Future High Efficiency Lighting Trends

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Executive Overview

The drastic increase in the worldwide use of energy and its increasing cost is driving an urgent demand for higher efficiency solutions in all types of energy consumption. High on the list for improvement is lighting. Many solutions are being implemented to increase lighting efficiency. However, most measures are attempting to be backwards compatible with existing wiring architectures. These solutions are not well suited to the demands of high efficiency light sources and generally do not achieve their full efficiency potential. In addition, the drive for backwards compatibility creates problems in other areas such as high conversion costs and increased hazardous and solid waste disposal. Changes in lighting fixtures and the way that power is supplied to them are required if the potential benefits from high efficiency light sources are to be realized. These benefits include lower initial labor and material costs, higher operating efficiency, low maintenance costs, and greatly enhanced operational flexibility in lighting levels, temperature range, distribution patterns, and other optical properties.

Goals

A high efficiency lighting system should achieve the following goals:

1. Assure high efficiency conversion of electrical power to light.
2. Require minimal maintenance over a long service life.
3. Operate efficiently in any temperature conditions.
4. Allow easy user replacement of light sources.
5. Minimize waste disposal problems and cost.
6. Minimize installation labor and material costs.
7. Allow flexibility in light sources within a given fixture.
8. Allow a wide range of dimming to reduce light output without compromising spectral balance or operational life.
9. Provide a high Color Rendering Index (CRI).
10. Utilize an optically efficient shape to facilitate control of light spread in fixtures.
11. Isolate failure in one light system segment from the others.
12. Allow for power on re-lamping for safety and convenience.
13. Allow changes of spectral balance to respond to changes in ambient light balance or to achieve a desired mood.
14. High immunity to physical shock.

15. Immediate light output upon application of power and no re-start time delay if turned off.
16. No explosion risk or high operating pressures.
17. Reduce burn risks from high operating temperatures.

The Most Promising Solution

Of all the current lighting technologies, the Light Emitting Diode (LED) provides the greatest opportunity to meet all of the previously stated goals for high efficiency lighting. None of the incandescent light sources including tungsten halogen lamps can provide efficacy numbers high enough to be considered high efficiency.

Fluorescent and compact fluorescent lamps are good short term solutions because they offer high efficacies. However, they have many drawbacks including:

1. Hazardous material content that presents safety and disposal problems.
2. Poor CRI unless very expensive lamps are used.
3. Poor cold temperature operation.
4. Dimming problems unless expensive ballasts are used.
5. Large physical size in relation to light output making control of light distribution patterns more problematic and retrofitting to existing fixtures limited.
6. Short life when used with low cost dimmers.
7. Poor shock resistance.
8. High per unit shipping and storage costs.

Gas discharge lamps such as HID, mercury, and high and low pressure sodium have many problems such as:

1. High operating temperatures presenting burn risks.
2. Higher than ambient operating pressures resulting in explosion risks.
3. High voltages needed for starting.
4. Cool down times needed before re-starts are possible.
5. Disposal risks because of high pressures and hazardous material content.
6. Except for some HIDs, generally poor CRI.
7. Only fair shock resistance.
8. For a given fixture, lamp choice is very restricted due to power supply characteristics.
9. Power on re-lamping is not possible.
10. Dimming, where possible, is limited.

Only LEDs can meet all of the design goals stated above.

LED Caveats

There are two operating conditions that must be met for LEDs to reach their full potential.

1. **Heat Dissipation.** LEDs are much more efficient than tungsten lamps. They currently require only about 1/7th of the power to achieve an equivalent light output. By 2015, that figure is expect to be 1/10ththe power. However, the minimal heat that is generated by an LED must be dissipated by means of a heat sink. The maximum allowable operating temperature of an LED is a fraction of that allowable for a tungsten lamp. Since LEDs are being retrofitted to existing fixtures not originally designed for them, the heat sink must be part of every lamp and is discarded with the lamp when re-lamping becomes necessary. This is an inherently wasteful design.
2. **Power Requirements.** Unlike tungsten lamps which are somewhat linear in their response to different applied voltages, LEDs along with most other high efficiency light sources are decidedly non-linear. Current mains power architectures in most buildings are essentially constant voltage if dimming is ignored. That works well for tungsten lamps but does not work for any type of high efficiency lighting. The LED is a current responsive device rather than a voltage responsive device. As with all high efficiency light sources, a power supply is necessary for proper operation from mains power. Existing attempts at using LED lamps in a retrofit situation require that each lamp have a built in power supply. This reduces efficiency, increases cost, increases power dissipation, and results in discarding the power supply along with the lamp when re-lamping.

Achieving efficiency and cost savings

To achieve the maximum efficiency and cost savings when using LEDs, they should be operated in a series configuration with all the LEDs in line with each other. This contrasts with the parallel configuration used with traditional tungsten lighting where all the lamps are side by side in the circuit. To achieve this, the lighting wiring should be separated from the power wiring in a building. If this is done, there can be significant cost savings for several reasons:

1. Since the LED is a current responsive device and the maximum voltage for a typical high powered LED is only 3 – 4 volts, many LEDs can be added in line and still have relatively modest demands on the voltage of any power supply. In a series string, no matter how many LEDs are in the string, the current is still the same as if only one LED is used. Therefore, the wiring gauge can be relatively small compared to parallel configurations. For example, using commonly available 3 watt LEDs in a series string results in a current of only 7/10ths of an ampere. The wire gauge could be a very modest #22 resulting in a cost savings of over 90% compared to traditional wiring.

2. In some cases, even with multiple LEDs in a string, the operating voltage may be below the maximum level allowed by the National Electrical Code for classification as low voltage lighting. That will also significantly reduce the cost of wiring as low voltage circuits have far less stringent requirements.
3. Since the configuration requires only one power carrying wire, if the wiring loops are properly configured additional savings will be realized as each socket does not require an additional return wire.

A constant current power supply will be used to power the LEDs thus allowing any number of LEDs to be used in the string at will. Since the LEDs are in series, only one power supply is required for any number of LEDs up to the maximum capability of the power supply. Since the power supply is external to any lamps, it is not discarded during the re-lamping process.

Lamps can be produced with any number of LEDs internally, giving a wide range of light output. Since the wiring is a series configuration using a constant current power supply, different light output lamps can be exchanged in the sockets at will to produce the desired distribution of illumination.

To eliminate waste, the lamps and fixtures can be designed to allow contact with the lamp heat conductor so that the function of heat dissipation is transferred to the socket and fixture which are not discarded during re-lamping. Instead of having the heat sink as part of the lamp, only a small heat conductor is needed in the lamp.

The Solution

It is not unusual for persons who lived in the days of series connected Christmas tree light strings to remember with great disdain having the whole light string go out when one bulb burned out. It was then a tedious job to locate the offending lamp and replace it. That can be a limitation with a series connected light string. However, it is now possible with new solid state electronics to provide the capability to sense any problems with either an LED or connection to the socket and bypass the string current to the remaining LEDs so the string does not go dark. This can be done directly in each socket resulting in a high degree of reliability for a very small cost. This function along with other features is covered in Patent number 8,896,217. Adopting this technology eliminates the outage problems common to serial connected circuits.

Additional Opportunities

The very small physical size and low current demands of LEDs open the door to many new innovative lighting benefits not currently practical with other light sources. Since LED wiring costs are very low, it is feasible to have multiple channels within a given socket. This is similar to a 3-way socket where two channels are provided to extend light output range. In the case of LEDs, multiple channels can be used to provide spectral balance control.

Individual LEDs come in various outputs that provide different color temperatures. They can be combined in the same lamp with individual connections to allow changes in spectral balance. For example, cool white and warm white LEDs can be combined in the same lamp but connected to different channels. By varying the drive level to the individual channels, any output from warm white to cool white can be selected to match a desired mood.

LEDs also come in tri color configurations. Each LED contains a red, green, and blue source. This tri color configuration is the basis for many devices such as a color TVs to provide any color output. If a three channel lamp is created using these LEDs, the user can create any color balance at will. This could have very interesting possibilities such as automatically adjusting inside color balance to match varying outdoor lighting conditions. In retail environments, lighting could be adjusted to match the requirements of the display designer. If there is a display for fall clothing, the lighting can be made dimmer and warmer. If it is a winter scene, the lighting can be made bright and cool. There is no limit to the intensity or color balance available to the designer. Having total control of light intensity and color balance will open up new avenues of creativity in lighting that were never before available…and it will come with the additional benefit of energy efficiency.

Summary

As with any major improvement, for high efficiency lighting to reach its potential a new way of looking at lighting systems must be embraced. Until current building wiring practices are changed, the potential gains from high efficiency lighting will be hobbled. However, once the commitment is made to enhance wiring architecture, techniques can be implemented that will provide significant benefits to ensure buy in by the various parties involved in the lighting process. It will take a thorough understanding of the changes to be made and the benefits that will be realized if this transformation is to be successful.