment is connected to against harmonic current.

Therefore, even if a harmonic current is generated, the harmonic generated by the equipment may be larger than the specified limit as long as the equipment is used in a power supply system in which its system impedance is low and voltage distortion is unlikely to occur. Such larger harmonic current can be acceptable.

If the limit is met at the strictest short-circuit ratio, Rsce=33, the equipment can be connected to any system. If the limit for Rsce=33 is exceeded but the limit can be met at a higher Rsce, it is possible to comply with the standard by choosing the Rsce and specifying the short circuit power, Ssc value that can be calculated from the Rsce in the operating environment conditions of the target product. It should be noted that the level of limits of even-order harmonics does not change according to the short circuit ratio Rsce.

Table 2. example of the limits specified by IEC61000-3-12 Limits for equipment other than balanced three-phase equipment *7)

Minimum Rsce	Admissible Individual harmonic current , I_n/I_{ref} [%]						Admissible harmonic currnet distortion factor [%]	
Rsce	I_3	I_5	I_7	I_9	I_{11}	I_{13}	THC/Iref	PWHC/Iref
33	21.6	10.7	7.2	3.8	3.1	2	23	23
66	24	13	8	5	4	3	26	26
120	27	15	10	6	5	4	30	30
250	35	20	13	9	8	6	40	40
≧350	41	24	15	12	10	8	47	47

6. Requirements for a power supply used in IEC61000-3-2, -3-12 testing

Since the IEC standards require highly accurate measurement of harmonic currents, they include the requirements for the measurement environment. The following requirements are specified for AC power supplies, which largely affect the measurement accuracy. *8)

(1) Rated voltage: within ±2.0%
(2) Nominal frequency: within ±0.5%
(3) For three-phase power supply, three-phase phase angle: 120° ± 1.5°
(4) No resonance occurs between the internal inductance of the power supply and the capacitance of the equipment under test.
(5) Harmonics included in measurement voltage do not exceed the values that follow.

Third harmonic: 0.9 %
Fifth harmonic: 0.4 %
Seventh harmonic: 0.3 %
Ninth harmonic: 0.2 %
Even harmonics of second to tenth order: 0.2 %
Odd harmonics of eleventh to 40th order: 0.1 %

7. Requirements for measuring instruments specified by IEC61000-4-7

The following shows the requirements for measuring instruments that measure harmonic currents specified in IEC61000-4-7 Edition 2.0: 2002. *9)

(1) Current measurement error
5% of the permissible limits or 0.15% x Ir of the rated current r, whichever is greater
(2) Instrumental loss of the current input circuit
Voltage drop of 0.15 Vrms or less
(3) Crest factor of the current input circuit
5 A range or less: 4
10 A range or less: 3.5
Range above 10 A: 2.5
Overload display is necessary.
(4) Range structure of the current input circuit and withstand overload input
Direct input range: 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50 and 100 A ranges are desirable.
External sensor range: 0.1 V to 10 V are adequate.
(5) Excessive input
1.2 times the range (continuous), 10 times the range (1 s)
(6) Anti-aliasing filter
50 dB or higher
(7) Window function shape
Rectangular (no gap, no overlap)
(8) Window width
10 cycles (50 Hz) / 12 cycles (60 Hz) / 16 cycles (50/60 Hz)
(9) Relative deviation of the sampling frequency and fundamental frequency
Within ±0.03%
(10) Grouping of inter-harmonics
Required
(11) Smoothing
Time constant: 1.5 s

(12) Smoothing filter coefficient

(Window width: 200 ms, 320 ms / 267 ms)

∗When the window width is 320ms / 267ms, the following coefficients change in order to realize the time constant of 1.5 seconds:

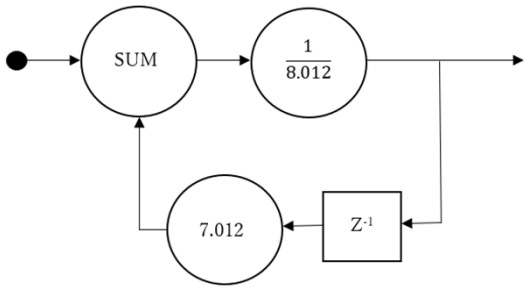

Figure 3. Smoothing filter coefficient *10)

(13) General specifications

The effects of temperature, humidity, supply voltage, common-mode voltage, static electricity, and electromagnetic field must be specified.

(14) Measurement of harmonic components from 2 kHz to 9 kHz

At present, annex B (Informative) of IEC61000-4-7 describes measurement of harmonic components from 2 / 2.4 kHz to 9 kHz for reference. Measurement of high frequency harmonic components up to 9 kHz is expected to be implemented as well as harmonic measurement up to 2 kHz (50Hz) or 2.4 kHz (60Hz).

8. Conclusion

This paper described the harmonic currents of electrical and electronic equipment and provided an overview of the international standards, IEC61000-3-2 and IEC61000-3-12. It is required that requirements of these standards are satisfied to obtain the CE marking. We hope this article will help the reader understand the harmonic current standards when evaluating harmonic currents according to them. The article “Harmonic Current International Standards and Measurement Techniques: Measurement Techniques” describes measurement techniques and may provide a better understanding.

References

・IEC61000-3-2 Ed 4.0：2014
*1)：5 Classification of equipment
*2)：7.4 Limits for Class D equipment
Table 1 and 3
*3)：3.16 partial odd harmonic current
*8)：Annex A
Measurement circuit and supply source
A.2 Supply source
・IEC61000-3-12 Ed 2.0：2011
*4)：3.1 total harmonic current
*5)：3.2 partial weighted harmonic current
*6)：3.10 short-circuit power
3.11 rated apparent power of the equipment
3.14 short-circuit ratio
*7)：5.2 Limits for emission Table 2
・IEC61000-4-7 Ed 2.0：2002
*9)：4.4.1 Main instrument
5 Harmonic measurements
*10)：5.5.1 Grouping and smoothing Figure 5
7 Transitional period Table 2

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