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Power Quality and Lighting Systems

A Look Into EN61000-3-2 Class C

Introduction

New technologies in lighting have today's designers focusing a keen eye toward power quality. Power quality is the ability of an electrical system to deliver power in the safest, most efficient manner. Power quality is an important consideration in all industries, but with the advent of LEDS, Compact Fluorescent Lighting (CFL), High Intensity Discharge (HID) lighting and others, the commitment to an efficient power distribution system is more essential than ever.

Many new lighting technologies, while certainly more efficient, can adversely affect power systems through harmonics which decrease power quality. Inefficiencies in power quality may limit the amount of devices that can be placed on the distribution network. It may also cause equipment to under perform or to behave erratically. In the most severe cases it can even harm the system and the devices along the network. Poor power quality management inevitably leads to an increase in operational costs and places an unnecessary strain on already dwindling resources. Therefore, lighting systems should be driven by efficient and sustainable power sources that will not unnecessarily burden the power grid while still providing the perfect electrical environment for advanced lighting systems.

There are several standards which exist for lighting industry compliancy. It is incumbent on power supply manufacturers to produce supplies capable of meeting the appropriate lighting standards for safety and emissions. The standard which most directly affects power quality is the standard for limitations on harmonic currents, or EN61000-3-2 Class C limits. ANSI C82.77-2002 is the harmonic emissions specifications for luminaries in the United States.

EN61000-3-2

This standard regulates the harmonic currents drawn from the main's supply connected to a low voltage distribution system. It is applicable to any electrical or electronic equipment with an input current of up to 16A per phase and nominal 230Vac, or 414Vac for three phase.

There are 4 classifications within the standard:

Class A	Balanced three phase equipment
Class B	Portable Tools
Class C	Lighting equipment and dimming devices
Class D	ITE

The allowable power consumption is 75 -1000 Watts and 25 Watts for Class C (a standard LED lamp or fluorescent strip consumes less than 25 Watts - though changes in the standard are still anticipated and this number may go lower).

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The limits for Class A and B are static while C and D have dynamic limits determined by current drawn from the equipment (See Table 1, 2, and 3).

Class B, (not shown) is 1.5 times the allowable limits of Class A.
Of note, out of the 4 classes, the limits for Class C are the most stringent.

Table 1 – 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
$15 \leq n \leq 39$	0.15 15/n
Even Harmonics	
2	1.08
4	0.43
6	0.30
$8 \leq n \leq 40$	0.23 8/n

Table 2 – Limits for Class C Equipment

Harmonic Order n	Maximum Permissible Harmonic Current Expressed as a Percentage of the Input Current at the Fundamental Frequency %
2	2
3	30 • λ *
5	10
7	7
9	5
$11 \leq n \leq 39$ (odd harmonics only)	3
*λ is the Circuit Power Factor	

Table 3 – Limits for Class D Equipment

Harmonic Order n	Maximum Permissible Harmonic Current per Watt 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	3.85/n	See Table 1
$13 \leq n \leq 39$ (odd harmonics only)		

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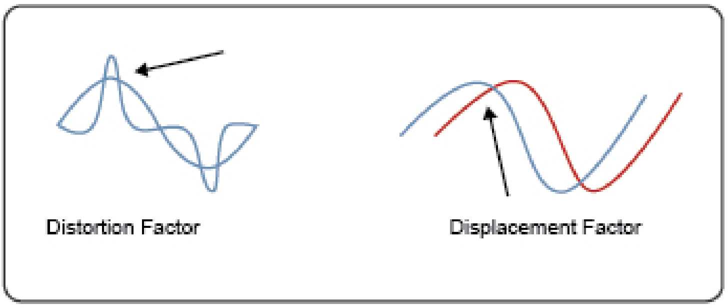
There are two major elements which affect power quality, phase displacement and wave distortion through harmonics.



Harmonic currents

Harmonic currents are distorted waveforms caused by non-linear loads which appear at multiples or “harmonics” of the power frequency. Switching power supplies are a major source of non-linear loads.

Figure 2 illustrates a power supply which draws its current in a non-sinusoidal burst. Note the difference between a linear (Figure 1) and non-linear voltage and current relationship (Figure2).

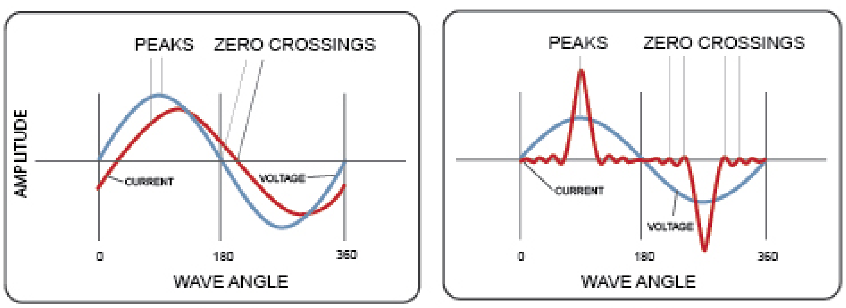


Figure 1 Figure 2

Harmonic currents cause distortions of the applied voltage. All distorted waveforms, current and voltage can be described as the fundamental waveform plus one or more harmonics (Figure 3). Even numbered harmonics tend to cancel each other out, but unfortunately the odd numbered harmonics add in a way that quickly increases distortion because the peaks of these waveforms often coincide. Note that Table 2 for Class C lighting is primarily concerned with odd numbered harmonics up to the 40^{th} harmonic.

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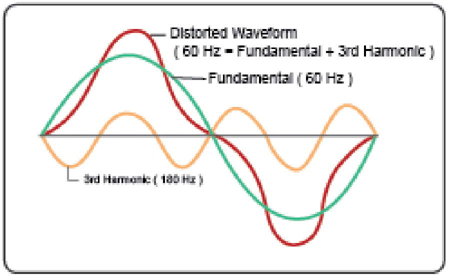

Figure 3

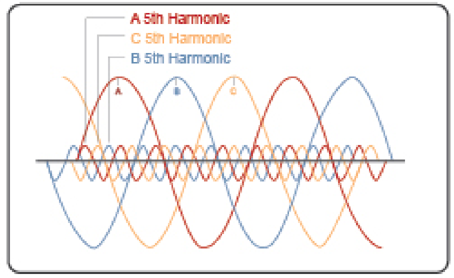

Figure 4

Total Harmonic Distortion(THD)

The aggregate or total of all harmonics is measured as the total RMS value of all harmonics to the *I* fundamental or first harmonic expressed as a percentage.

$$THD_I = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + I_5^2 + \ldots}}{I_1}$$

The Total Voltage Distortion (TVD) may be calculated by substituting V for *I*.

Effects of Harmonic Distortion

- **Current Distortion**

  Fortunately harmonic currents are path dependent and can only flow in the non-linear loads that created them, so their effect on other loads in the system is negligible. However, they can and do impact the distribution system.

  Since real power can only be delivered at the fundamental frequency, harmonic currents reduce system capacity and limit the amount of power to additional loads.

  In three phase systems, the odd triple harmonics (or triplens) are sent to the voltage supply. These currents may be larger than any of the phase currents. Currents may be as high as 200% of phase currents. If the wire is not properly sized it may cause a fire.

  An indirect effect takes place when harmonic currents excite resonant frequencies which in turn cause high harmonic voltages capable of destroying a load.

- **Voltage Distortion**

  Unlike current distortion, voltage distortion is not path dependent; therefore, voltage distortion will appear on common busses within a facility.

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Harmonic voltages are higher the farther away from the source due to the increased impedances that harmonic currents must flow through. These harmonic voltages in turn cause voltage distortions that may cause significant harm, such as shortening the performance of capacitor banks or shortening the life of the utility's transformers.

Voltage distortions also cause multiple zero crossings that may adversely affect the operation of equipment that rely on zero crossing for the sequencing of devices.

Non-linear loads with phase-to-neutral or phase-to-phase connections are not generally affected. However the fifth harmonic voltage distortion in a three-phase motor will cause a negative torque to be place on the motor. This might cause the motor to overheat, fail or the motor will try to draw more current from the fundamental frequency in an attempt to regain its speed. The elimination of the fifth harmonic is crucial in industrial applications.

Phase Displacement

Harmonic currents may also be displaced or out of phase with the applied voltage. In Figure 5, the current lags the voltage by 90 degrees of displacement. During part of the cycle the voltage is positive and the current is negative. This means the voltage and current are working against each other in a reactive manner. This is called reactive power. Unless a power supply has a purely resistive impedance or power factor of 1 it will have some phase displacement.

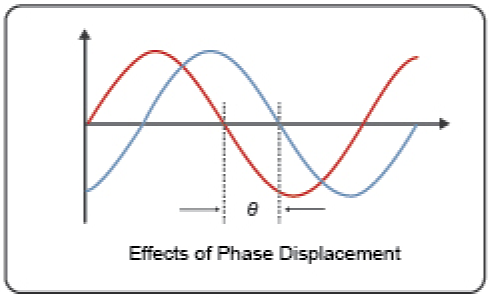

Figure 5

Effects of Phase Displacement

Many incandescent lighting systems do not reduce power quality because they have sinusoidal waveforms that are in phase with the voltage waveform. However magnetic ballasts for fluorescent and HID lamps have lagging current and create reactive power. Switching power supplies also exhibit phase displacement and also create reactive power. Reactive power is not useful work. The power is merely absorbed and returned to the load.

The equation for reactive power is V x A x sin (displacement angle (Figure 6)). Any power that is does not perform useful work is detrimental to the system since it reduces power quality.

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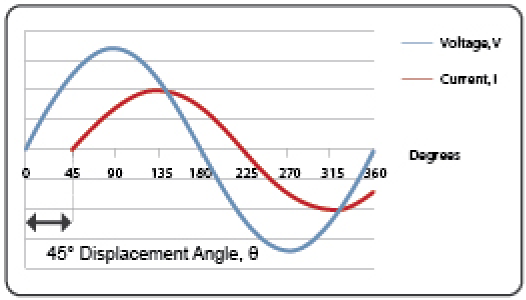
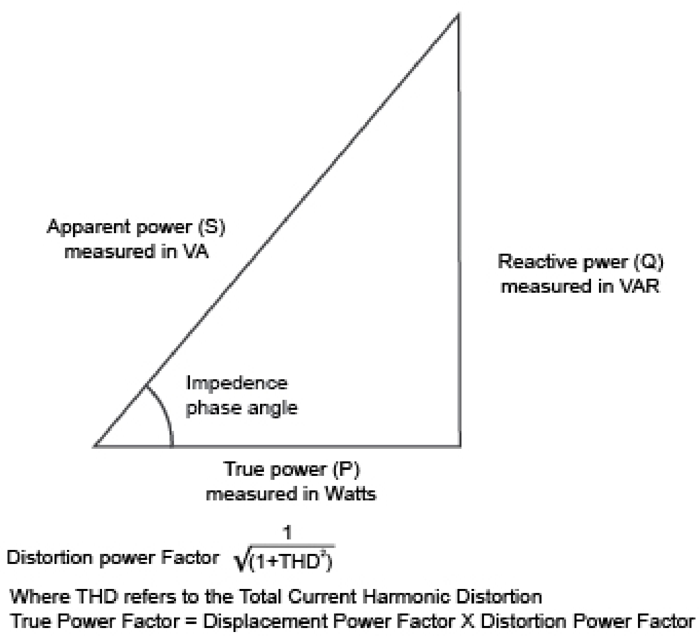


Figure 6

Summary

Power quality in a system can be measured by its *power factor*. The power factor is the ratio of its true power to its apparent power. True power is the power delivered to the load, while apparent power is the product of its voltage and current. If the true power equals the apparent power then the system is said to have a power factor of 1, or unity. This means that the system is drawing AC current directly proportional to the AC line voltage. Once a waveform becomes distorted or displaced as in the case of harmonics, the power factor is less than 1 and there is a reduction in power factor (and power quality).

Traditional power factor is generally thought of as displacement power factor (DPF) since it measures the displacement or phase angle or shift between voltage and current, measured as the cosine of that angle. However, true power factor takes into account the wave shaping or distortion as well as the displacement of the phase angle.



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It is now clear to see how Harmonics Distortion (THD) and Displacement Factor (DF) can greatly influence power quality.

The important methods to reduce these factors and restore Power Quality will be discussed in the next article concerning THD Limits, Filters and Power Factor Correction.

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