GE Consumer & Industrial
Lighting

Normal Power Factor Operation of Low Wattage, Hard Wired Electronic Ballasts

Power Factor and Electronics Ballasts:

Power factor is defined as the ratio of real power in Watts to complex power in Volt-Amperes (VA). It is always a number between 0 and 1. Power factor is significant to power generating utilities because it is a measure of what they must generate in VA to what is actually consumed in Watts. As an energy user's power factor decreases the utility has to supply more current for a given amount of real power use. This extra power generated is a reactive component and is referred to as Volt – Amperes Reactive (VARs). This reactive power component develops due to characteristics of the load. Note, utilities may charge large commercial users an additional fee if the site power factor is below a stipulated value. Small commercial users and residential users are not economically penalized for lower power factors.

Power factor is comprised of two components. The first is the phase shift induced between the sinusoidal input voltage and current due to either the inductive or capacitive nature of the load and is referred to as the displacement power factor (DPF). DPF is defined as the cosine of the phase shift angle phi (ϕ). The second component is due to non-linear characteristics of the load and is referred to as the distortion factor. It is expressed as a function of the load's total harmonic distortion (THD). The load's power factor is the product of its distortion factor and its displacement power factor.

$$P.F. = \frac{1}{\sqrt{1+THD^2}}\cos(\phi)$$

Basic electronic ballasts are non-linear loads with high levels of THD and a low power factor. This can be corrected with additional electronic circuitry added to the ballast but with a number of trade-offs.

Historically, most hard wired lighting ballasts have been power factor corrected to 0.9 P.F. since it was considered likely that large commercial buildings will result in a dense aggregation of ballasts. Typically these densely ballast populated commercial buildings were illuminated with fluorescent lamp ballast systems with a high input Watt rating per fixture and potentially a high input VA rating.

In contrast, residential installations or commercial installations where the density of hard wired normal power factor ballasts is low, a reduced power factor has typically been accepted, especially where the ballast wattage level is also low. In these applications the expected VA impact is minimal. Residential low density installations also tend to be cost sensitive and power factor correction in low wattage ballasts is disproportional in cost compared to the end user value added circuitry.

In applications that demand physically small products, such as integral self ballasted lamps and track mounted lamps, the addition of extra circuitry needed to significantly increase power factor (PF> 0.9) may also result in added efficiency losses and the need for a physically larger configuration that would limit product appeal or practicality[1].

Harmonic Content and Neutral Currents:

A second sometimes expressed concern with lower power factor loads has been increased neutral currents in 3-phase commercial distribution systems. In a 3-phase wye connected distribution network the neutral current is dominated by any DC component and odd triplen harmonics[2]; the 3rd, 9th, 15th, etc.

$$i_{n(rms)} = \sqrt{I_0^2 + \sum_{K=3,9,15,...}^{\infty} I_K^2}$$

The fundamental and the remaining harmonic currents will tend to subtract or cancel out in the neutral. If the load is balanced on all phases they will completely cancel out in the neutral leaving the DC factor and odd triplens. The concern arises from the additive effect of the triplen harmonics. If the triplen harmonic content is high enough the increased neutral current may exceed the ratings of the neutral wiring or other distribution equipment resulting in system overheating. However this is mitigated in most energy saving commercial retrofit situations by three considerations.

- ***First with energy saving retrofits the overall load VA is reduced.*** For typical applications this reduced load current will tend to offset the increase neutral current due to increased harmonic distortion.

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[1] National Electrical Manufactures Association (NEMA), Lamp Section "Power Quality Implications of Compact Fluorescent Lamps in Residences", (1999), LSD 9-1999

[2] R.W. Erickson, "Fundamentals of Power Electronics", (1997), Chapter 15

- ***The second consideration is load diversity.*** Lighting typically accounts for 25 to 30% of the energy consumed in commercial buildings[3]. In the case of low wattage energy efficient lighting products this percentage may even be lower. Any increase in triplen harmonics due to the lighting may be insignificant compared to the total distribution system load. In many cases large percentages of the overall distribution load have become linear as newer OEM equipment, compliant with industry standards for power factor and harmonic content, has been installed[4].

- ***Finally, designs that are not only power factor corrected but also restrict specific harmonics such as the critical odd triplen harmonics will further mitigate the cumulative build up in the neutral that may otherwise occur in commercial installations.***

In cases where a large number of normal power factor products will be concentrated, such as in a large commercial installation, a qualified professional familiar with building electrical distribution systems should review the proposed installation.

Regulations and Standards:

Regulatory and standardization agencies have recognized that energy efficient lighting is a contributor to a user's overall power factor due to their electronic ballast interface and have established limits for acceptable power factor. ANSI C82.77, most recently revised in 2002 recommends that all commercial indoor, hard wired ballasts meet a minimum power factor of 0.9 with a maximum of 32% THD. Note at the time of the ANSI standard publication most discharge lighting hard wired ballasts were 28 Watts or greater. The cost of correcting the power factor at this wattage level to ANSI commercial limits was considered acceptable for hard wired electronic ballasts. ANSI C82.77 requires residential hard wired luminaires below 120 Watts meet a minimum power factor of 0.5 with a maximum of 200% THD. ***The ANSI standard acknowledges that low density installations do not have same impact on the VA load and require less power factor and harmonic content control.***

ANSI C82.77 has special allocations for specific applications such as task, down lighting and modular office furniture. For these applications ANSI recommends a minimum power factor of 0.5 with maximum THD of 32% for products below 50 Watts. This gives an allowance for ballasts that have an increased displacement

[3] United Stated Environmental Protection Agency, “Energy Star Building Upgrade Manual”, (2004), Lighting Chapter

[4] American Power Conversion, “Harmonic Currents in the Data Center: A Case Study”, White Paper #38, (2003)

factor. ***By granting this allowance ANSI has permitted lower cost power factor appropriate solutions to be used.***

Another harmonic standard, IEC 61000-3-2[5], sets requirements for lighting equipment as a function of product input wattage. Specifically the IEC standard sets a two level limit on individual harmonics. Individual harmonics are the factors that comprise the distortion factor and impact the over all power factor. The threshold to determine the particular limit applicable is specified by IEC as 25 Watts. ***By setting performance limits based on the product wattage level this standard acknowledges that products with low power levels present less need for power factor and harmonic mitigation.*** For non-lighting products the wattage break point is 75 watts. Note, the limits contained in IEC 61000-3-2 are based upon the specific network characteristics such as line impedance of European 50Hz networks. Individual harmonic limits for some products would be relaxed for 60 Hz networks. IEC has not yet developed limits for products operating on 60 Hz networks

Effective use of Generated Power:

The U.S. Department of Energy (D.O.E.) estimates the U.S. electricity demand will increase from 3821 billion kilowatt-hours in 2005 to 5478 billion kilowatt-hours by the year 2030[6]. Lighting has historically consumed 17% of all electricity sold in the United States[7]. To help curtail the growing demand for additional power generation capacity the D.O.E. and power generation industry has supported a series of demand side management (DSM) programs to entice end users to reduce their overall energy consumption. The lighting industry has supported this movement with a continuous flow of new energy efficient products. The majority of these new energy efficient lighting products require an electronic ballast.

Table 1 highlights an example between a traditional 75 watt incandescent bulb and three types of energy efficient compact fluorescent lamps (CFLs). The VA savings is significant in all cases ranging from approximately 40% in the normal power factor (NPF) case to approximately 70% in the high power factor (HPF) case. However the real Watts consumed is practically identical in the energy efficient products independent of the level of power factor correction. There is no additional energy savings for the end user in going to higher levels of power factor correction.

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[5] International Electrotechnical Commission, “Limits for Harmonic current Emissions”, (2004), Edition 2.2

[6] Energy Information Administration, “Annual Energy Outlook 2007 Early Release”, (2007), Table 8 Electricity Supply, Disposition, Prices, and Emissions

[7] United Stated Environmental Protection Agency, “Energy Star Building Upgrade Manual”, (2004), Lighting Chapter, originally published in e Source, “Lighting Technology Atlas”, (1994), Ch 4

Now consider that the HPF solution may be twice the price of a LPF product to the end user. The incentive for the end user to move to energy efficient lighting is greatly reduced if not eliminated. In order to facilitate market acceptance of energy efficient lighting the product must be kept at price level such that when combined with the realized energy savings in Watts results in a reasonable payback to the end user. Energy efficient lighting cannot help manage the growing energy demand if these barriers are not minimized.

IEC 61000-3-2 by means of its wattage dependent requirements and ANSI C82.77 by means of its load density, wattage dependent and application specific requirements have taken into account the cost impact of the power factor correction circuitry. Cost appropriate power factor correction solutions can be selected for electronic ballasts rated 25 Watts or lower.

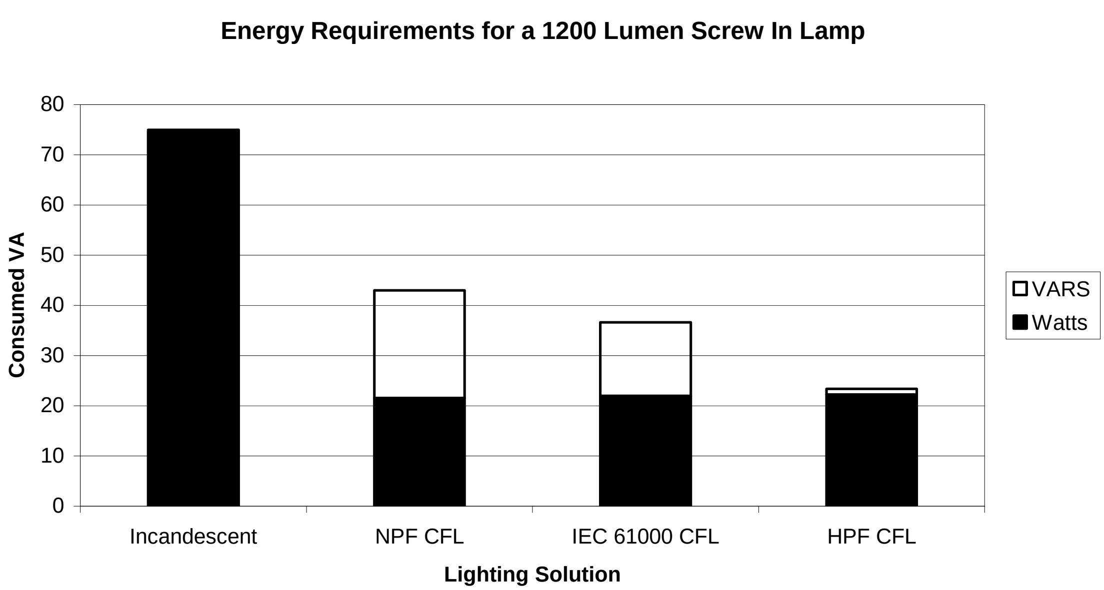

Table 1

Conclusion:

Hard wired GE fluorescent and HID lighting ballasts are designed to voluntarily meet the latest requirements contained in both ANSI C82.77 and IEC 61000-3-2 which contain specific limits on individual harmonic currents that are injected into AC mains. By restricting harmonic content, both ANSI C82.77 and IEC 61000-3-2 have indirectly set limits on THD and Power Factor. Although the United States has not formally adopted either standard as a mandatory requirement, both standards are relevant when considering the power quality implications of hard wired ballast installations.

Both ANSI C82.77 and IEC 61000-3-2 standards acknowledge the concept of permitting normal power factor operation for low power lighting products where the anticipated density is low or where other mitigating factors such as load diversity are typical.