The Voltech Handbook of Measurements to IEC61000-3-2/3 Harmonics and Flicker

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1. Introduction

A large range of electrical and electronic products are subject to a standard called 'IEC61000'. Section 3 of this standard is concerned with the level of distortion of the current drawn by equipment connected to an a.c. power line and with the voltage fluctuations that the equipment may cause to the a.c. line.

Many engineers have been influenced by this standard and although many understand its meaning and relevance there is still a proportion of engineers who experience a degree of confusion with the application of this standard. This application note aims to clarify that confusion and explain its application.

Since its inception in 1986, Voltech has been dedicated to designing instruments that provide a solution to measurement problems in the power field. In 1988 Voltech introduced the PM3000, a three phase power analyzer that soon became an industry standard. In January 1993, the PM3000A was introduced. This was a second generation product derived from the PM3000 with greatly enhanced processing power. The PM3000A became the first power analyzer in the world with the capability of measuring current harmonics and flicker to the IEC 61000-3 standard. In 2002 Voltech introduced it's latest multi-phase power analyzer, the PM6000, which is a 1 to 6 channel analyzer.

In addition to the enhanced performance for established power measurement applications, the PM6000 has the processing power to offer all the required measurements to meet the new IEC61000 standard, which includes inter-harmonics. The PM6000, together with its associated PC software offers a complete measurement solution for testing to IEC61000.

A Solution to Meet Your Standard

The International Electrotechnical Commission are an issuing authority who generate documents defining a remit for standards compliance.

IEC61000 is therefore the parent document from which National Standard bodies will derive their standards for adoption by relevant industries or services.

Voltech have developed the PM6000 in accordance with the IEC61000 documents in order that the various standards derived from it are fully encompassed.

Acknowledgements

Descriptions contained in this application note include information from the following documents:

IEC61000-3 Part 2 Amendment 1, 2008.
IEC61000-3 Part 3, 2008.
IEC61000-4-7, October 2002.
IEC61000-3-11, 2001.
IEC61000-3-12, 2004.
IEC61000-4-15, 2003.

IEC documents can be obtained from your local standards authority or from:
IEC - International Electrotechnical Commission or
CEI - Commission Electrotechnique International (French):
3, Rue de Varembé,
Genève,
Suisse.

<u>Addendum : October 2008</u>

Since the production of Application Note 104 (Issue 1.01), subsequent amendments and draft international standards relating to IEC61000 (or IEC1000-3-2/3 as it is ultimately known) have been produced, and this document has been amended to reflect these revisions.

Voltech remains aware of all the latest revisions to ensure our continued compliance to them. Whilst the functionality of our products is enhanced in accordance with prevailing requirements, this document will be updated to reflect only major revisions of the standard.

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2. Why Is the IEC61000 Standard Necessary?

2.1 Current Harmonics Standards

Many years ago, all the loads connected to the a.c. supply lines were resistive loads such as filament lamps or heaters, and simple inductive loads such as fixed speed a.c. motors. Such loads draw sinusoidal currents from the a.c. supply and hence do not cause any special problems for the supply.

Today, an increasing proportion of loads that are connected to the a.c. supply draw currents that are distorted (non- sinusoidal) in shape. Examples of such loads are power supplies for computers, T.V. and audio equipment, lamp dimmers, variable speed motor drives, and electronic ballast lights. Figure 1 shows the input circuitry of a typical power supply:

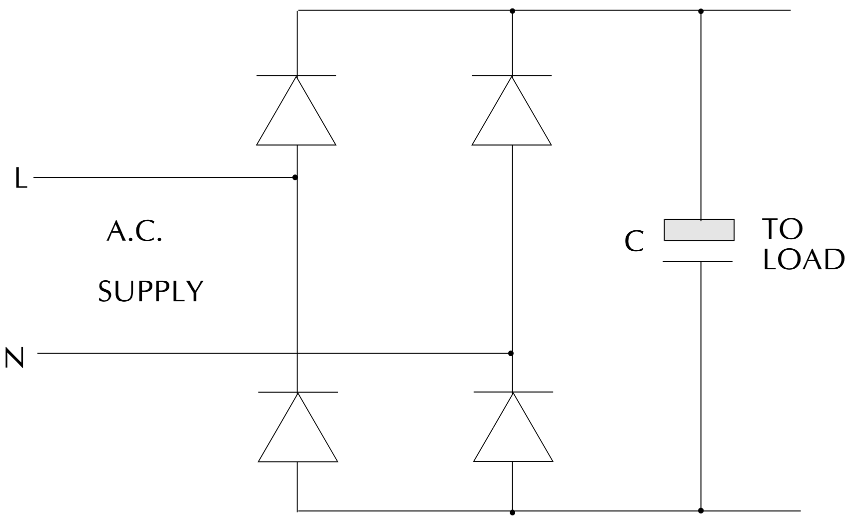

Figure 1 - Power supply input circuit.

When a.c. voltage is applied to the diode bridge, this voltage is rectified by the bridge, and the capacitor (C) charges to near the peak of the rectified a.c. voltage.

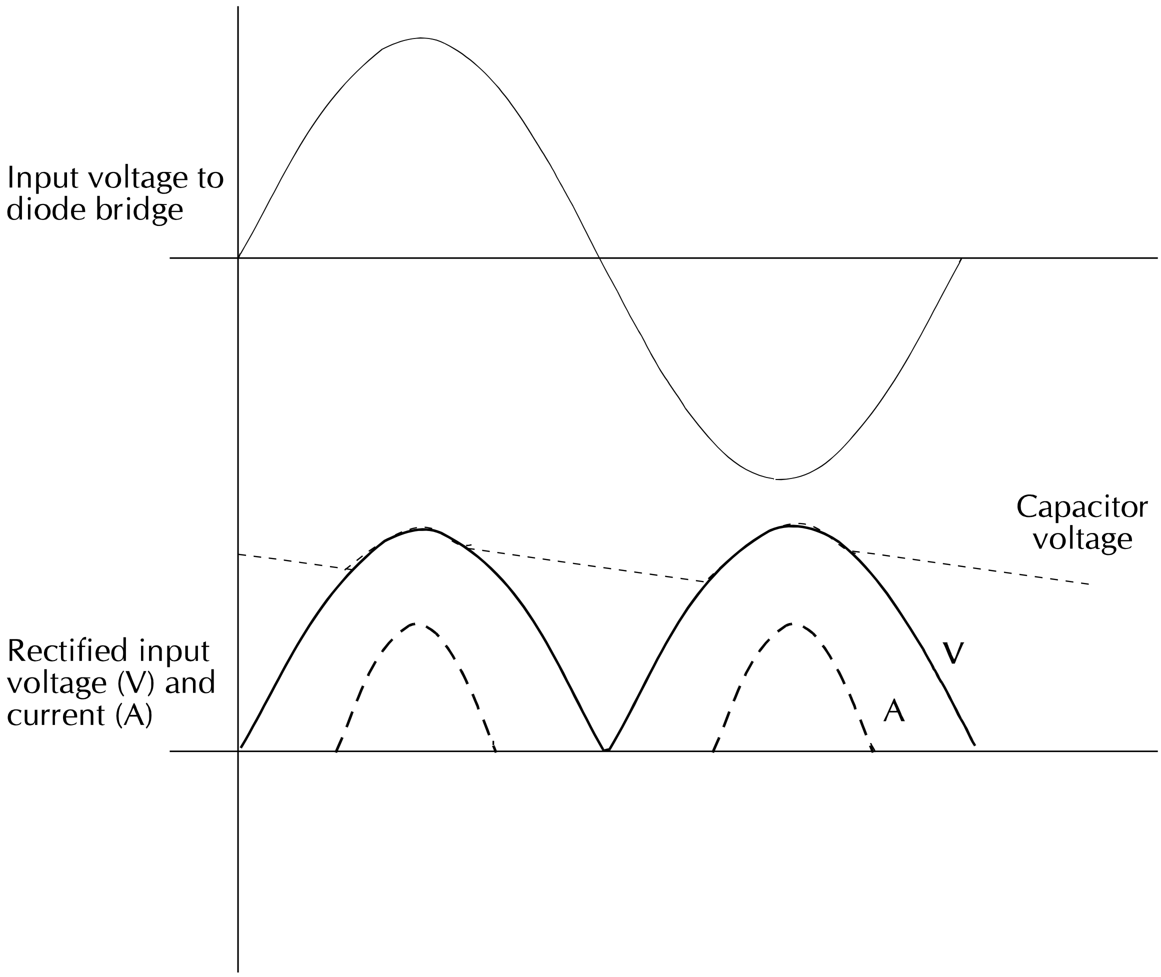

Figure 2 - Bridge rectifier output current.

Current can only flow in the diode bridge when the applied a.c. voltage is greater than the capacitor voltage. When the applied voltage is less than the capacitor voltage, current flow is blocked by the diodes. As a result, current flow into the capacitor is a series of narrow, high current pulses. This creates a current in the a.c. line that is very distorted (non-sinusoidal) in shape.

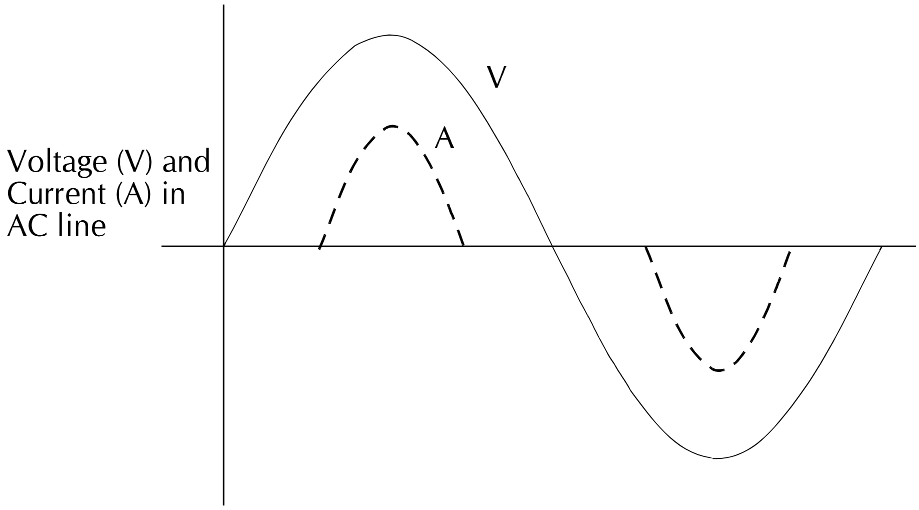

Figure 3 - Input current to diode bridge.

Another source of distorted current waveforms is the use of a.c. phase control to control the power supplied to a load. This principle is used in lamp dimmers and heater controls. A typical phase control circuit is shown below:

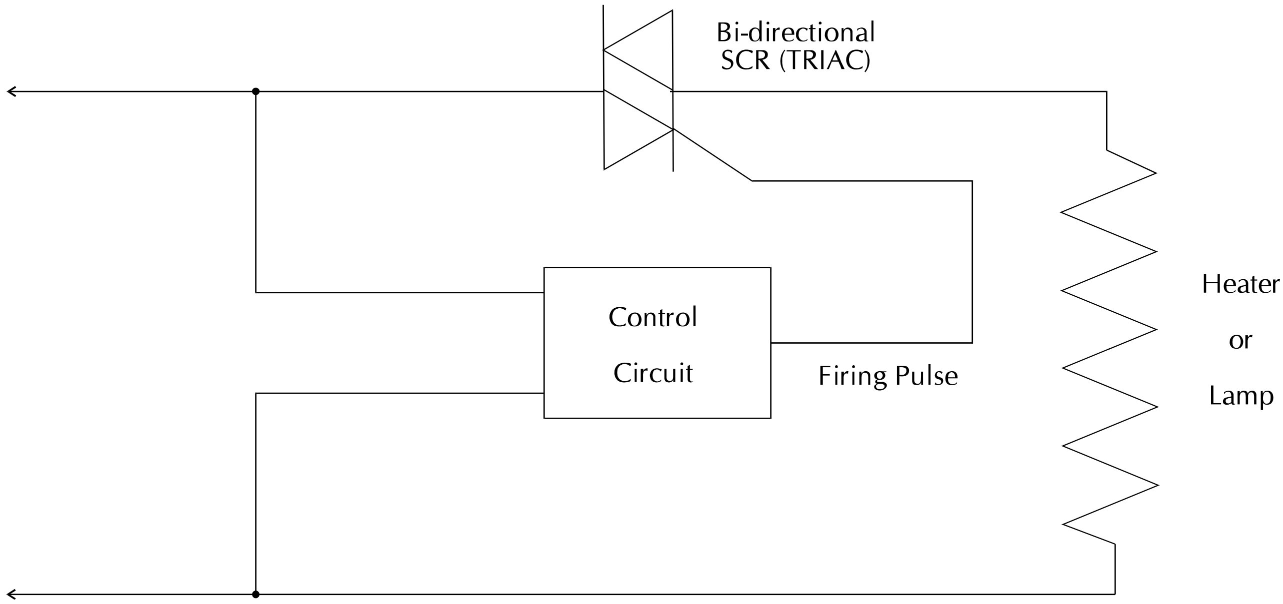

Figure 4 - Phase control circuit.

The power supplied to the load is controlled by delaying the firing pulse relative to the start of each half cycle:

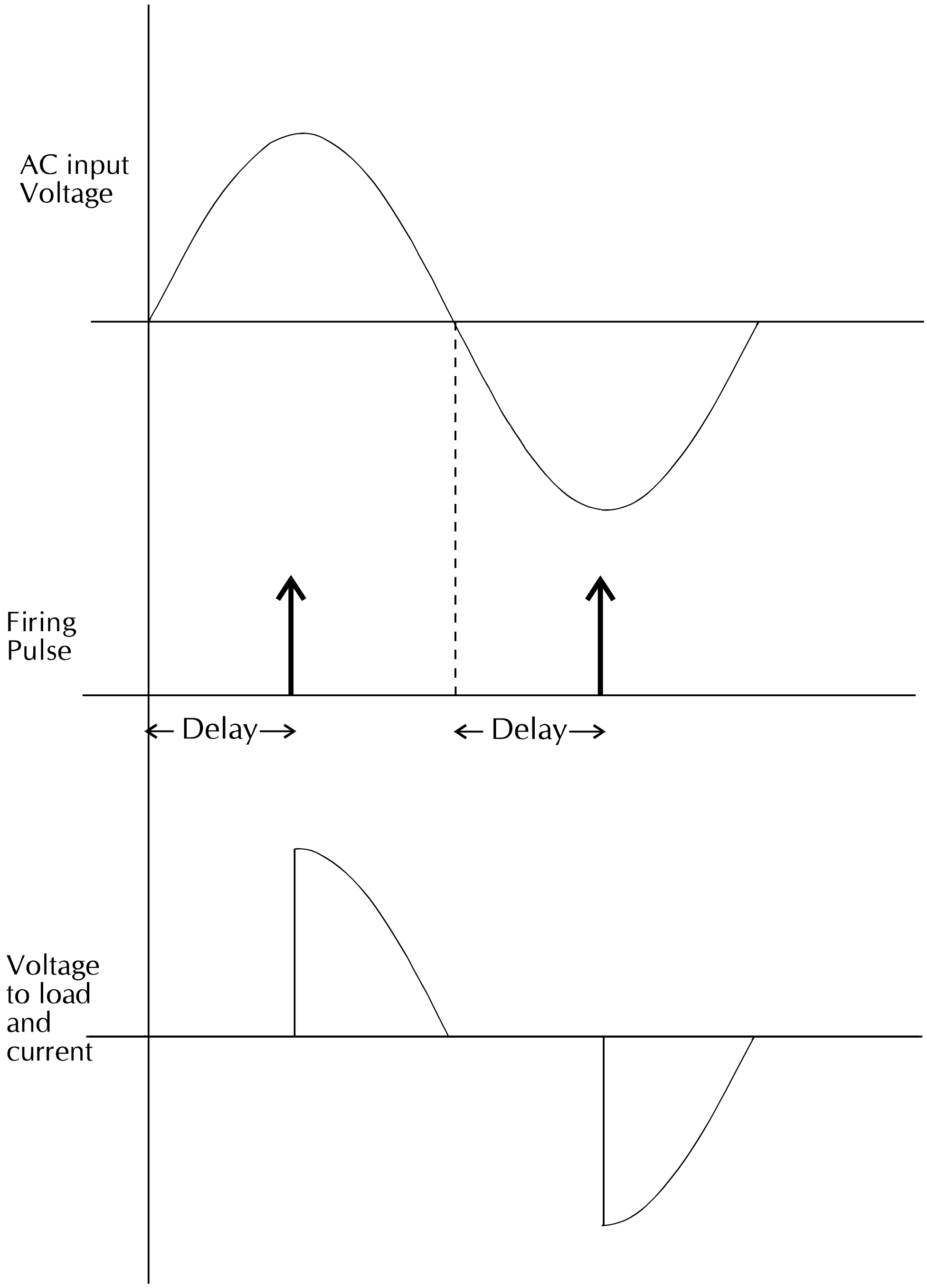

Figure 5 - Waveforms of phase-control circuit.

It can be seen that phase control introduces significant distortion of the a.c. current waveform. Distorted current waveforms can cause many undesirable effects on the a.c. supply. For example: -

1) Distorted currents reduce the effective power factor of a load, (Appendix G), and therefore cause wasteful heating of cables and transmission lines which must be oversized to deal with such loads. Heating due to distorted currents is also a frequent cause of burnout of neutral conductors in three phase systems.

2) The distorted current waveform causes distortion of the a.c. supply voltage. This results in overheating and reduced output from a.c. motors connected to the same a.c. supply system.

3) The distorted currents can interfere with the proper operation of other loads connected to the system, such as power factor correction capacitors. They may also cause electromagnetic interference with communication equipment in the vicinity of the supply.

2.1 Flicker Standards

As well as loads that cause distortion, more and more loads incorporate controls such as thermostats and timers which cause frequent changes of the load to the supply. Examples of such loads are cooking appliances, heaters, air conditioners, photocopiers and welding equipment.

Every a.c. supply has a certain amount of source impedance from the generating source to the distribution point, with a number of loads connected at the distribution point: -

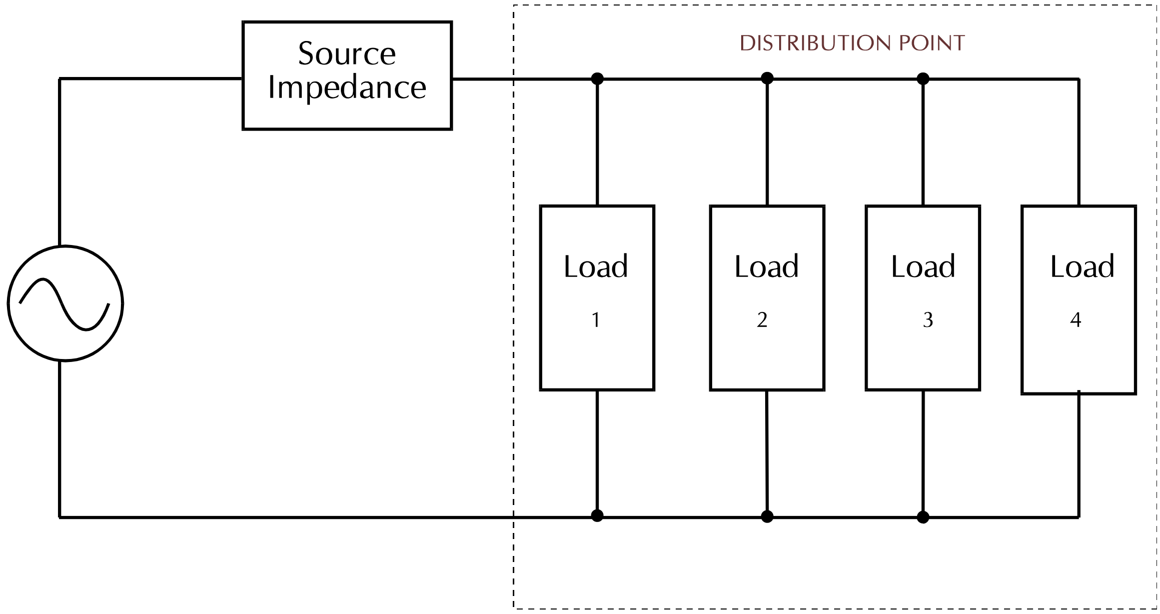

Figure 6 - a.c. supply system.

When a fluctuating load is one of the loads at the distribution point, it causes fluctuations in the voltage drop across the source impedance, and therefore fluctuations in the r.m.s. voltage at the distribution point. Variation in the r.m.s. voltage will cause fluctuations in the light output of any filament lamps connected as one of the loads.

As the energy output of a filament lamp is proportional to the square of the applied voltage, the change in light intensities can be very significant for even small changes in voltage as shown in figure 7.

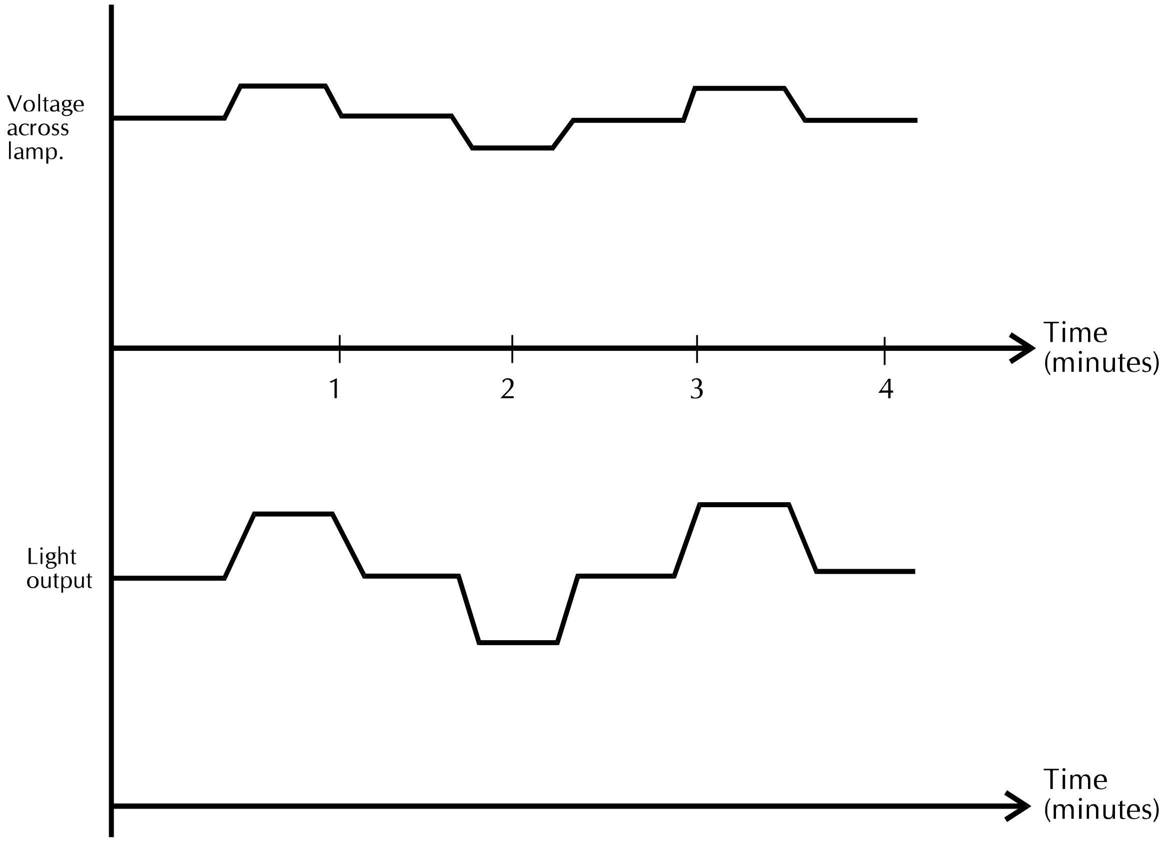

Figure 7 - Variation of lamp intensity with voltage changes.

The effect of this variation in light output of a filament lamp on a human observer is known as flicker.

Many a.c. loads therefore cause disturbances to the a.c. supply due to distortion and/or flicker. The IEC61000-3 standard is therefore necessary to limit the disturbance that such equipment can cause to the supply.

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3. What is IEC61000-3, and What Are its Requirements?

The IEC61000-3 standard (formally IEC 555) was created by the International Electrotechnical Commission based in Geneva, Switzerland. The IEC standard consists of three parts:-

Part 1- Glossary of terms.
Part 2- Specification of harmonics
Part 3- Specification of voltage fluctuations.

The standard was created to provide limits on the disturbing effect that equipment has on the a.c. supply. The standard achieves this in two ways:-

1) By providing limits on the magnitude of harmonic currents created by equipment (IEC61000-3 Part 2 - Harmonics).

2) By providing limits on the level of voltage fluctuations produced by equipment (IEC61000-3 Part 3 - Voltage fluctuations)

3.1 Harmonics

Using Fourier Analysis, a distorted current waveform, such as that drawn by a power supply, can be shown to consist of a fundamental component (at the supply frequency) plus a series of harmonic components (at multiples of the supply frequency): -

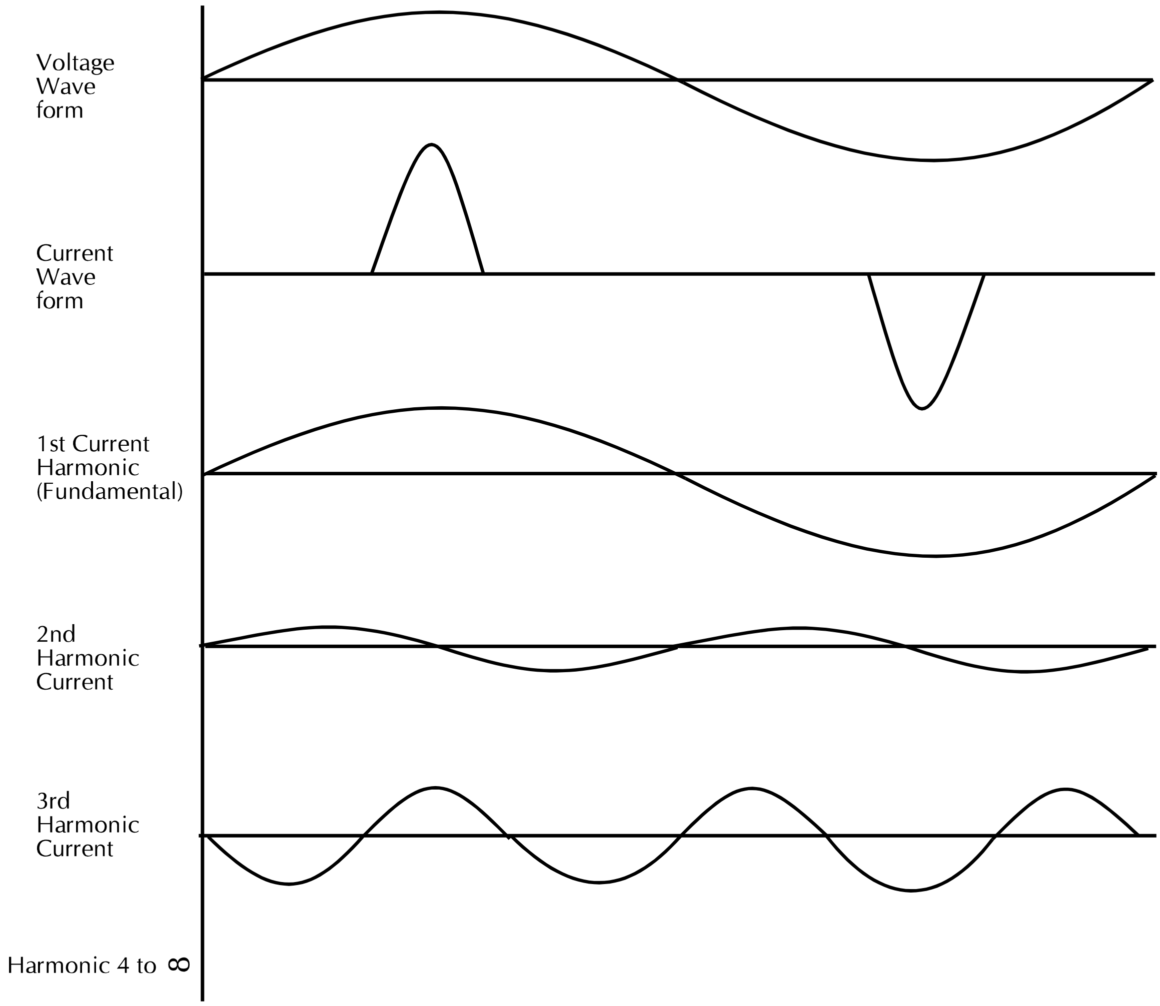


Figure 8 - Analysis of distorted current waveform.

In general, the magnitude of harmonics becomes smaller with increasing harmonic order, so harmonics above the 40th harmonic are usually very small.

An ideal current waveform would consist of only the 1st (fundamental) component. IEC61000-3-2 defines limits on the magnitude of the 2nd to the 40th current harmonic, and thereby controls the level of current distortion that can be produced by equipment.

The limits on the magnitude of each harmonic that IEC61000-3-2 specifies for equipment depend on which Class (A,B,C or D) the equipment falls in. Appendix A describes the IEC61000 classification of equipment, and Appendix B gives the limits for each of the Classes.

3.1.1 Fluctuating harmonics

Fluctuating harmonics are produced by equipment that generates distorted current waveforms, but presents a varying or fluctuating load on the a.c. supply. In this case the magnitude of any particular harmonic will vary during the time the equipment is energized from the supply.

For example:-

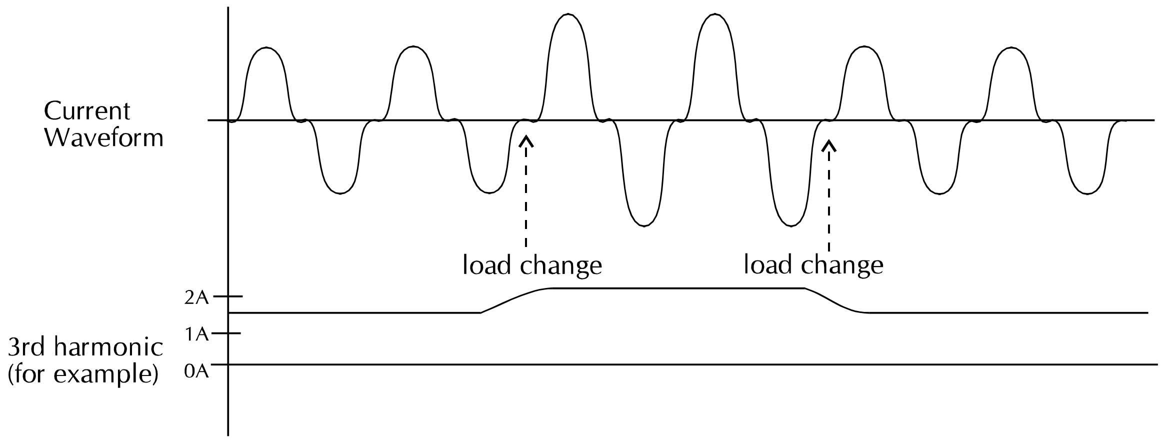


Figure 9 - Fluctuating harmonics.

3.1.2 Inter-Harmonics

A fluctuating load, as well as producing harmonics of the supply frequency, can also produce frequency components that are not multiples of this frequency, but are components at frequencies between the supply harmonic frequencies. These components are known as inter-harmonics. The standard defines that these harmonics are measured at 5Hz intervals as showed in figure 10, and that these inter-harmonics are considered in the evaluation of the harmonic conformance.

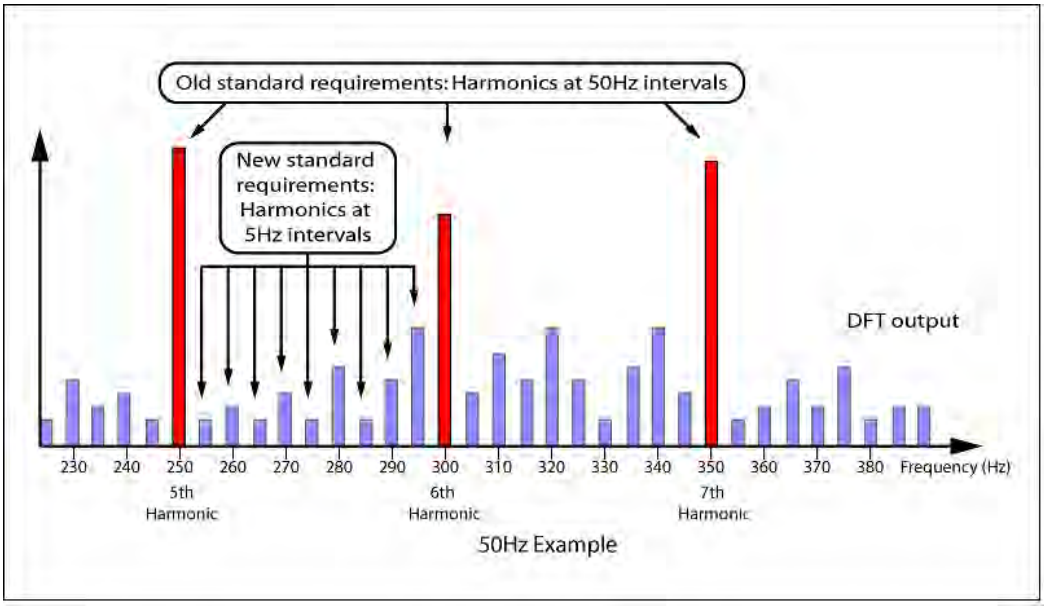


Figure 10 – Interharmonics Example.

3.2 Voltage fluctuations

In section 2 it was shown that a fluctuating load will cause changes in the r.m.s. voltage of the supply, and this will cause flicker in lamps connected to the same supply. The level of voltage changes that equipment can cause to the supply is specified in IEC61000 Part 3 by monitoring the voltage changes at the load when the load is supplied through a specified value of source impedance: -

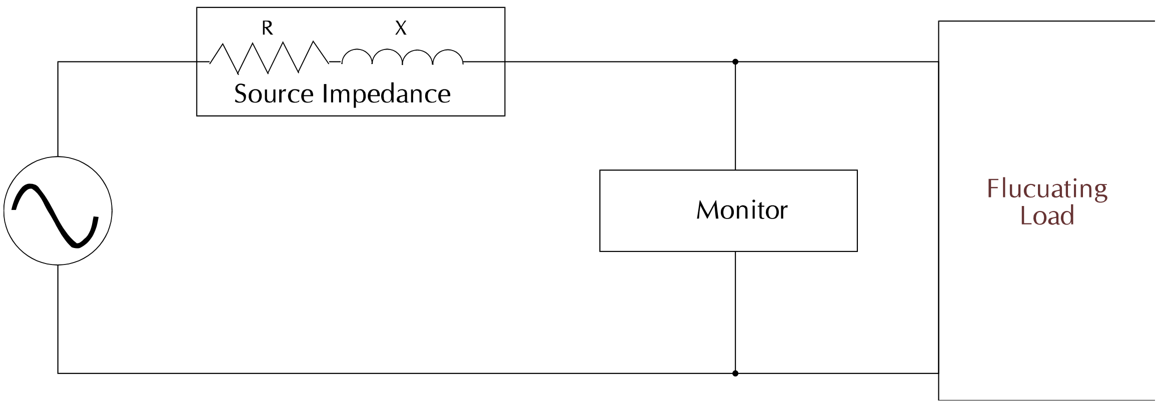


Figure 11 - Determination of voltage changes.

The value of source impedance to be used is defined by the IEC61000 standard, and depends on the type of the a.c. supply.

The standard recognizes that the disturbing effect of voltage fluctuations depends not only on the magnitude of the voltage fluctuations, but also on their repetition rate. For example, it has been observed that even quite large voltage changes will have little disturbing effect if these changes occur only occasionally, while quite small voltage changes are quite noticeable if the changes occur at a frequent rate. The following curve, reproduced from IEC61000 Part 3, shows the observed relationship between the magnitude of repetitive voltage changes, and the rate of occurrence of these changes, for the same perception of flicker: -

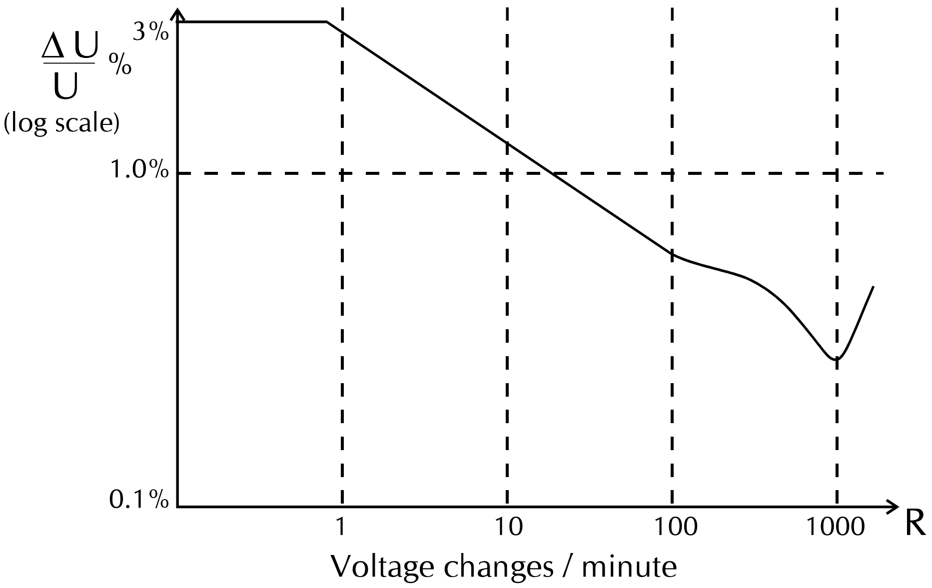


Figure 12 - Magnitude of maximum permissible voltage changes with respect to number of voltage changes per minute (Pst = 1 curve).

IEC61000 provides for two techniques for assessing whether the level of voltage fluctuation is acceptable, depending on the nature of the voltage fluctuation. One method is by direct measurement or calculation of the voltage changes themselves and comparing this with the graph of Figure 12. Another method, the preferred one, is by assessment of the disturbing effect of the voltage changes, to provide a direct measurement of flicker, together with a measurement of the maximum level of voltage deviation caused by the equipment.

3.2.1 Voltage changes

Loads that provide a regular or repeatable load variation can be monitored by installing a source impedance and directly recording the level of voltage changes appearing across the load: -

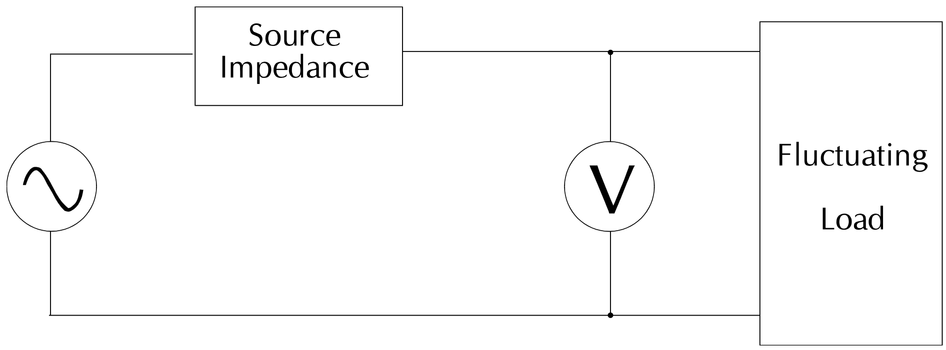


Figure 13 - Determining the level of voltage changes by voltage measurements.

These voltage changes can also be determined by measuring the in-phase and quadrature (Ip and Iq) components of the load current, and using vector calculations to determine the voltage drop across the specified value of source impedance.

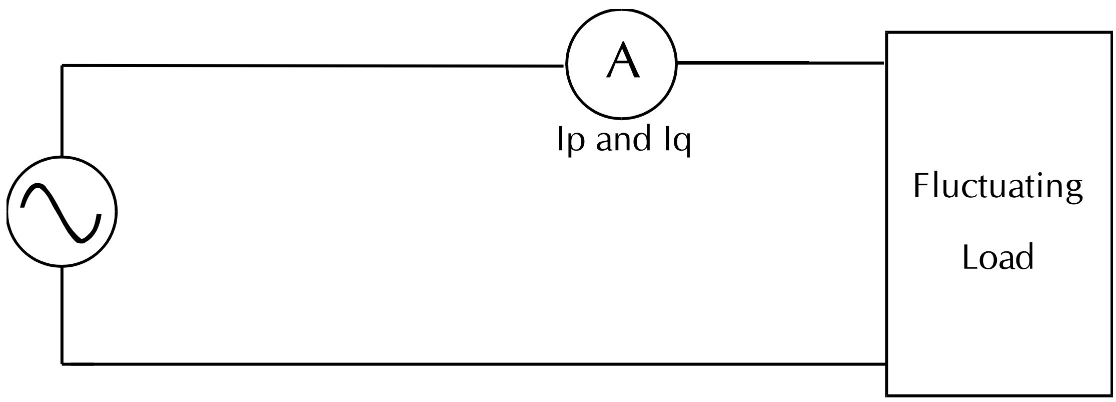


Figure 14 - Determining the level of the voltage changes by current measurement.

The magnitude and frequency of the voltage changes can then be directly assessed against the Pst = 1 curve contained in the standard (Figure 12).

3.2.2 Flicker and voltage deviations

If the load fluctuations are more complex, e.g. if a series of random or continuous voltage changes occurs, then the disturbing effect on human perception cannot be determined from a simple analysis of the magnitude and frequency of these changes. The assessment of these more complex changes requires a simulation of the whole of the lamp-eye-brain chain. This is the preferred method for even simple regular changes.

IEC have shown that this can be achieved by processing the voltage changes that occur using a technique (IEC61000-4-15-Flickermeter - Figure 15) that uses filters and statistical analysis to produce a flicker value (Pst and Plt) representing the disturbing effect of the voltage fluctuations on the human observer.

Where:-

Pst is the short term flicker severity evaluated over a short period (in minutes).

and

Plt is the long term flicker severity evaluated over a longer period, using successive Pst values.

IEC61000 provides limits on the maximum value of Pst or Plt that equipment is allowed to produce.

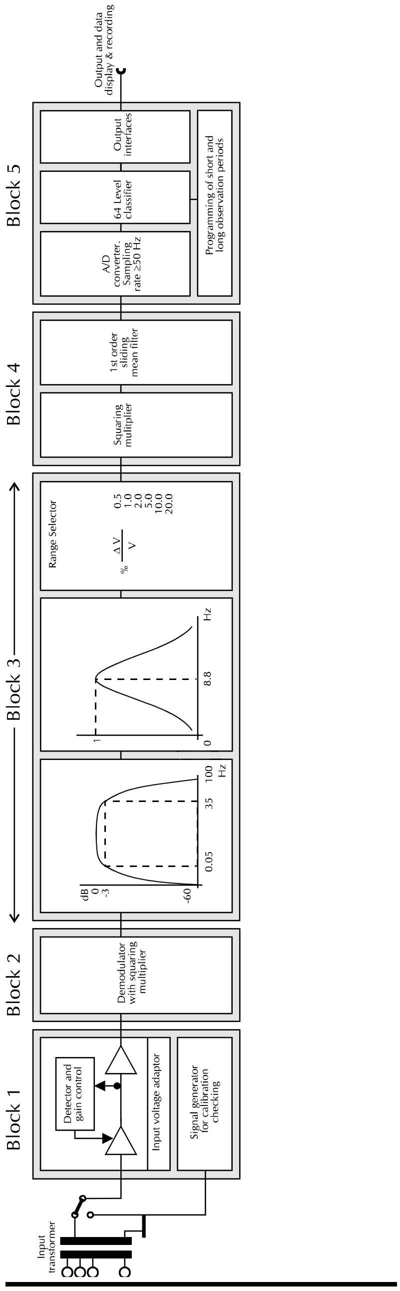


Figure15 - Functional Diagram of IEC Flickermeter

In addition to measurements of flicker value Pst and Plt using the flickermeter technique, IEC61000-3-3 requires that measurements of voltage deviation (dc and dmax) are also made. This is because whilst the flickermeter technique provides an excellent assessment of continuous voltage changes, a load that causes a single or very occasional large voltage change will have only a small effect on the Pst/Plt measurement, yet this large voltage change will be very disturbing.

For example, an appliance may draw a very large inrush current from the supply when it is first switched on, particularly if the input has no inrush current limiting circuitry. This inrush current may cause a substantial deviation in the supply voltage, causing disturbance to other loads on the same supply: -

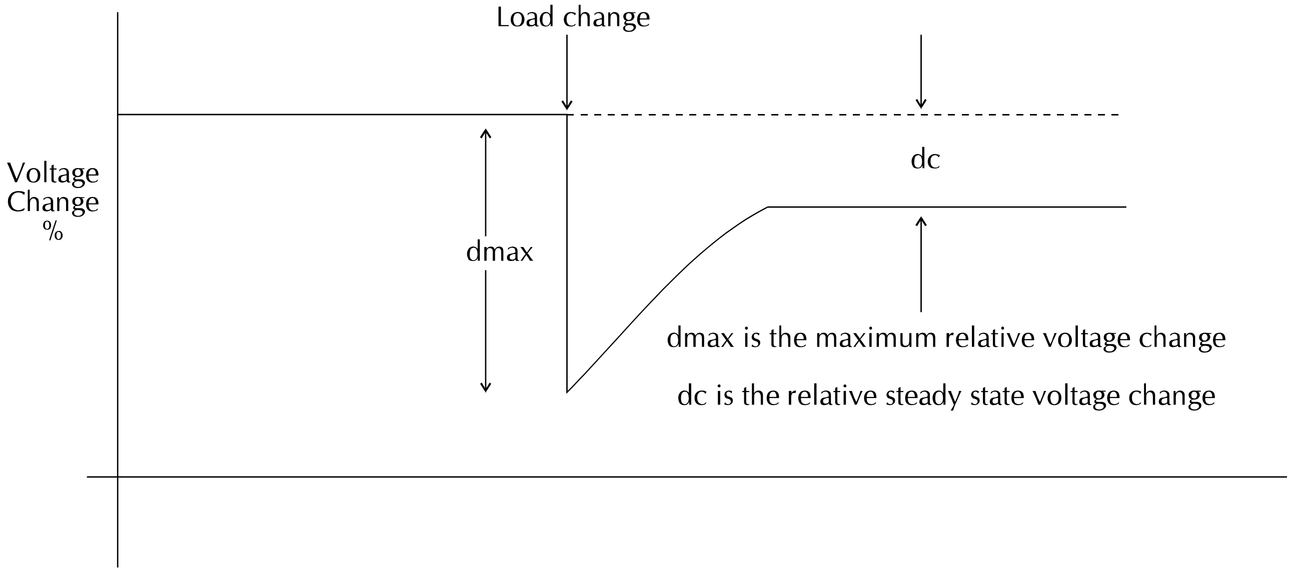


Figure 16 – Diagram of Voltage Changes

Setting of limits for the voltage deviations, as well as for flicker, controls the level of disturbance due to load changes that equipment can cause to the supply.

4. To what equipment is the IEC61000 standard applicable and what measurements should be made?

IEC61000-3 is currently applicable to electrical and electronic equipment for household and similar use. From 1st January 1995 the scope encompassed all electrical equipment having an input current of up to and including 16A per phase, intended to be connected to public low voltage distribution systems.

IEC61000-3-11 and IEC61000-3-12 specify harmonics and voltage fluctuations for equipment exceeding 16A.

At the moment the standard considers only a.c. distribution systems of the following types:-

> nominal voltages up to 240V, single-phase, two or three wire.
> nominal voltages up to 415V, three-phase, three of four wire.
> nominal frequency 50Hz or 60Hz (harmonics only).

For systems with nominal voltages less than 220V line to neutral e.g. 100V,120V a.c. , limits have not yet been established by the standard. However, as other organizations such as Underwriters Laboratory are also considering disturbance standards, designers must expect that equipment for use on lower voltage networks will in due course have to meet disturbance standards similar to IEC61000. At the moment the standard is therefore applicable to equipment such as cooking and heating appliances, motor operated and magnetically driven appliances, portable tools, light dimmers, radio and television receivers, video recorders and audio equipment, as well as a wide range of office equipment.

To meet the standards, equipment must conform to the requirements of the standard for both harmonics and for voltage fluctuations. In some cases, it will be clear that equipment will meet the requirements of the standard and will not need to be tested. For example, a simple filament lamp that does not incorporate an electronic transformer or dimming device will clearly not produce harmonics or voltage fluctuations, so will not need to be tested - in fact IEC61000-3 considers such a lamp as meeting the requirements.

In some cases it will be evident that the equipment will meet, for example, the standard for harmonics, but there may be some doubt as to whether it meets the standard for voltage fluctuations. An electric heater with bi-metal thermostat would be one example. In this case it would be necessary to test only for voltage fluctuations as the heater draws sinusoidal currents so no harmonics are produced.

In most cases, however, it will be necessary, and desirable, to test equipment for both harmonics <u>and</u> for voltage fluctuations, not only to confirm that the requirements of both Part 2 and Part 3 of IEC61000 are being met, but to provide evidence to customers and to the electrical supply authority that this is the case.

To meet requirements of IEC61000 the following measurements should be made:

IEC61000-3 Part 2:- Fluctuating harmonics.

If the equipment produces a steady or fluctuating load to the supply, then the equipment should be measured for fluctuating harmonics. A photocopier is an example of such a piece of equipment.

AND

IEC61000-3 Part 3:- Voltage changes.

If the equipment incorporates a control device that causes the load presented to the supply to change in a regular and repeatable manner, then the equipment can be measured for voltage changes.

OR

Flicker and voltage deviations.

This is the preferred method of verifying conformance to Part 3 of the standard. If there is any possibility that the equipment produces an irregularly-varying load, then the equipment should be measured for flicker and voltage deviations. Examples of such equipment are hot-plates, ovens, washing machines, hairdryers, copiers, laser printers and many others.

5. Making IEC61000 measurements.

5.1 Full Compliance and Pre-Compliance testing.

Full compliance testing is required by test laboratories that need to offer customers traceable certification that equipment meets the required standard. In this case it is necessary to set up a test environment (power source, source impedance, measuring equipment) that meets all the requirements of the IEC61000-3 specification.

Pre-compliance testing requires setting up a test environment that will provide a very high degree of confidence that the equipment meets the required specification, but without the traceability inherent in full-compliance testing. Such an environment is much less expensive to create. If equipment is shown to meet the standard with a reasonable margin during pre-compliance testing then it can be submitted for full-compliance testing to an outside authority with the confidence that it will meet the required specification. In addition pre-compliance testing provides valuable feedback to engineering departments during product development.

5.2 Test equipment required

5.2.1 Power source

Full compliance testing.

For full compliance testing the a.c. power source must meet the stability and distortion specifications contained in the standard, and summarized in appendix E.

Pre-compliance testing.

Many users choose to utilize the regular single-phase or three-phase a.c. line for pre-compliance testing. The user should choose an a.c. line that is as clean and as stable as possible. In general, if the equipment meets the standard with a good margin when tested with the regular a.c. line, the equipment should meet the standard easily when submitted for full compliance testing.

5.2.2 Source Impedance.

Full compliance testing.

A source impedance is not required when testing for harmonics, as current is measured.

Full-compliance testing for flicker is by voltage measurement and a calibrated source impedance is required.

Pre-compliance testing.

A source impedance is not required for pre-compliance testing for flicker, as the PM6000 and PM1000+ both offer the means to measure flicker by measurement of the changing load current. This method is not described in the standard, but Voltech have found that results using this method give good agreement with results made using voltage measurement. Measurements having a good margin below the limits should meet the standard easily. Alternatively, flicker can be measured with the PM6000 by voltage measurement using the specified source impedance, which is available from Voltech.

5.2.3 Current Transducers.

Full-compliance testing.
See section 5 of IEC61000-4-7 for current transducers.

5.2.4 Measuring equipment.

Full compliance testing.

The PM6000 is suitable for full-compliance testing to IEC61000-3-2 and IEC61000-3-3 with the addition of an impedance network, which is available from Voltech.

Pre-compliance testing.

Both the PM6000 and the PM1000+ are suitable for pre-compliance testing to IEC61000-3-2 and IEC61000-3-3 without the need for an impedance network.

5.3 Equipment set-up for tests requiring current measurement.

(Harmonics and pre-compliance flicker)

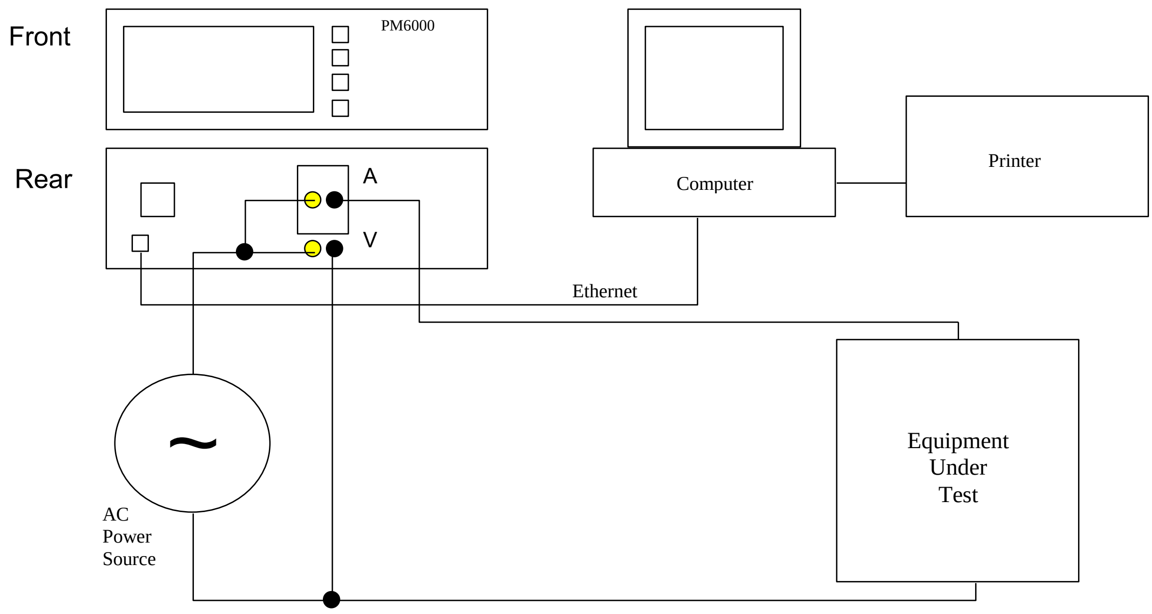


Figure 18 –Harmonic Measurement Setup.

Note 1: For Power Source Requirements see Appendix E.
Note 2: For Source Impedance Requirements see Appendix F.

5.4. Equipment set up for tests requiring voltage measurements.

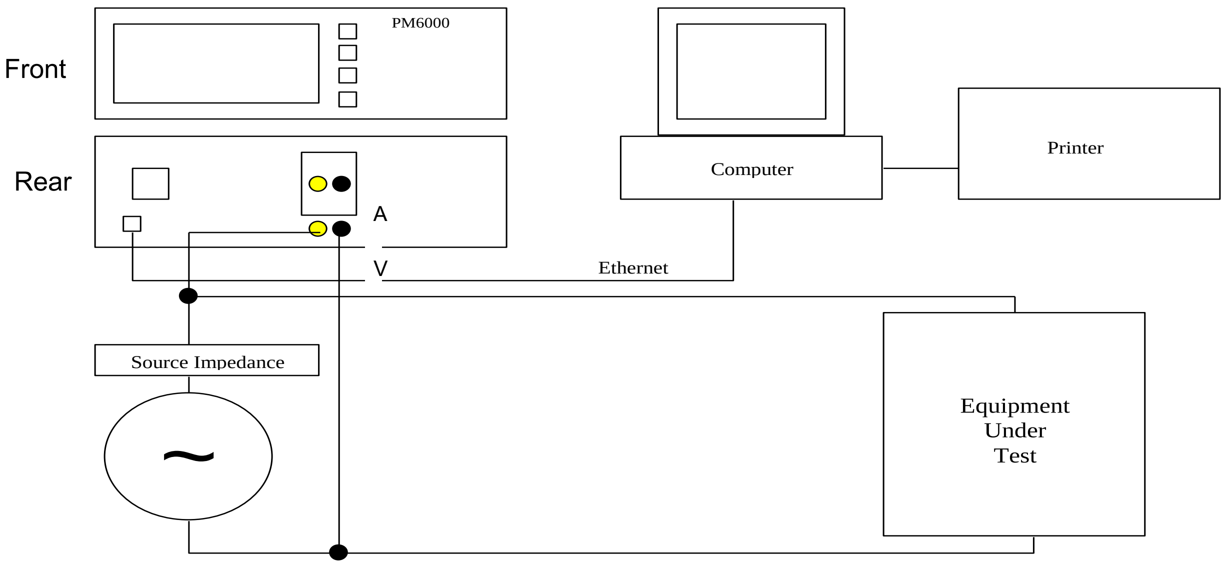


Figure 19 – Fliker Measurement Setup.

Note 1: For Power Source Requirements see Appendix E.
Note 2: For Source Impedance Requirements see Appendix F.

6. Measuring Fluctuating Harmonics with PM6000.

The PM6000 tests for fluctuating harmonics by continuously capturing data every 200mS, with no gap between the data, and each data capture is equal to 10 cycles of the input current wave form @ 50Hz or 12 cycles for 60Hz: -

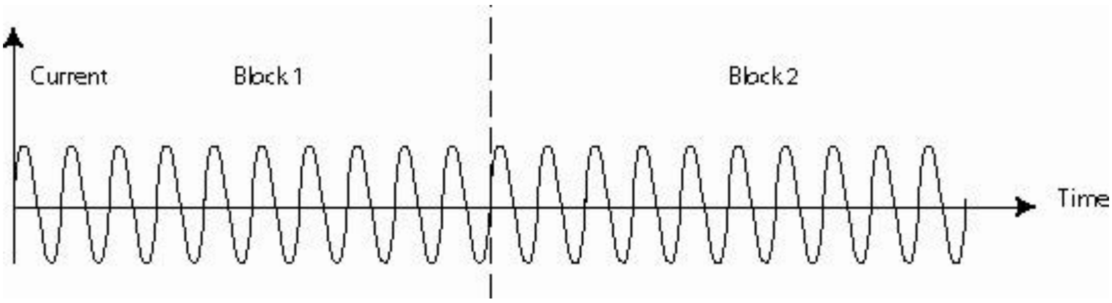


Figure 20

Each block is analyzed using Discrete Fourier analysis to determine the magnitude of each of the 40 current harmonics.

Results representing the magnitude of each harmonic are then passed through 1.5 second time constant low pass RC filters to provide smoothing of the amplitudes as defined by the standard. The output from these filters is continuously read by the PC that will log the results.

The PC examines the results as they are read from the PM6000 to determine if the magnitude of any harmonic exceeds the limit values defined in the standard for the particular class (A, B, C or D) for which the equipment is being tested.

6.1 Requirements of IEC61000-4-7 (inter-harmonics)

This standard defines how to measure fluctuating harmonics, including inter-harmonics. In a very special way, measurements are made continuously, without gaps, in blocks of 200s (10 cycles or 50Hz or 12 cycles of 60Hz). The standard requires, in each block, over 400 harmonics from 5Hz to 2025Hz to be measured, as illustrated in figure 21. The harmonics are then presented as 40 harmonics by grouping the 400 inter-harmonics in a particular way as illustrated in figure 22 for the 6th harmonic of 50Hz.

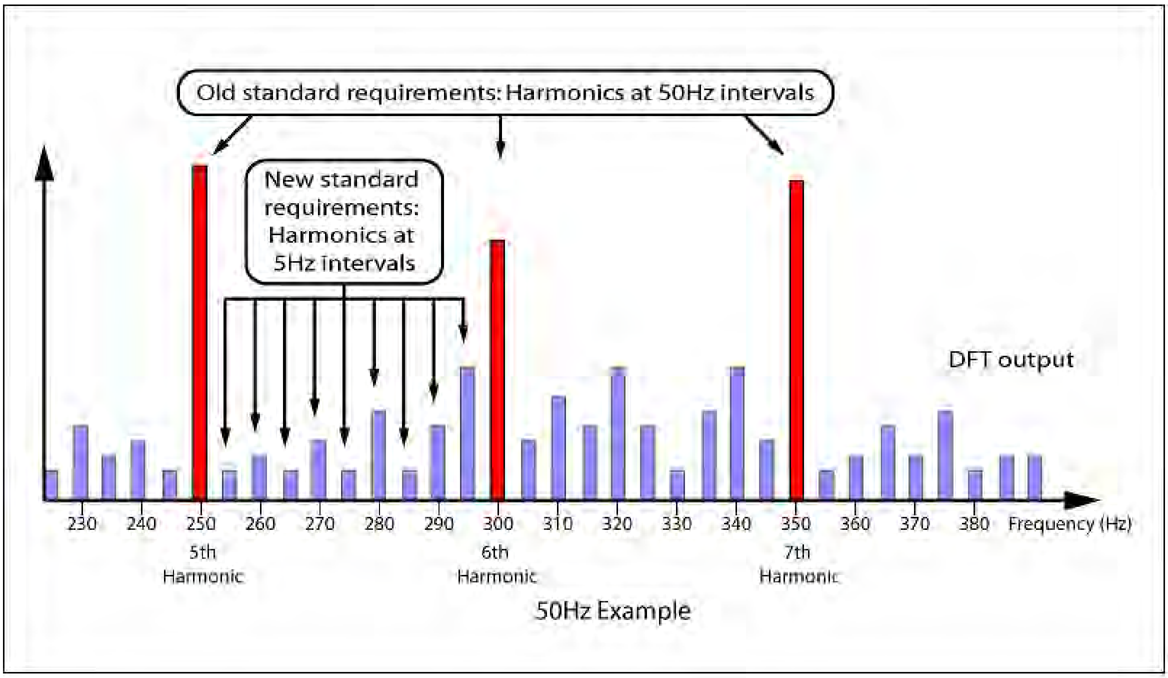


Figure 21 – Difference between harmonics and inter-harmonics.

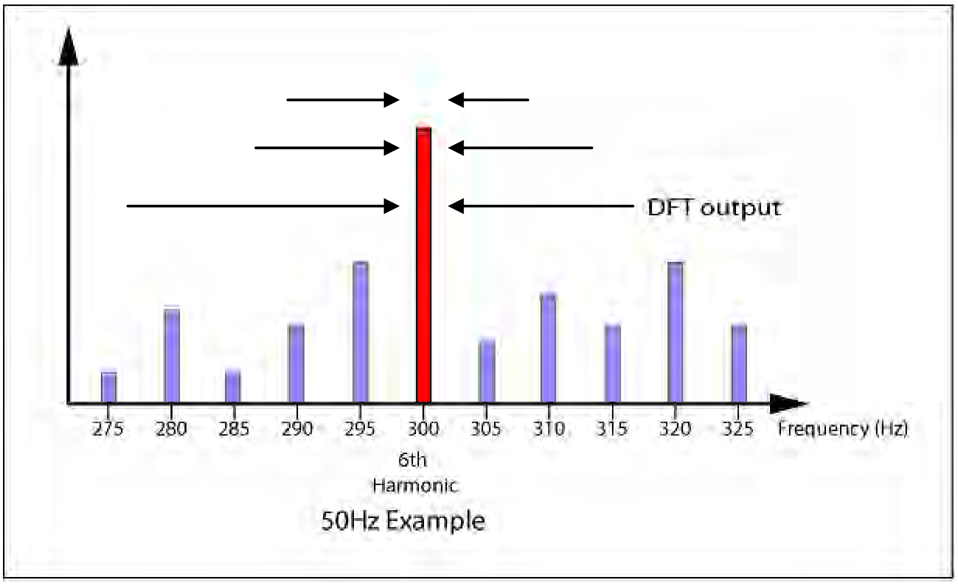


Figure 22 – Example of inter-harmonics grouped around the 6th harmonic of 50Hz.

If addition to making harmonics measures, IEC61000-3-2 requires other measurements such as Frequency, Power, Power Factor,

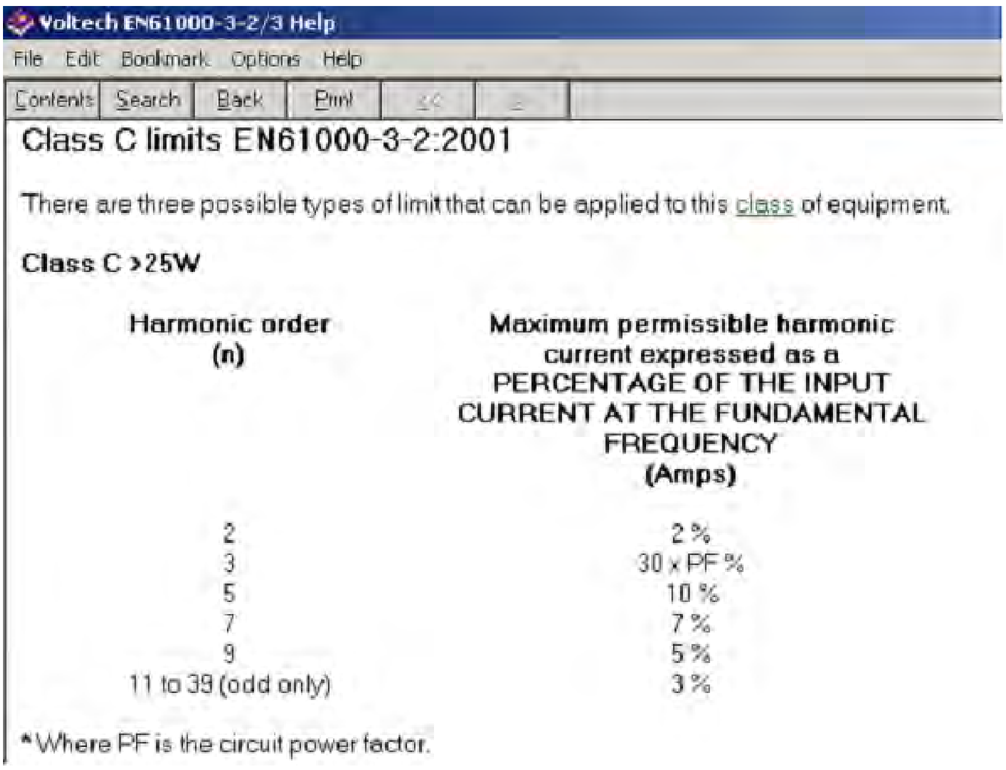
Voltage Harmonics, Fundamental Current, and POHC (Partial Odd Harmonic Current) to be made.
The limits for pass and fail are set by product groups called classes. The classes are called A, B ,C and D, as described in appendix A.

The following rules are used to determine what class a product falls in to:

- If device power is 75-600W and a PC, Monitor or TV then class D.
- If hand held portable then class B.
- If Luminaries then class C.
- If not class B, C or D then class A.

The harmonic limit differ for each class. The limits can be found in the on line help of the IEC61000-3-2/3 software or in the latest version of the standard available from the IEC at www.iec.ch, and are summarized in appendix B.

Figure 23 shows an example of how the limits for Class C limits – calculated from AH01 and PF, are shown in the PC software.


Voltech EN61000-3-2/3 Help

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Class C limits EN61000-3-2:2001

There are three possible types of limit that can be applied to this class of equipment.

Class C >25W

Harmonic order (n)	Maximum permissible harmonic current expressed as a PERCENTAGE OF THE INPUT CURRENT AT THE FUNDAMENTAL FREQUENCY (Amps)
2	2 %
3	30 x PF %
5	10 %
7	7 %
9	5 %
11 to 39 (odd only)	3 %

*Where PF is the circuit power factor.

Figure 23 - Example of on-line help showing class limits.

The average value, taken over the entire test period, of any harmonic order must always be less than the limit. Any individual harmonic may exceed the calculated limit up to 150% of the limit. In addition, each harmonic may exceed the limits above 150% if the harmonic measurement is less than or equal to 200% of the applicable limits, and the following condition shall apply:

- The UUT belongs to class A for harmonics.
- The excursion beyond 150% of the applicable limits was less than 10% of the test observation period or in total 10 minutes (within the test observation period), whichever is smaller
- The average value of the harmonic current taken over the entire test observation period is less than 90% of the applicable limits.

Figure 24 shows and example of an individual harmonic exceeding the limit, bur being below the 150% limit.

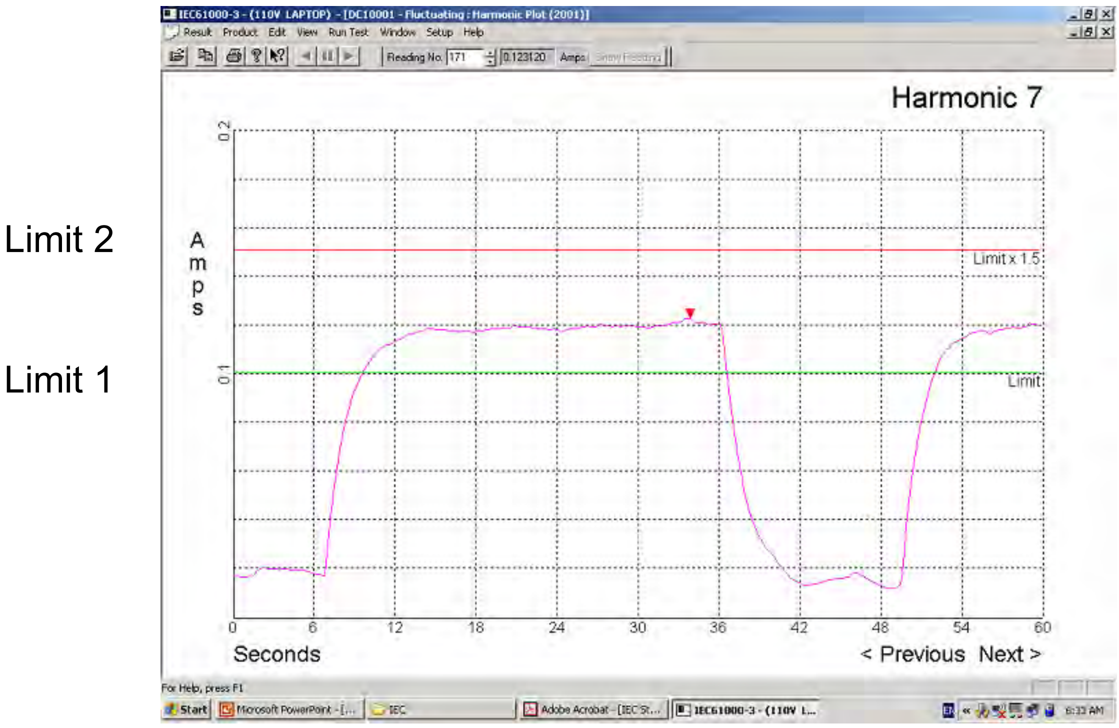

Figure 24 – Current harmonic over time

7. Measuring Voltage Changes with PM6000

If the load presented by equipment changes in a regular and repetitive manner, the equipment may be tested for conformance to IEC61000 Part 3 by measuring voltage changes.

Voltage changes can be determined by measuring the current drawn by the equipment, and calculating the voltage drop across a value of source impedance as specified by the standard.

The magnitude of the current during every half-cycle is measured, together with its phase relative to the a.c. voltage waveform. The current can then be represented in terms of its in-phase (Ip) and quadrature (Iq) components.

The percentage voltage change (ΔU/U) is calculated as specified in the standard as:

$$\frac{\Delta U}{|U|} = \frac{(I_p \times R) \ + \ (I_q \times X)}{|U|} \times 100\%$$

Where the source impedance is defined R + jX. The PM6000 determines the magnitude of all the voltage changes, and the number of changes per minute for that magnitude.

These results are sent to the PC, which then plots these results on a graph showing the IEC61000 Part 3 limits for voltage changes as shown in figure 25.

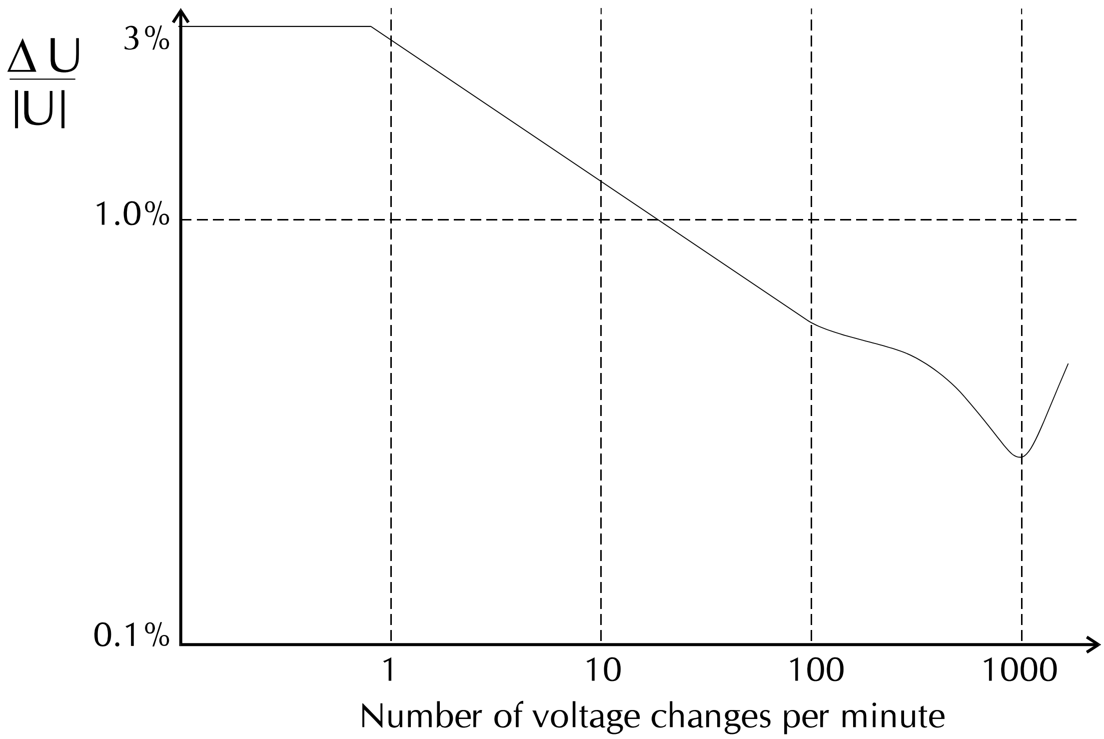

Figure 25 - Magnitude of maximum permissible voltage changes with respect to number of voltage changes per minute (Pst = 1 curve)

All results must be below the limit curve - if any result is above the curve the PC will indicate failure of the voltage change test.

8. Measuring flicker and voltage deviation with PM6000.

The PM6000 measures flicker by performing the functions required by IEC61000-4-15 specification (Flickermeter - functional and design specification.) These functions are represented in figure 15.

- Block 1 is a voltage adapter that scales the input mains frequency voltage (carrier) to a reference level so that flicker measurements will be made independently of the actual carrier level. This function is implemented digitally so calibration checking is not required as would be the case if implementation was analogue.

- Block 2 is a demodulator that recovers the voltage fluctuation by squaring the output of Block 1, thus simulating the behaviour of the lamp.

- Block 3 is composed of cascade filters which eliminate the dc and double frequency components in the demodulator output, and simulate the frequency response to voltage fluctuations of a filament lamp combined with the human visual system. No ranging is required as the digital implementation employed by the PM6000 operates over the whole range required for a flickermeter.

- Block 4 consists of a squaring multiplier and 300ms low pass filter, which combines with Blocks 2 and 3 to provide an overall response that simulates the lamp, eye and brain.

- Block 5 is implemented partly by the PM6000 and partly by the PC software that is used with the instrument. The output of Block 4 is the instantaneous flicker sensation. During the whole of the observation period the value of instantaneous flicker severity is classified 100 times per second into 1024 logarithmically scaled bins, providing a 1024 level classifier. (The class levels 0.01 to 6400 as defined by IEC61000 are required to be divided into a minimum of 64 divisions. The PM6000 uses 1024).

Flicker Class 6400	BIN # 1024	0
“	BIN # 1023	0
“		
“		
“	BIN # 4	3
“	BIN # 3	66
“	BIN # 2	72
Flicker Class 0.01	BIN # 1	120

At the end of the observation period no more values are stored in this set of bins, and the values in the bins are available to be read by the PC.

(If a second observation period immediately follows the first, for measurement of Plt for example, the PM6000 continues measurements and stores results in an alternate set of bins).

The PC reads the values in the bins, and from these results creates a cumulative probability function, representing the proportion of the observation period for which a particular flicker level has been exceeded (or, the probability that a particular flicker level would be exceeded at any point of time during the observation period).

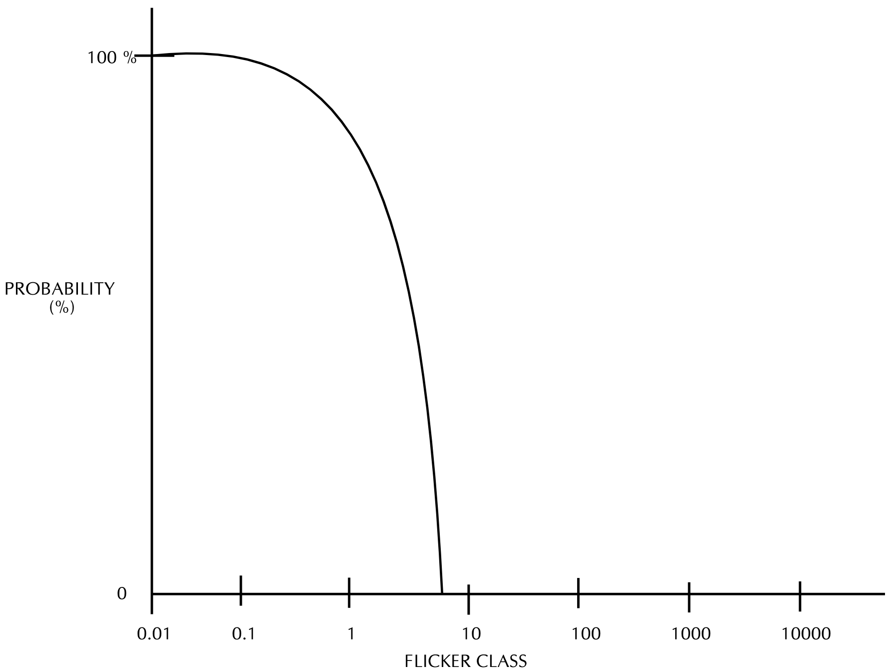

Figure 26 – Probability Curve

Using the cumulative probability function, the PC can then calculate values for Pst and Plt. Where:

$$Pst = \sqrt{(0.0314P_{0.1}+0.0525P_{1S}+0.0657P_{3S}+0.28P_{10S}+0.08P_{50S})}.$$

Where P_X represents the flicker level exceeded x% of the time. The suffix s in the formula indicates that smoothed values are used derived from the following equations: -

- $P_{50S} = (P_{30} + P_{50} + P_{80}) / 3$
- $P_{10S} = (P_6 + P_8 + P_{10} + P_{13} + P_{17}) / 5$
- $P_{3S} = (P_{2.2} + P_3 + P_4) / 3$
- $P_{1S} = (P_{0.7} + P_1 + P_{1.5}) / 3$

Plt is calculated using the expression:-

$$Plt = \sqrt[3]{\frac{\sum_{i=1}^{N} (Pst_i)^3}{N}} \quad \textit{for successive } \text{Pst values}$$

The values for Pst and Plt are then compared with the limits.

The PM6000 measures voltage deviations at the same time as it is performing the flicker measurements.

- The rms voltage is calculated in real time during each half-cycle interval.

- The PM6000 determines the maximum deviation in the value of rms voltage, (dmax), at each voltage change.

- The PM6000 determines the value of steady-state voltage change (dc) due to a change in load.

- The PM6000 measures the time interval (dt) during which any rms voltage deviation exceeds a prescribed limit.

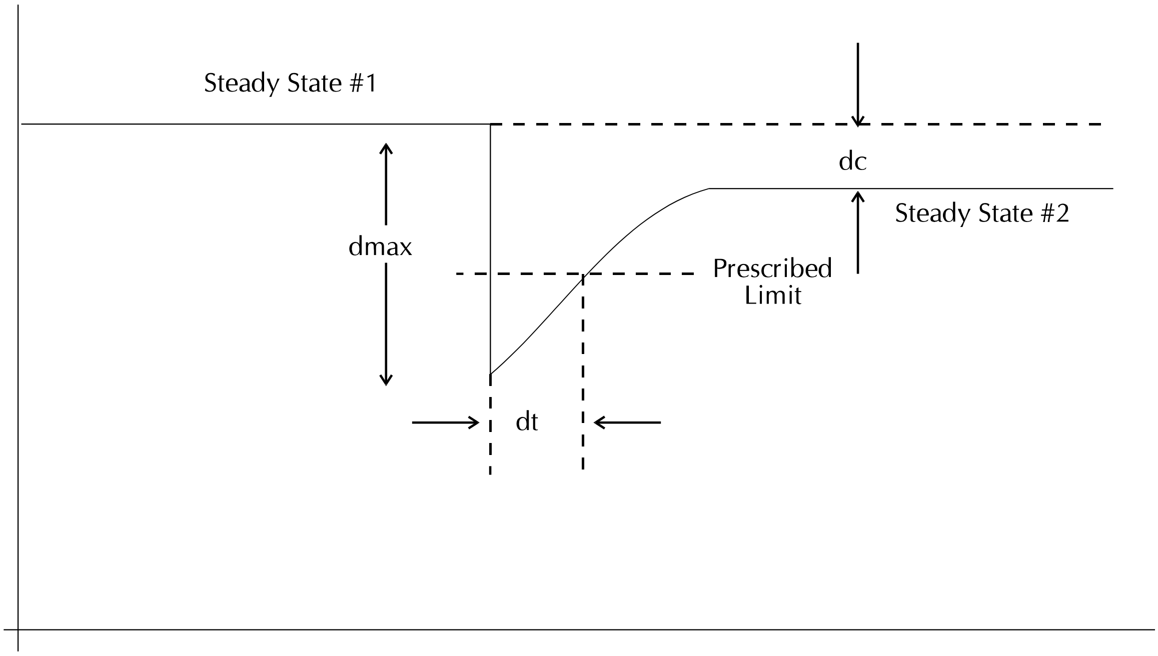

Figure 27 – Definition of Voltage Changes.

These values are read by the PC at the end of the observation period , and the PC compares these values with the limits.

The PM6000 can make the above measurements using either:

Voltage measurement - full-compliance testing. This requires a physical source impedance and the voltages appearing at the load are analyzed directly.

Or

Current measurement - pre-compliance testing. This method does not require a physical source impedance.

The current drawn by the appliance is analyzed, and the PM6000 or PM1000+ uses a proprietary technique to compute in real time the voltage drop in the value of source impedance (R,X) entered at the PC by the user.

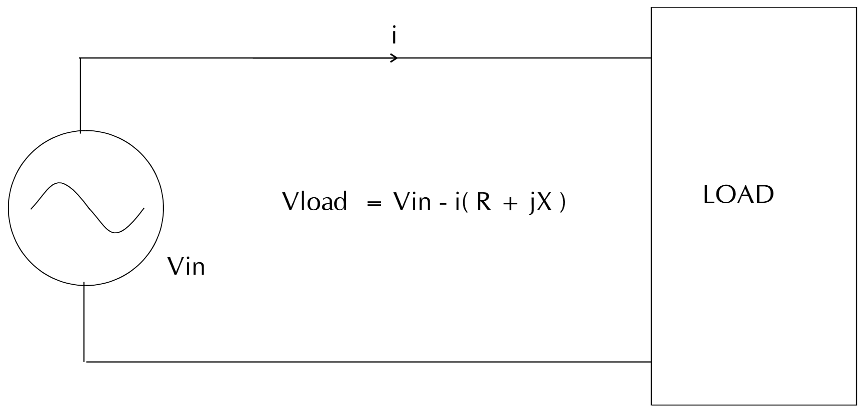

Figure 28 – Source Connection to Load

Values for flicker and voltage deviations are calculated from the real time values of load voltage as determined above.

This technique, as well as having the advantage of not requiring a physical source impedance, has been designed to provide the additional benefit of significantly reducing the effect of input voltage variations on the measured results. It can therefore provide excellent results with the regular line supply.

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APPENDIX A (Equipment Classification)

Classification of Equipment into Classes A,B,C,D for Harmonic Measurement.

Class A:
- Balanced three-phase equipment.
- Household appliances, except those identified as class D.
- Tools excluding portable tools.
- Dimmers for incandesant lamps.
- Audio equipment.

Class B:
- Portable tools.
- Arc welding equipment, which is not professional equipment.

Class C:
- Lighting equipment including dimming devices.

Class D:
- Equipment having an active power of less than or equal to 600W and is either a PC or PC monitor, or a television.

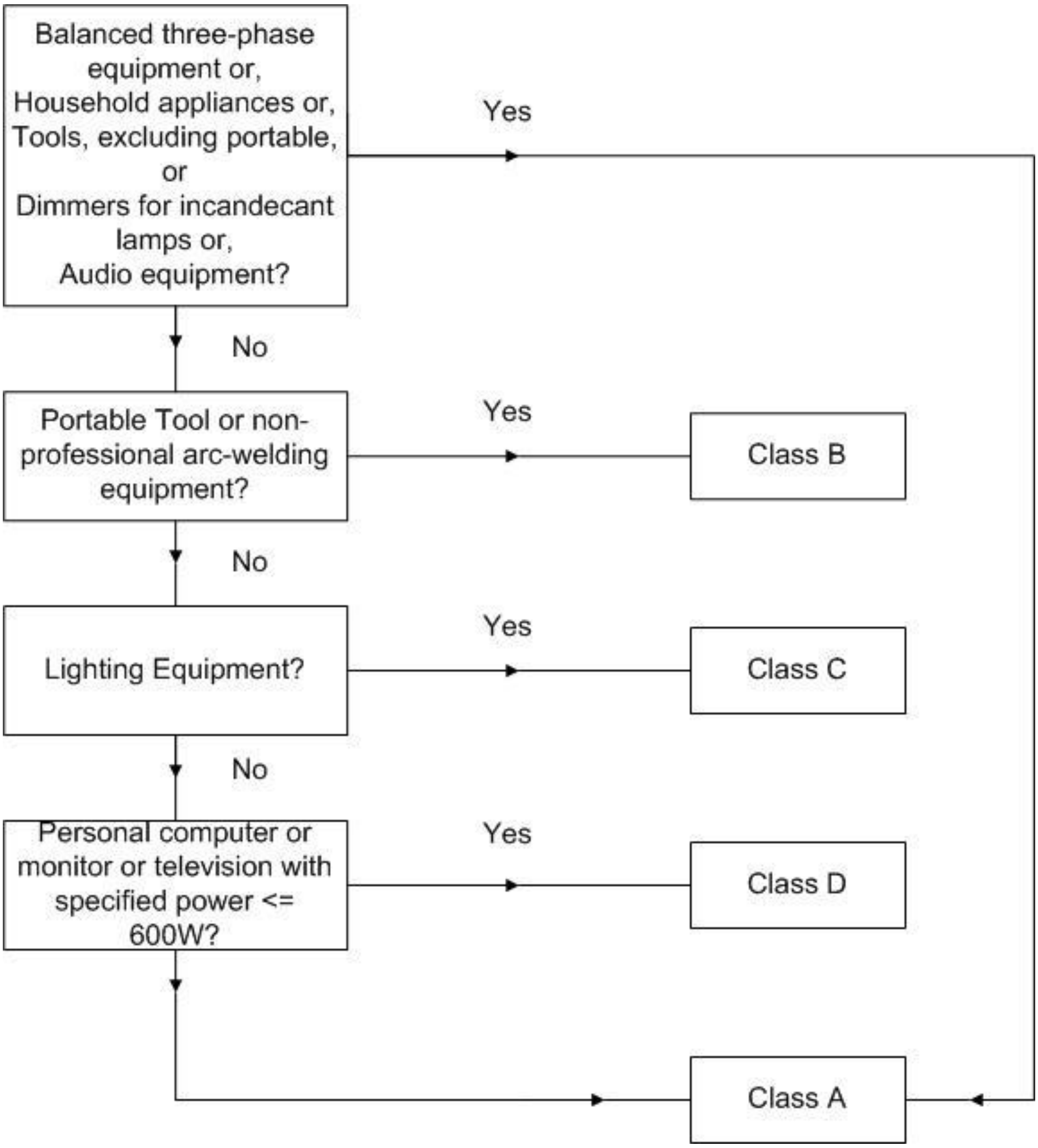

Figure 29 – Flow chart summarizing the Classification of equipment for IEC61000 Part 2 (Harmonics).

APPENDIX B (Class Limits and Test Conditions)

Harmonic Limits for Classes A, B, C, D and test conditions.

Limits for class A equipment.

Harmonic order (n)	Maximum permissible harmonic current (A)
Odd harmonics.	
3	2.30
5	1.14
7	0.77
9	0.40
11	0.33
13	0.21
15 -39	0.15 × 15/n
Even harmonics.	
2	1.08
4	0.43
6	0.30
8 - 40	0.23 × 8/n

$$e.g.\ \ Harmonic\ \#23$$

$$Limit\ =\ 0.15 \times \frac{15}{23}\ =\ 0.098A$$

Limits for Class B equipment.

Class B limits are set at 1.5 × Class A limits: -

Harmonic order (n)	Maximum permissible harmonic current (A)
Odd harmonics.	
3	3.45
5	1.71
7	1.155
9	0.60
11	0.495
13	0.315
15 - 39	0.225 × 15/n
Even harmonics	
2	1.62
4	0.645
6	0.45
8 - 40	0.345 × 8/n

$e.g.\ Harmonic\ \#34$

$$Limit = 0.345 \times \frac{8}{34} = 0.081A.$$

Limits for Class C equipment.

Harmonic order (n)	Maximum value expressed as a percentage of the fundamental input current of luminaires
2	2
3	30 × λ
5	10
7	7
9	5
11 - 39	3

Where λ = Power Factor (W/VA)

e.g. PF = 0.63
H(1) = 0.305A

$$\text{Harmonic \#3} = 0.305\text{A x } \frac{(30 \text{ x } 0.63)}{100} = 57.6\text{mA}$$

$$\text{Harmonic \#29} = 0.305\text{A x } \frac{3}{100} = 9.15\text{mA}$$

Limits for class D equipment.

Harmonic order.	mA / W	Maximum permissible harmonic current A
3	3.4	2.30
5	1.9	1.14
7	1.0	0.77
9	0.5	0.40
11	0.35	0.33
13 and on	Linear extrapolation 3.85/n	See limits for class A equipment.

For example:-

Active input power of a 5V 40A d.c. power supply = 253 watts.
3rd harmonic limit = 253 x 3.4mA = 860.2mA.
15th harmonic limit = 253 x 3.85/15mA = 64.9mA.

In the above table for class D, the harmonic limit is the smaller of the values calculated as 'mA/W', and the value in 'maximum permissible harmonic current'. For example, if

P_{IN} = 600W
15th harmonic from 'mA/W' = 154mA
15th harmonic from 'max permissible' = 150mA
Use 150mA value as limit.

The PC software supplied with the PM6000 takes care of this automatically

The Class D limits provide no values for even harmonics. Equipment that draws currents that are symmetrical in positive and negative half cycles will create negligible even harmonics. It is believed that the standard intends for Class D equipment to have this symmetry.

The following is reproduced from IEC61000-3-2.

1 General test conditions

The test conditions for the measurements of harmonic currents are given in the following Clauses. For equipment not mentioned there, user's operation controls or automatic programs shall be set to produce the maximum harmonic components under the normal operating conditions, for each successive harmonic component in turn.

The equipment is tested as presented by the manufacturer. Preliminary operation of motor drives by the manufacturer as long as necessary may be needed before the tests to ensure that results corresponding to those of normal use are obtained.

2 Test conditions for television (TV) receivers

2.1 General conditions

Measurements shall include the loading of any auxiliary circuits included in the receiver, but exclude the loading of any peripheral equipment powered from the receiver.

2.2 Conditions for measurement

A radio-frequency signal modulated in accordance with 2.2.1 shall be supplied by a test generator, and the receiver shall be adjusted to display a picture with appropriate settings for brightness, contrast and sound level in accordance with 2.2.2.

2.2.1 The TV receiver is fed by an r.f. TV input signal
with a level of 65 dB(μV) across 75 Ohms and with the following test modulations.

a) Color television
Radio-frequency signal: a full TV signal with modulated picture chrominance and sound carrier:

- The sound modulation factor is 54 % at 1 000 Hz

- The picture modulation content is a color bar test pattern according to Recommendation ITU-R BT.471-1:
  - 100 % reference white level bar
  - 0 % reference black level bar
  - 75 % amplitude (reference made to the white level)
  - 100 % saturation.

b) <u>Monochrome television</u>
Radio-frequency signal: a full TV signal with modulated picture and sound carrier:

- sound modulation: see item a) above;
- The picture modulation is a monochrome test pattern with a black and white level according to item a) and an average overall picture content of 50 % of the reference white level.

2.2.2 The receiver shall be tuned according to IEC 60107-1. The white reference level corresponds to 80 cd/m^2 and the black level to less than 2 cd/m^2 . The magenta bar corresponds to 30 cd/m^2 . The volume control is set in such a manner that one-eighth of rated output power is obtained, measured at the loudspeaker terminals, at a frequency of 1000 Hz. In the case of stereophonic equipment, this output shall be present at both outputs.

3 Test conditions for audio amplifiers

Audio amplifiers which draw a supply current which varies by less than 15 % of the maximum current with input signals between no signal and rated source e.m.f. (as defined in IEC 60268-3) shall be tested with no input signal.

Other audio amplifiers shall be tested under the following conditions:

- rated supply voltage;
- normal position of user controls. In particular, any controls affecting the frequency response shall be set to give the widest flat response achievable;
- input signals and load conditions as given in 4.2.4 of IEC 60065.

4 Test conditions for video-cassette recorders

Measurements shall be made in the playback mode with the standard tape speed.

5 Test conditions for lighting equipment

5.1 General conditions

Measurements shall be made in a draught-free atmosphere and at an ambient temperature within the range from 20 °C to 27 °C. During measurement the temperature shall not vary by more than 1 K.

5.2 Lamps

Lamps shall be aged for at least 100 h at rated voltage. They shall be operated for at least 15 min before a series of measurements is made. During ageing and measurement, lamps shall be installed as in normal use.

NOTE Some lamp types may require a stabilizing period exceeding 15 min. Information given in the relevant lamp specification must be observed.

5.3 Luminaires

The luminaire is measured as manufactured. It shall be tested with reference lamps, or with lamps having electrical characteristics close to their nominal values. In case of doubt measurements are made with reference lamps. When the luminaire incorporates more than
one lamp, all lamps are connected and operated during the test. When the luminaire is assigned for use with more than one type of lamp, measurements shall be made with all the types and the luminaire shall comply each time. In the case where the luminaire is equipped with a glow starter, a starter in accordance with IEC 60155, shall be used.

Incandescent lamp luminaires which do not incorporate an electronic transformer or a dimming device are deemed to fulfill the harmonic current requirements and need not be tested. If separate tests with reference lamps have proved that ballasts for fluorescent or other discharge lamps or step-down converters for tungsten halogen or other filament lamps, comply with the requirements, the luminaire is deemed to comply with these requirements and need not be checked. Where these components have not been approved separately, or do not comply, the luminaire itself shall be tested and shall comply. If a luminaire has a built-in dimming device, the harmonic currents shall be measured at the maximum load of the lamps as specified by the manufacturer. The setting of the dimming device is varied in five equidistant steps between the minimum and the maximum power in order to obtain comprehensive results.

5.4 Ballasts and step-down converters

Ballast for fluorescent or other discharge lamps or step-down converters for tungsten halogen or other filament lamps shall be tested with reference lamps, or with lamps having electrical characteristics close to their nominal values. In case of doubt, measurements are made with reference lamps.

In the case where a ballast can be used, with or without a series capacitor, or where a ballast or step-down converter is designed for several types of lamps, the manufacturer shall indicate in his catalogue for which type of circuit and lamps the ballast fulfils the harmonic requirements, and the ballast shall be tested accordingly.

6 Test conditions for independent and built-in incandescent lamp dimmers

The dimmer is tested with incandescent lamps having the maximum power allowed for the dimmer. The control is set to firing-angle of 90° ± 5°, or if controlled by steps, to that step closest to 90°.

7 Test conditions for vacuum cleaners

The air inlet of the vacuum cleaner is adjusted according to normal operation as defined in IEC 60335-2-2.

During the test observation period, which shall not be shorter than 6 min, vacuum cleaners with electronic control are tested in three modes of operation, each for an identical time interval, with the control adjusted:

- to maximum input power,
- to a firing-angle of 90° ± 5°, or, if controlled by steps, to that step closest to 90°,
- and to minimum input power.

If the vacuum cleaner includes a control to select a temporary high-power ('booster') mode of operation, which automatically returns to a lower power mode, this high-power mode is not considered for the calculation of the average values. This mode shall be tested only against the limits for single 1,5 s smoothed r.m.s. values (see 6.2.3.3 of IEC 61000-3-2).

8 Test conditions for washing machines

The washing machine shall be tested during a complete laundry program incorporating the normal wash-cycle filled with the rated load of double hemmed, pre-washed cotton cloths, size approximately 70 cm × 70 cm, dry weight from 140 g/m^2 to 175 g/m^2 .

The temperature of the fill water shall be:

- 65 °C ± 5 °C for washing machines without heater elements;
- 15 °C ± 5 °C for other washing machines.

For washing machines with a programmer, the 60 °C cotton program without pre-wash shall be used.

If the washing machine does not incorporate a programmer, the water is heated to 90 °C ± 5 °C or lower if steady conditions are established, before starting the first wash period.

9 Test conditions for microwave ovens

The microwave oven is tested with 100 % nominal power. It is operated with a potable water load of initially 1 000 g ± 50 g in a cylindrical borosilicate glass vessel, having a maximum material thickness of 3 mm and an outside diameter of approximately 190 mm. The load is placed at the centre of the shelf.

10 Test conditions for information technology equipment (ITE)

ITE is tested with the equipment configured to its rated current. In this case, the equipment, if necessary, may be configured with its power supplies loaded with additional load (resistive) boards to simulate rated current conditions.

For ITE systems designed for use with a manufacturer-supplied power distribution system, e.g. transformers, UPS, power conditioner, etc., compliance with the limits of this standard shall be met at the input to the power distribution system.

11 Test conditions for induction hobs

Induction hobs are operated with an enameled steel pan which contains approximately half its capacity of water at room temperature, and positioned at the centre of each cooking zone, in turn. Thermal controls are adjusted to their highest setting.

The diameter of the base of the pan is to be at least the diameter of the cooking zone. The smallest pan complying with this requirement is used. The maximum concavity of the base of the pan is 3D/1000 where D is the diameter of the flat area of the base of the pan. The base of the pan is not to be convex.

The concavity is checked at room temperature using an empty pan.

12 Test conditions for air conditioners

If the input power of the air conditioner is controlled by an electronic device so that the revolution speed of the fan or compressor motor is changed in order to get the suitable air temperature, the harmonic currents are measured after the operation becomes steady-state under the following conditions:

- The temperature control shall be set to the lowest value in the cooling mode and to the highest value in the heating mode.
- The ambient temperature for testing shall be 30°C ± 2°C in the cooling mode, and 15°C ± 2°C in the heating mode. If in the heating mode the rated input power is reached at a higher temperature, the air conditioner shall be tested at this ambient temperature but no higher than 18°C. The ambient temperature is defined as the temperature of the air inhaled from the indoor and from the outdoor unit of appliance.

If the heat is not exchanged to the ambient air but to another medium for example water, all settings and temperatures shall be chosen so that the appliance is operated with the rated input power.

If the air conditioner does not contain power electronic elements (e.g. diodes, dimmers, thyristors, etc.), it need not be tested against harmonic current limits.

13 Test conditions for kitchen machines as defined in IEC 60335-2-14

Kitchen machines as listed in the scope of IEC 60335-2-14 are deemed to conform to the harmonic current limits of this standard without further testing.

14 Test conditions for arc welding equipment which is not professional equipment

The arc welding power source is connected to a conventional load, which is adjusted in accordance with Table C1. The equipment is tested at the load current given by the maximum size of the rated electrode as specified by the manufacturer.

Rated electrode diameter mm	Load current* A	Load voltage V
1.6	40	19.6
2	55	20.2
2.5	80	21.2
3.15	115	22.6
4	160	24.4

*Interpolation is allowed.

APPENDIX C (Testing Harmonics, Specifications)

As taken from the current standard (IEC61000-3-2), all referrals to tables, clauses and section numbers are taken from the actual standard IEC61000-3-2. For the latest version of the standard visit www.iec.ch.

6.2.3.1 Repeatability

The repeatability of the measurements shall be better than ±5 %, when the following conditions are met:

- the same equipment under test (EUT) (not another of the same type, however similar it may be);
- identical test conditions;
- the same test system;
- identical climatic conditions, if relevant.

6.2.3.2 Starting and stopping

When a piece of equipment is brought into operation or is taken out of operation, manually or automatically, harmonic currents and power are not taken into account for the first 10 s following the switching event.
The equipment under test shall not be in stand-by mode (see 3.20) for more than 10 % of any observation period.

6.2.3.3 Application of limits

The average values 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 s smoothed r.m.s. harmonic current values, as defined in IEC 61000-3-2 section 6.2.2, shall be either:

a) less than or equal to 150 % of the applicable limits, or
b) less than or equal to 200 % of the applicable limits under the following conditions, which apply all together:

-the EUT belongs to Class A for harmonics;

-the excursion beyond 150 % of the applicable limits lasts less than 10 % of the test observation period or in total 10 min (within the test observation period), whichever is smaller, and

-the average value of the harmonic current, taken over the entire test observation period, is less than 90 % 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 21 st and higher odd order harmonics, the average value obtained for each individual odd harmonic over the full observation period, calculated from the 1,5 s smoothed r.m.s. values according to 6.2.2, 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 s smoothed r.m.s. individual harmonic current values shall be less than or equal to 150 % of the applicable limits.

6.2.3.4 Test report

The test report may be based on information supplied by the manufacturer to a testing facility, or be a document recording details of the manufacturer's own tests. It shall include all relevant information for the test conditions, the test observation period, and, when applicable for establishing the limits, the active power or fundamental current and power factor.

6.2.4 Test observation period

Observation periods *(*Tobs) for four different types of equipment behavior are considered and described below.

Quasi-stationary: is of adequate duration to ensure repeatability.
Short cyclic: is of adequate duration to ensure repeatability.
Random: is of adequate duration to ensure repeatability.

Long cyclic: the full equipment program cycle or a 2.5 minute representation considered by the manufacture to contain the highest THC (Total Harmonic Content).

6.3 Equipment in a rack or case

Where individual self-contained items of equipment are installed in a rack or case, they are regarded as being individually connected to the mains supply. The rack or case need not be tested as a whole.

7 Harmonic current limits

The procedure for applying the limits and assessing the results is shown in Figure 1. For the following categories of equipment, limits are not specified in this standard: NOTE 1 Limits may be defined in a future amendment or revision of the standard.
equipment with a rated power of 75 W or less, other than lighting equipment;
NOTE 2 This value may be reduced from 75 W to 50 W in the future, subject to approval by National Committees at that time.
professional equipment with a total rated power greater than 1 kW;
symmetrically controlled heating elements with a rated power less than or equal to 200 W;
independent dimmers for incandescent lamps with a rated power less than or equal to 1 kW.

7.1 Limits for Class A equipment

For Class A equipment, the harmonics of the input current shall not exceed the values given in Limits for Class A Table. Audio amplifiers shall be tested according to Clause C.3. Dimmers for incandescent lamps shall be tested according to Clause C.6.

7.2 Limits for Class B equipment

For Class B equipment, the harmonics of the input current shall not exceed the values given in Limits for Class B Table (Class A Table multiplied by a factor of 1,5).

7.3 Limits for Class C equipment

a) Active input power >25 W For lighting equipment having an active input power greater than 25 W, the harmonic currents shall not exceed the relative limits given in Table 2. However, the limits given in Limits for Class A Table apply to incandescent lighting equipment that has built-in dimmers or consists of dimmers built in an enclosure. For discharge lighting equipment that has built-in dimmers or consists of independent dimmers or dimmers built in an enclosure, the following conditions apply:

- the harmonic current values for the maximum load condition derived from the percentage limits given in Limits for Class C Table shall not be exceeded;
- in any dimming position, the harmonic current shall not exceed the value of current allowed in the maximum load condition;
- the equipment shall be tested according to the conditions given in C.5.

b) Active input power <=25 W
Discharge lighting equipment having an active input power smaller than or equal to 25 W shall comply with one of the following two sets of requirements:

- the harmonic currents shall not exceed the power-related limits of Limits for Class D Table, column 2, or:
- the third harmonic current, expressed as a percentage of the fundamental current, shall not exceed 86 % and the fifth shall not exceed 61 %; moreover, the waveform of the input current shall be such that it begins to flow before or at 60°, has its last peak (if there are several peaks per half period) before or at 65° and does not stop flowing before 90°, where the zero crossing of the fundamental supply voltage is assumed to be at 0°.
- If the discharge lighting equipment has a built-in dimming device, measurement is made only in the full load condition.

7.4 Limits for Class D equipment

For Class D equipment, the harmonic currents and the power shall be measured as defined in 6.2.2. The input currents at harmonic frequencies shall not exceed the values that can be derived from Limits for Class D Table according to the requirements specified in 6.2.3 and 6.2.4.

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APPENDIX D (Limits for voltage changes)

Reference: IEC61000-3-3. For the latest version of the standard visit www.iech.ch.

Limits.

Tests made to prove the compliance with the limits are considered to be type tests.

The following limits apply:

- the value of Pst shall not be greater than 1,0;
- the value of Plt shall not be greater than 0,65;
- the value of d(t) during a voltage change shall not exceed 3,3 % for more than 500 ms;
- the relative steady-state voltage change, d c , shall not exceed 3,3 %;
- the maximum relative voltage change dmax , shall not exceed
  a) 4 % without additional conditions;
  b) 6 % for equipment which is:
    - switched manually, or

- switched automatically more frequently than twice per day, and also has either a delayed restart (the delay being not less than a few tens of seconds), or manual restart, after a power supply interruption.

  c) 7 % for equipment which is

    attended whilst in use (for example: hair dryers, vacuum cleaners, kitchen equipment such as mixers, garden equipment such as lawn mowers, portable tools such as electric drills) or,

    switched on automatically, or is intended to be switched on manually, no more than twice per day, and also has either a delayed restart (the delay being not less than a few tens of seconds) or manual restart, after a power supply interruption.

In the case of equipment having several separately controlled circuits in accordance with 6.6, limits b) and c) shall apply only if there is delayed or manual restart after a power supply interruption; for all equipment with automatic switching which is energized immediately on restoration of supply after a power supply interruption, limits a) shall apply; for all equipment with manual switching, limits b) or c) shall apply depending on the rate of switching.

If voltage changes are caused by manual switching or occur less frequently than once per hour, the Pst and Plt requirements shall not be applicable. The three requirements related to voltage changes shall be applicable with the previously mentioned values multiplied by a factor of 1.33.

The limits do not apply to emergency switching or emergency interruptions.

General test conditions.

The test conditions for the measurement of voltage fluctuations and flicker are given in the following clauses. For equipment not mentioned in Annex A, controls or automatic programs shall be set to produce the most unfavorable sequence of voltage changes using only those combinations of controls and programs that are mentioned by the manufacturer in the instruction manual, or are otherwise likely to be used. Particular test conditions for equipment not included in Annex A are under consideration.

The equipment shall be tested in the condition in which it is supplied by the manufacturer. Preliminary operation of motor drives may be needed before the tests to ensure that results corresponding to those of the normal use are obtained.

For motors, locked-rotor measurements may be used to determine the largest rms voltage change, dmax, occurring during motor starting.

For equipment having several separately controlled circuits, the following conditions apply:

- Each circuit shall be considered as a single item of equipment if it is intended to be used independently, provided that the controls are not designed to switch at the same instant.

- If the controls of separate circuits shall be designed to switch simultaneously, the group of circuits so controlled are considered as a single item of equipment.

For control systems regulating part of a total load only the voltage fluctuations produced by each variable part of the load alone shall be considered.

Detailed type test conditions for some equipment is given in Annex A.

Annex A

(Normative) Application of limits and type test conditions for specific equipment.

A.1 Test conditions for cookers

For cookers designed for use in domestic premises the evaluation of Plt shall not be required.
The tests of Pst shall be performed at steady state temperature conditions unless otherwise stated.
Each heater shall be tested separately as follows:

A.1.1 Hot plates

Hot plates shall be tested using standard saucepans with diameter, height and water quantity as follows:

Diameter of the hotplate (mm)	Height of the pot (mm)	Quantity of water (g)
145	about 140	1000+/-50
180	about 140	1500+/-50
220	about 120	2000+/-50

Possible losses by evaporation have to be compensated for during the time of measurement.

In all the following tests the hot plate shall comply with the specified limits.

a) Boiling temperature range: Set the control to the position where the water just boils. The test is made 5 times and the mean value of the test results calculated.

b) Frying temperature range: Fill the pot, without a lid, with silicone oil to 1.5 times the quantity of water shown in the table. Set the control to a temperature of 180°C measured by a thermocouple in the geometric centre of the oil.

c) Total range of power settings: The total power range shall be checked continuously during a 10 minute observation period. If control switches have discrete stages, test all stages up to a maximum of 20 stages. If there are no discrete stages divide the total range into 10 equally spaced steps. The measurements shall then be made starting at the highest power stage.

A.1.2 Baking ovens.

The oven shall be tested empty with the door closed. Adjust the control so that a thermocouple fixed in the geometric centre measures a mean temperature of 220°C for conventional ovens and 200°C for hot air ovens.

A.1.3 Grills.

The grill shall be tested empty with the door closed if not otherwise stated by the manufacturer. If a control is available it shall be set to the lowest, medium and highest setting for grilling operation and the worst result recorded.

A.1.4 Baking oven/grill combinations

The oven/grill combination shall be tested empty with the door closed. Adjust the control so that a thermocouple fixed in the geometric centre measures a mean temperature of 250°C or that available temperature closest to this value.

A.1.5 Microwave ovens.

The microwave oven or the microwave function of a combination oven shall be tested at the lowest, medium and a third stage that is the highest adjustable power less than or equal to 90% of the maximum power. Load the oven with a glass bowl containing 1000±50g of water.

A.2 Test conditions for lighting equipment.

Lighting equipment shall be tested with a lamp of that power for which the equipment is rated. If lighting equipment includes more than one lamp, all lamps have to be in use.
Pst and Plt are only evaluated for lighting equipment that is likely to produce flicker, for example, disco lighting.

A.3 Test conditions for washing machines.

The washing machine shall be tested in a complete laundry program at 60°C filled with the nominal quantity of cotton cloths, size 70cm × 70cm, dry weight from 140 to 175g/m².
Neglect simultaneous switching of heater and motor in the evaluation of dc, dmax and d(t).
Pst and Plt shall be evaluated.

A.4 Test conditions for clothes dryers.

The dryer shall be tested with 50% of the nominal quantity of cotton cloths, size 70cm x 70cm, dry weight from 140 to 175 g/m² and 100% residual humidity.

If a control of the drying degree is available the test shall be performed at the maximum and minimum settings,
Pst and Plt shall be evaluated.

A.5 Test conditions for refrigerators.

Refrigerators shall be operated continuously with the door closed. Adjust the thermostat to the mid-value of the adjusting range. The cabinet shall be empty and not heated. The measurement shall be made after a steady state has been reached. Pst and Plt shall not be evaluated.

A.6 Test conditions for copying machines, laser printers and similar appliances.

The appliance is tested for Pst at the maximum rate of copying. The original to be copied/printed is white blank paper and the copy paper should have a weight of 80g/m² if not otherwise stated by the manufacturer.
Obtain the Plt value in the stand-by mode.

A.7 Test conditions for vacuum cleaners.

For vacuum cleaners Pst and Plt shall not be evaluated.

A.8 Test conditions for food mixers.

For food mixers Pst and Plt shall not be evaluated.

A.9 Test conditions for portable tools.

For portable tools Plt shall not be evaluated. For portable tools without heating elements Pst shall not be evaluated. For portable tools with heating elements Pst shall be evaluated as follows:

Switch on the tool and allow to operate continuously for 10 minutes or until it switches off automatically, in which case 6.5 applies.

A.10 Test conditions for hairdryers.

For hand held hairdryers Plt shall not be evaluated. To evaluate Pst switch on the hairdryer and allow to operate continuously for 10 minutes or until it switches off automatically, in which case 6.5 applies.

For hairdryers incorporating a power range, check the total power range continuously during a 10 minute observation period. If control switches have discrete stages all stages shall be tested up to a maximum of 20 stages. If there are no discrete stages divide the total range into 10 equally spaced steps. The measurements shall then be made starting with the highest power stage.

A.11 Test conditions for consumer electronics products (brown goods).

For brown goods, only the dmax test is made.

(Authors note: dmax limit = 4% × 1.33 = 5.32% as manual switching)

A.12 Test conditions for direct water heaters.

For direct water heaters without electronic controls evaluate dc only by switching the heater on and off (sequence 0 - Pmax - 0).

For direct water heaters with electronic controls the output temperature of the water has to be chosen so that by means of the variation of water flow-rate all electric power consumption rates between Pmin and Pmax may be produced. Pmax is defined as the minimum power which can be chosen.

NOTE - For some appliances the maximum power Pmax which can be chosen may be less than the rated power.

The set temperature value shall be kept unchanged during the total test. Starting from the water-flow rate demand for maximum power consumption, Pmax, reduce the rate of flow in 20 approximately equal steps to minimum power consumption, Pmin. Then, in another 20 approximately equal steps, increase the water flow-rate to power consumption Pmax. For each of these 40 stages the Pst, i value shall be evaluated; the measurements start when the steady state is reached, i.e. about 30 seconds after changing the water flow-rate.

Additionally, the flicker Pst, z caused by switching the heater on and off has to be measured within a ten minute interval. In this interval the power consumption has to be changed twice in the quickest possible way between the stages P = 0 and P = Pmax. (sequence: 0 - Pmax - 0 - Pmax - 0)

The duty cycle of the heater shall be 50% i.e. Pmax during 5 minutes.

Evaluate the resultant Pst value by:

$$Pst = \left(\mathrm{Pst,z}^3 + \frac{1}{40}\sum_{i=1}^{i=40} Pst,i^3 \right)\frac{1}{3}$$

and compare against the limit value.
Plt shall not be evaluated.

Author's notes:

Where the test conditions specify a value shall not be evaluated, it is still necessary to test for all other values specified as limits. For example, if test conditions specify that Pst and Plt shall not be evaluated, then test for dc, dmax and d(t) only).

APPENDIX E (IEC61000 Source Specification)

IEC61000 Specification of A.C. Voltage Sources for Full-Compliance Testing.

The source shall meet the following requirements:

For both Part 2 and Part 3:-

While the measurements are being made, the voltage shall be maintained within +/- 2% of the selected value and the frequency within +/- 0.5% of nominal value. In addition under part 2 the peak value of the test voltage shall be within 1.4 and 1.42 times its rms value and shall be reached within 87 to 93 degrees after the zero crossing. This requirement does not apply for class A and class B equipment.

For Part 2 (Harmonics):-

The internal impedance of the supply source, including that of the measuring equipment, at each frequency at which measurement has to be made, shall be sufficiently low so that the measured harmonic components of the input current do not deviate from the ideal values (obtained with an ideal zero impedance supply source) by more than 5% of the permissible limits.

NOTE:- In some special case, particular care may be necessary to avoid a resonance between the internal inductance of the source and capacitances of the equipment under test.
The harmonic ratios of the voltage(s) supplied by the source (at no load and when supplying a resistive load corresponding to the rated power of the equipment under test) shall remain small in order to avoid influencing the measurements.

The following maximum values are given as a guideline:
0.9% for harmonic of order 3;
0.4% for harmonic of order 5;
0.3% for harmonic of order 7;
0.2% for harmonic of order 9;
0.2% for even harmonics of order from 2 to 10;
0.1% for harmonics of order from 11 to 40.

For Part 3 (Voltage fluctuations)
The percentage total harmonic distortion of the supply shall be less than 3% (Authors note - this will be met if supply source meets the Part 2 specification given above).

Fluctuations of the supply voltage during a test may be neglected if the Pst value (of the supply voltage) is less than 0.4. This condition shall be verified before and after each test.

APPENDIX F (Source Impedance)

Source Impedance for Measurement of Voltage Changes and for Flicker Measurements.

Three Phase, four wire, 230/400V supplies, 50Hz.

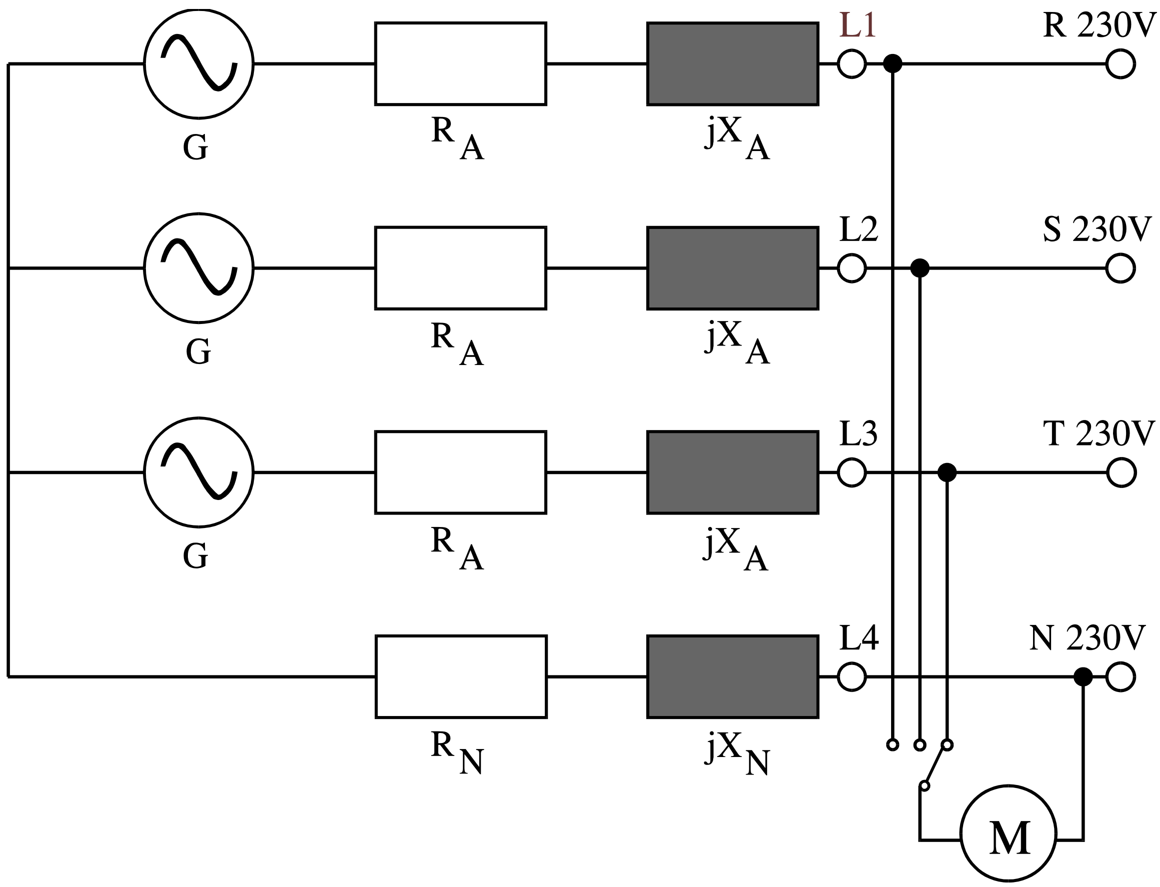

Figure 29

R_A = 0.24 Ω
jX_A = $j\omega L_A$ = j0.15 Ω (L = 477.5μH @ 50Hz).
R_N = 0.16 Ω
jX_N = $j\omega L_N$ = j0.10 Ω (L = 318.3μH @ 50Hz).

Note - In general, three-phase loads are balanced and Rn and Xn can be neglected as there is no current in the neutral wire. Measurements on a balanced three - phase load can therefore be made as shown with R_N and jX_N equal to zero (eg no impedance)

Single phase, two wire, 230V supplies, 50Hz.

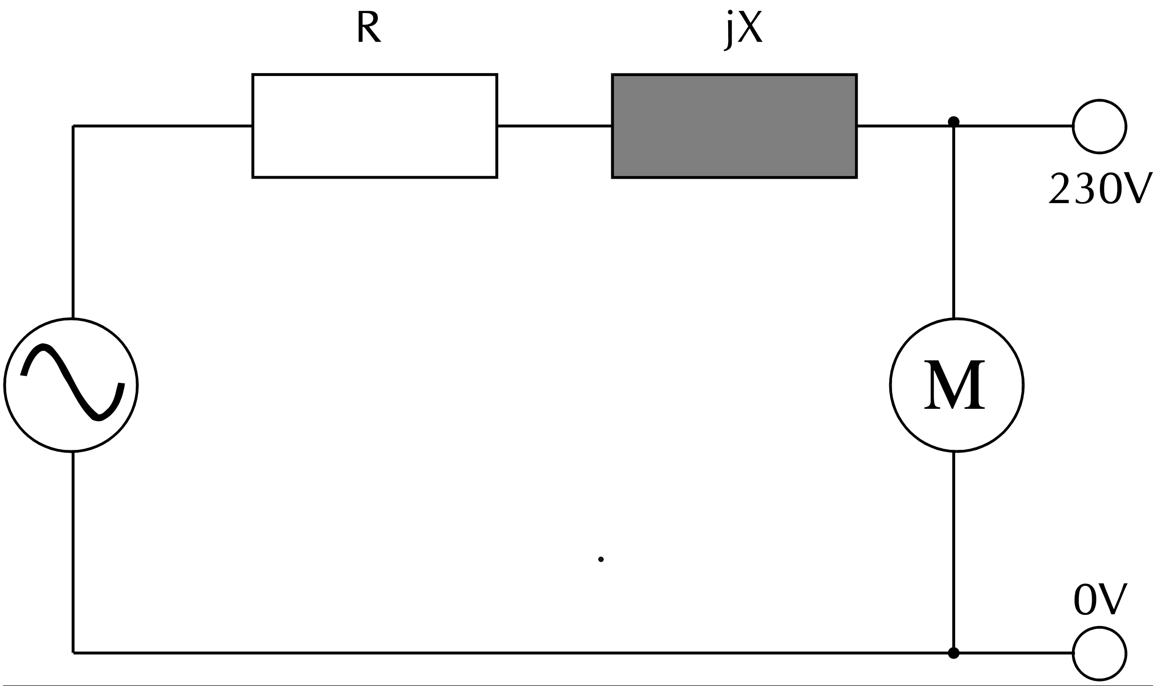

Figure 30

R = Ra + Rn = 0.24 Ω + 0.16 Ω = 0.4 Ω.
jX = jω(La + Ln) = j(0.15 Ω + 0.10 Ω) = j0.25 Ω
(L = 795.8μH @50Hz).

APPENDIX G (Harmonics and poor power factor)

Why Harmonics Cause Poor Input Power Factor.

The power factor of an a.c. system is defined as the ratio W/VA, where W is the real power drawn by the system, and VA is the apparent power (Vrms × Arms).

In Section 3.1, it was shown that a distorted current waveform consists of a fundamental component of current plus a series of harmonic currents. Using Fourier analysis, a distorted current waveform f(t) can be expressed as:

A1 sin wt + B1 cos wt (Fundamental component)
A2 sin 2wt + B2 cos 2wt (2nd harmonic)
A3 sin 3wt + B3 cos 3wt (3rd harmonic).
etc..

Where An and Bn represent the magnitude of the in-phase and the quadrature components of current harmonic n.

Note - The magnitude of harmonic n is given by:

$$Mn = (An^2 + Bn^2)^{1/2}$$

The rms current of the distorted waveform is due to ALL the frequency components in the waveform:-

$$\text{e.g. } Arms = (A1^2 + B1^2 + A2^2 + B2^2 + A3^2 + B3^2......)^{1/2}$$

The harmonic currents therefore increase the rms current of the system, and as VA = Vrms × Arms, the harmonic currents increase the apparent power in the system.

The real power (W) supplied by a system is the average of the product of the supply voltage and the current. e.g.

$$W = \frac{1}{2\pi}\int_0^{2\pi} \mathrm{V x I}$$

As the supply voltage is essentially sinusoidal, the power due to each component of current in the distorted wave form can be expressed as:

$$\left.\begin{aligned} Real\ power = \frac{1}{2\pi}\int_0^{2\pi} V\sin\omega t \times A1\sin\omega t = \frac{VA1}{2} \\ + \frac{1}{2\pi}\int_0^{2\pi} V\sin\omega t \times B1\sin\omega t = 0 \end{aligned}\right] \mathit{Fundamental\ power}$$

$$\left.\begin{aligned} + \frac{1}{2\pi}\int_0^{2\pi} V\sin\omega t \times A2\sin 2\omega t = 0 \\ + \frac{1}{2\pi}\int_0^{2\pi} V\sin\omega t \times B2\sin 2\omega t = 0 \end{aligned}\right] 2nd\ \text{harmonic}\ \mathit{power}$$

$$+\ldots\text{etc} \qquad etc\ldots$$

When these expressions are evaluated, it is seen that only the fundamental component of current that is in phase with the supply voltage is capable of transmitting real power. The quadrature component of fundamental current cannot transmit any power, and neither can the in-phase or the quadrature components of any harmonic currents.

As the rms current is due to all the components in the current wave form, it can be seen that the VA of the system is increased, (but the power is not) if the current contains any of those components that do not transmit useful power. It follows therefore that the power factor (W/VA) is decreased if:

1) The fundamental component of current is not in-phase with the fundamental voltage.

and/or

2) The current contains any harmonic components.
The 'ideal' current drawn by equipment is therefore a sinusoidal current in-phase with the supply voltage.