The Inaccuracies of Measuring Energy Efficiency in Watts

Overview

The measurement of energy efficiency needs to go beyond watts. Why?

- The staggering increase in electrical devices with low power factor on the grid will impact efficiency investments
- Harmonic distortion created by devices adds significant costs to the system

This article uses Compact Fluorescent Lamps (CFLs) as a case study for discussion as:

- High power factor (HPF) CFLs increase Volt-Amp savings by 60%, yet the vast majority of CFLs being installed have low power factor
- The sale of inefficient light bulbs will be banned in Canada in 2012
- Ontario's 4.5M homes are installing increasingly larger volumes of CFLs

Background on the Ontario Market

Through promotional efforts by the Ontario Power Authority and individual LDC's, CFLs have become a significant part of Ontario homes. Why? Energy conservation is far more cost effective than building new capacity.

CFLs are one of the most cost effective methods for reducing energy usage. A 77% reduction in energy usage can be achieved by replacing a 100 watt incandescent bulb with a 23 watt CFL, right? Actually, it doesn't.

Unfortunately, standard CFLs have hidden costs that haven't been properly quantified in the electricity sector. We need to assess these costs in energy efficiency programs, starting with power factor.

Why Power Factor?

The power factor of the majority of CFLs is extremely poor.

Power factor describes the efficient use of electricity of a device. Calculated by dividing the watts (W) of an electrical appliance by the Volt-Amps (VA) it draws; it always equals 1 or less. The majority of CFLs sold in the Canadian market have low- or nominal-power factor of approximately 0.55. HPF CFLs, in contrast, have a power factor greater than 0.9[1], which creates significant savings for the utility. To give an example, the calculation for a standard 23W CFL may look like this: 23W / 42VA = 0.55PF. Comparisons are provided in the chart below.

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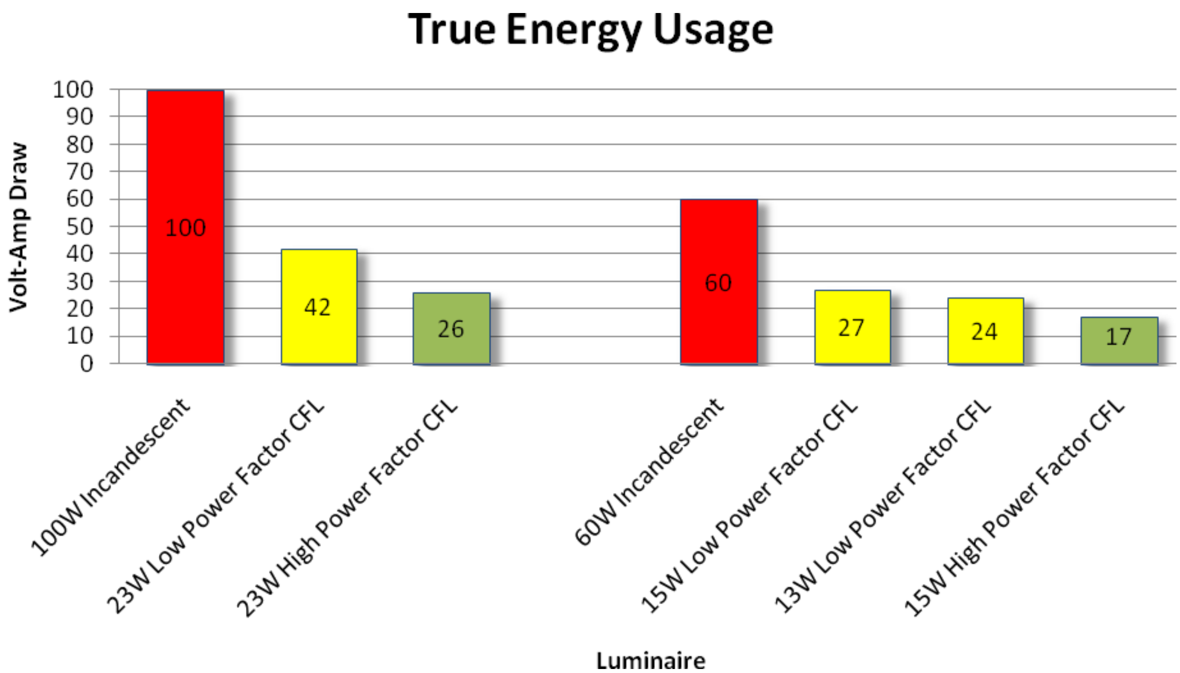
[1] CSA definition



The utility has to supply 42VA of electricity to power the 23W CFL. The unused 19VA is known as reactive power, and cannot be used by an appliance. Not only does the utility need to produce or purchase the additional 19VA of reactive power that it can't charge for, it also needs to ensure that it has adequate infrastructure in place to distribute this power.

And There's More...Harmonics

The low power factor of standard CFLs results in significant Total Harmonic Distortion (THD). This can be as high as 130% on a CFL with a power factor of 0.55. High harmonics result in what is known as 'dirty power', and increases costs within the electricity system. Examples include increased line losses during distribution and reduced life of distribution components, such as transformers, due to increased heat. The THD of HPF CFLs, in contrast, is approximately 30%.

Resulting Total Opportunity Cost

Given the fact that:

- The uptake of CFLs is set to significantly increase, particularly with sale of inefficient light bulbs likely to be eliminated in 2012 in Canada, creating a significant market shift
- The effects of low power factor CFLs won't be seen until it needs to be corrected
- There are very cost effective solutions to these problems, but they need to be implemented now

Since Ontario has approximately 87 million incandescent bulbs[2] installed, we can calculate the following:

Estimated Peak Energy Saving if All Incandescents were Replaced with CFLs, in Watts			
Incandescent	Average bulb load	(60W X 0.85)+(100W X 0.15) = 66W[3]	
	Load for all incandescents	66 X 87,000,000 = 5,742,000,000W	= 5.742GW
	Peak Load discount factor	5.742 X 0.5	= 2.871GW
CFLs	Equivalent CFLs	(15W X 0.85)+(23W X 0.15) = 16.2W	
	Load if all CFLs	16.2 x 87,000,000 = 1,409,400,000W	= 1.409GW
	Peak Load discount factor	1.409 X 0.5	= 0.705GW
	CFL energy saving %	**(2.871 - 0.705) / 2.871**	**= 75%**

True Peak Energy Savings, as Measured in Volt-Amperes			
Incandescents (PF = 1)	VA draw	2.871GW / 1 = 2.871GVA	
Standard CFL (PF = 0.55)	VA draw saving	0.705GW / 0.55 = 1.28GVA	2.871 – 1.28 = 1.591GVA
	VA draw saving, percentage	1.591 / 2.871 = 0.554	= 55%
High power factor CFLs (PF = 0.9)	VA draw saving	0.705GW / 0.9 = 0.78GVA	2.871 – 0.78 = 2.091GVA
	VA draw saving, percentage	2.091 / 2.871 = 0.728	= 73%
Deferred distribution infrastructure investment ($1 million/MVA)[4] with high power factor CFLs		**$1,000,000 X 2,091MVA**	**= $2,091,000,000**

Replacing all of the incandescents in Ontario with high power factor CFLs, peak load could be reduced by 2GVA and would save LDCs $2 billion in distribution system investment.

Solutions – An International Perspective

The simplest way to greatly reduce the hidden costs of low power factor CFLs is to promote the uptake of HPF CFLs.

In New Zealand, the Electricity Commission could foresee that CFLs would be beneficial to the electricity system load. However, it was realised that although CFLs would be beneficial, the hidden costs of low power factor CFLs would eliminate cost savings in the long-run, or even add to overall costs. As a result, the Electricity Commission offered a split subsidy on CFLs, with a higher subsidy paid to HPF CFLs. Energy Mad worked with the Electricity Commission, LDCs and retailers to utilise this subsidy in extremely effective campaigns for residential users. The result is that half of all homes in New Zealand have 5 or more of Energy Mad's HPF CFLs.

Australian utilities are also beginning to invest in the better value proposition of HPF CFLs. In one example, a utility experienced brown-outs as the harmonics created by low power factor CFLs interfered with its ripple control system for Demand Control Programs. HPF CFLs are seen as a way to overcome this issue. Other countries, such as India and Vietnam, are assessing making HPF a requirement for CFLs.

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[2] Ontario Ministry of Energy and Infrastructure, 2007

[3] Assumptions based on NRCan statistics, 2003, wattage of primary and secondary ordinary household light bulb

[4] Price based on Whitby Hydro, 2005, 'Power Factor Correction at the Residential Level – Pilot Project'

Energy Mad will be sponsoring a seminar on power quality at the Marriot Eaton Centre in downtown Toronto on November 12 at 10:00 am, which will delve into more detail on this problem. The keynote speaker is industry expert Roy Hemmingway, former Chairman of the New Zealand Electricity Commission.

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