Dimming LFL Systems
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Introduction
There are many "myths" and misunderstandings regarding dimming linear fluorescent lamps (LFL). This article will discuss several of these, while providing a basic understanding of how components operate and their relationship to one another within a system.

Myths and Misunderstandings
Three of the most common myths and misunderstandings are listed below:

- *Incandescent lamps work in all environments, so fluorescent lamps work in all environments.*
- *Dimming incandescent lamps saves energy, so dimming fluorescent lamps would save energy.*
- *Dimming incandescent lamps extends lamp life, so dimming fluorescent lamps would extend lamp life as well.*

To understand why the above statements are not necessarily true, it is important to understand the different components within a dimming system. Further discussions of the “truths” of these myths are presented at the end of this article.

Components of a System — Lamps
*Lamp Operation Basics*

The basic operation of a LFL is affected by many variables; therefore, it is essential to understand these and what is needed during the application of control methods.

This graphical depiction demonstrates the basic principles of how a linear fluorescent lamp operates. There is a filament at each end of the lamp, also called an electrode, which functions both as a cathode and an anode. This coiled wire electrode, commonly called a cathode, has an oxide coating that is highly emissive. As AC voltage is applied, an arc is struck between the cathodes. The mercury pellet is converted into a low-pressure mercury vapor and when it mixes with the inert fill gasses, UV photons are produced. The phosphor coating on the inside of the glass tube absorbs UV photons and re-radiates the energy as visible light.
**Lamp Life**

For most lamp types, rated lamp life is the length of time of a statistically large sample between first use and the point when 50% of the lamps have failed. It is possible to define “useful life” of a lamp based on practical considerations involving lumen depreciation and color shift. The 20,000 hour mean life rating in a catalog refers to lamps operating at 3 hours per start on RAPID START ballasts. In practice, most (80%) of T8 lamps are operated on INSTANT START ballasts and at 10–16 hours per start. You need to find out rated life on the specific ballast being used, at the specific hours per start at the site. This is almost always different from 20,000 hours.

**Lamp Seasoning**

NEMA (www.NEMA.org) has a paper (LSD-23-2002) commenting on the seasoning of fluorescent lamps. When new fluorescent lamps are installed in a dimming system, some of the lamps may exhibit flicker or other visual instabilities. This condition can be caused by residual impurities that may be present in a new lamp as a result of normal manufacturing processes or affected by initial mercury distribution in a new lamp.

However, NEMA fluorescent lamp manufacturers recommend that lamps should be operated at full output overnight (approximately 12 hours) as a part of the commissioning process whenever visual instabilities become apparent or to avoid the situation with new dimming systems. Overnight seasoning is particularly recommended for optimum initial performance or installations where dimming performance (tracking, stability) is considered critical.

If overnight operation is not practical, operation of the lamps at full output for a few hours should clear up any impurities or allow time for the mercury to distribute, eliminating any visual instability. Turning lamps off a few times in the first days helps the lamp as well. The start-up sequence tends to burn off impurities inside the lamp. Thus, some hard starting lamps become easier to start after the first days.

**Temperature Effects**

The wall temperature affects the light output of linear fluorescent lamps during operation. This, in turn, is a function of the ambient temperature of the air surrounding the lamp. T8 and T12 lamps are designed to provide maximum light output around 25°C ambient (77°F), while T5s have their maximum light output around 35°C (95°F).

There is a distinction between the ambient temperature of the air surrounding the bulb vs. the environment temperature in the room. Suppose we have T8 and T5 fixtures operating in the same room at 25°C environment temperature. The ambient temperature in the T5 fixture will generally be higher than in the T8 fixture; a T5 HO lamp produces twice as much heat as a T8 lamp of the same length. To accommodate this effect, T5 lamps were designed to operate well at a higher ambient temperature.

Fluorescent lamps are harder to start at lower temperatures and require a higher open circuit voltage from the ballast. The minimum starting of the fluorescent lamps; therefore, depends on both the rating of the lamp and of the ballast. Ratings commonly used for lamps are 60F, 50F, 32F, 0F and –20F. 800ma HO and 1500ma VHO lamps are rated for –20F. Full wattage F40T12 and F32T8 are rated to 0F. Watt-Miser® lamps, both T12 and T8, have a 60 degree F, 16 C, minimum temperature rating. All ballasts are marked with the minimum acceptable operating temperature. Since light output changes with temperature, light output testing is done at a standardized ambient temperature of 77 F / 25 C. The temperature environment must be considered when selecting the lamp and ballast combination.
**Components of a System — Ballasts**

**Ballast Operation Basics**

Just as with a variety of lamp choices, there are a variety of ballast choices from which to select. All lamps and ballasts must be matched to create the proper system.

At the bottom left corner, the technology that has recently been prohibited by EPACT, is the T12 magnetic ballast. The replacement ballast for that is the T8 electronic ballast, which has an efficiency in the mid-80s, dedicated voltage, 20% THD. For the most part, this has been in place for many years. The standard electronic ballast is typically an instant start technology. Now, multi-voltage high efficiency instant start or program rapid start ballasts are available.

In addition, GE has a line called Ultra that has other features such as parallel wiring, anti-arcing, anti-striation and low THD.

<table>
<thead>
<tr>
<th>Performance Features</th>
<th>Price</th>
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<tbody>
<tr>
<td>Magnetic T12</td>
<td></td>
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<tr>
<td>• Old technology…</td>
<td></td>
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<tr>
<td>• 82% efficiency</td>
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<tr>
<td>• &lt;30% THD</td>
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**Electronic T8 Ballasts**

| High Efficiency T8  | 91% efficiency |
|                     | <10% THD       |
| Universal Voltage T8| 86% efficiency |
| 108-305 V capable   | <20% THD       |
| Can size varies     | <10% THD       |

**Standard Ballasts**

The following sections describe in more detail the differences in ballast types.

**Rapid Start (RS)** includes dimming systems. Rapid Start is a softer start of the lamp. It provides Cathode power (3.6V AC) to warm up the lamp while applying a lower Open Circuit Voltage (~250V) to start the lamps. The lamp tends to sputter during this start time until enough electrons from the emission mix make it into the arc stream. Rapid Start is good for 20,000 to 30,000 starts. Dimming use is growing, but it still makes up less than 1 percent of the applications today. Rapid Start maintains the Cathode power while operating and thus uses more energy while operating.

**Instant Start (IS)** ballast provides a hard start on the lamps. It does not provide any Cathode power to warm up the lamp. It starts the lamp by providing a high Open Circuit Voltage (450-600V) to drive the arc from one end of the lamp to the other. It is good for 3,000 to 10,000 starts on the lamp and is best used when only starting a couple times per day.
Programmed Rapid Start (PRS) or Program Start is the softest start of the lamp. It applies cathode power (3-6V) to warm up the lamp and then applies the Open Circuit Voltage (450-600V) to start the lamp. It is good for 50,000 to 250,000 starts and it the best choice for switching more than a couple times per day. It is the preferred choice when using Occupancy Sensors. Also, it is good for temperatures down to 0F, just like Instant Start. PRS ballasts are the fastest growing segment in ballast selection.

The GE Programmed Start ballast has Cathode Cutout that removes Cathode power once it is started. This saves energy while operating the lamp.

Dimming Ballasts

It is best to standardize on one dimming ballast manufacturer. There is no true ANSI standard for dimming and all are different. Therefore, dimming ballasts must assume use under all operating conditions, and use ANSI C82.11–2002 For High Frequency Fluorescent Lamp Ballast.

There are two main types of dimming ballasts: Continuous and Switched Level.

Continuous Dimming

Continuous Dimming is accomplished by controlling the amplitude of the current flowing through the lamp via reduction in the lamp power. As lamp power decreases, lamp voltage increases proportionally to maintain heating of the lamp cathodes and prevent the lamp from being extinguished.

Switched Level Dimming

Switched Level Dimming has set percentages of light levels that the ballast will control. Also called "Variable Dimming", the ballast adjusts to a different ballast factor to accomplish the changes or transfers between high and low light levels to provide subtle light changes.

GE Dimming Ballasts

GE offers several options for variable lighting control or dimming: Continuous dimming (100% to 5% and 100% to 60%) and three forms of light level switching (either 100/50%, 100/80/60% or 100/60/30%).

GE has 1, 2, and 3 lamp models with full range dimming from 100% to 5% for 4-foot F32T8 lamps. This V5 ballast is designed for optimal lamp performance in providing positive starting at all dimming levels and by increasing the cathode voltage as lamps dim. This provides for no flicker at all dimming levels. Increasing the cathode heating when dimming to maintain the cathodes proper temperature provides for enhanced lamp life and performance stability. There is no lamp dropout, meaning all lamps remain on at low light levels. Some manufacturers dimming ballast actually drop out or turn off some of the lamps to achieve low light levels.
The GE dimming ballast is controlled by using a 10 – 0 V DC dimmer switch. There is a listing of compatible controls for the V5 ballast in the catalog. Care should be taken to ensure that the line voltage (AC) wires are not connected to the low voltage DC wires. The V5 dimming ballasts have a protection circuit that will sense if the ballast has been connected in this manner to prevent harm to the ballast or the installer. The lamps will dim to the 30% level.

GE does not have a dimming ballast for line voltage control in which low voltage wires are not needed. Line voltage controls limit the amount of current that can pass through the dimmer switch. This allows for only a few fixtures to be connected per circuit. The Total Harmonic Distortion (THD) of the ballast rises when the lamps are dimmed using line voltage control.

**Other Ballast Info**

There are other common aspects of ballasts that play a role in the design of a system. Though there are many, the following will be discussed: Ballast Factor, Total Harmonic Distortion and Temperature Affects.

**Ballast Factor — Light Output from a lamp and ballast system.**

Ballast factor (BF) used to be referred to as “relative light output.” It is expressed as a percent of the light output of a lamp. A general rule is: the higher the ballast factor, the higher the lumen output and the higher the energy consumption. The reverse is also true: the lower the ballast factor, the lower the light output and the lower the energy consumption. The range of 0.6 to 1.2 is considered a safe operational range.

Ballasts may have different ballast factors for different lamps. For example, a two-lamp ballast with an .88BF is applicable on the primary F32T8 lamp. The ballast can also operate the F25T8 and the F17T8. On the F25T8, the ballast factor is .90BF. On the F17T8, the ballast factor is .93BF.

**Total Harmonic Distortion (THD)**

THD refers to Total Harmonic Distortion. Harmonic distortion is present with most electrical equipment. THD is the measurement of the distortion created from the equipment’s current draw. True resistive loads, such as an incandescent light bulb, do not have THD. Equipment that contains switch mode power supplies, such as motors, drives, fluorescent lighting and HID lighting, has some measure of THD.

It is a common misconception that electronic ballasts increase THD. Electronic ballasts actually decrease the THD on an electrical system. ANSI C82.11 requires that the maximum THD of electronic ballasts not exceed 32% and the maximum triplets not exceed 30%. Electronic ballasts today are rated less than 20%, 15%, or less than 10% THD. The magnetic ballast is rated in the 20 to 28% range. ANSI C82.11 states the line voltage should be measured at less than 3% VOLTAGE Total Harmonic Distortion.

**Temperature Affects**

Lamps and ballasts each have minimum starting temperatures. The temperature rating of the ballast can change depending on the lamp. Fluorescent lamps are inherently more difficult to start at low temperatures. All ballasts have limitations as to their ability to start lamps at low ambient temperatures. The low starting point for each lamp/ballast combination appears in the GE Ballast Catalog in the column marked “Minimum Starting Temperature.”

High temperature affects ballasts by reducing its life. The general rule of thumb is reducing by 10C can double the life of the ballast.
Dimming Control Basics

Dimming Methods/Interfaces & Protocols

The two primary dimming methods are analog and digital. Analog has long been the established method and is more familiar in the industry. Therefore, there is a wider range of compatibility with control mechanisms and it is also a lower cost option.

Analog

The analog method performs several functions, including:

- Ballast output to control the lamp
- Power factor correction
- Electromagnetic interference (EMI) filtering
- Rectification

In addition, local and central points of control signal communications can be networked to the ballasts.

0-10V DC Four-Wire Control

This is the most popular analog method used today. At 10VDC, full light output is achieved. Decreasing the voltage decreases the light output.

This method uses two line-voltage leads, hot and neutral, plus two low-voltage controls wires. The line-voltage wires power the ballast and low-voltage wires control the light levels.

For the Class 1, the same raceway may be used for all four wires if the voltage ratings are the same. In Class 2, the controls wires will be in a separate raceway.

Two-Wire Phase Control

Two-wire Phase Control cuts out part of the signal by taking the zero crossing point of the AC power supply’s signal and presetting the time the current is turned on. This is approximately half of the waveform (0 to 8.3 milliseconds). This method is also called two-wire dimming, AC dimming or phase chop dimming, as dimming results from the part of the AC cycle being cut out.

Phase-control ballasts use the same two line-voltage leads for both power and ballast control. The ballast receives the dimming signal through the dimmed hot wire connected to the power line.

Because the standard wiring configuration is utilized, phase-control dimming ballasts represent a lower-cost dimming solution, typically found in architectural dimming applications such as conference rooms, boardrooms and individual offices. It is also ideally suited to retrofits, stand-alone applications and cost-sensitive projects. In addition, the control signals are less sensitive to interference than low-voltage analog signals.

Three-Wire Phase Control

In addition to hot and neutral, a third wire is used to carry the control signal to the ballast. These wires are Class 1 rated and are running in the same conduit. This method is typically used on magnetic dimming
ballasts.

Digital
The digital method performs several functions similar to the analog method mentioned above. In addition, there is a micro-controller, which performs the function of storing digital inputs, such as ballast addresses. The digital method allows the ballasts to have individual addresses and allows for zones or groups of ballasts. Status information is sent by the micro-controller and signals from the control device(s) are received through the micro-controller. The sending and receiving of information allows the user to set various lighting scenes, which are flexible over time.

Methods/Interface
Class 1-rated 5-conductor cable that uses one hot (live), one neutral, one ground and two polarity-insensitive control wires, all routed together in the same conduit, are recommended.

In Class 2 installations, control wires must be routed through separate conduit from power wires. Verify product classifications with the manufacturer.

Wireless Infrared Control
An IR transmitter is the control mechanism and no other additional wires are needed. The dimming mechanism is part of the ballast or the luminaire.

Industry Standards & Practices
Control
For the entertainment industry, an ANSI standard exists for 01-10V DC control, though not applicable to dimming ballasts. As a result, there is currently no ANSI standard for the analog method. This creates potential compatibility and performance issues between the ballast equipment and the control equipment.

Part of Europe’s IEC Standard 60929, provides a standard for the digital method. Digital Addressable Lighting Interface (DALI) ensures performance and compatibility between products.

Dimming Issues
Returning to the common myths and misunderstandings, all of the components are complex and when put together into a system, it is imperative to match the proper components together.

Myth #1
*Incandescent lamps work in all environments, so fluorescent lamps work in all environments.*

TRUTH
- Incandescent lamps (and HID) are not temperature sensitive
- LFL are temperature sensitive and also are dependent upon fixture

Myth #2
Dimming incandescent lamps save energy, so dimming fluorescent lamps would save energy.

TRUTH

- Yes, variable and step dimming methods do save energy but there are other ways to save energy on LFL systems. An example of this is to use dimming controls, such as bi-level switching, where the inboard lamps are switched separate from the outboard lamps.
- Also, dimming ballasts traditionally start out at higher wattage consumption than standard or high efficiency ballasts.

Myth #3

Dimming incandescent lamps extends lamp life, so dimming fluorescent would extend lamp life as well.

TRUTH

- Life is not necessarily extended, as the cathode heat must be maintained for the lamp to operate as specified.
  - NEMA has completed an entire study dedicated to this aspect of dimming LFL.

Troubleshooting Dimming Fluorescent Systems

Lamp Failures

Proper electrode heating is the biggest culprit. This may happen for a variety of reasons:

- Lamps must be seated properly in both sockets to make the proper electrical contact.
- The ballast and dimming control are incompatible and are not providing the proper cathode heat.

Ballast Failures

Check the temperature of the ballast case. If it is cold, then the ballast is not receiving power (not energized).

Dimming System Failures

Typically, the wiring of the system was improperly done.
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GE Consumer and Industrial, Lighting Institute Resources