Dimming Ballasts: As Good as We Think?

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ABSTRACT

Changes in Title-24 (California's building code) regularly update the minimum requirements for light fixture dimming, which, in turn, improve the rigor of energy efficiency lighting control strategies. The 2014 update to the building code calls for requirements for light fixture dimming controls (CEC 2013). Dimming controls are used where the space has varying light level requirements and can be periodically dimmed to save energy. Dimming strategies include daylight harvesting, occupancy dimming, task tuning, and demand response. Experts in the industry have assumed the power such fixtures consume is linear with dimming levels – that is, as the ballasts dim the lights, energy consumption decreases apace.

Experts expect this linear relationship because light output vs control signal curves are well documented and are linear, but the less published power vs control signal curve is not always linear. It is desirable for the power vs control signal profile to be linear because then you know how much you are saving and a linear fit is the most efficient power profile for dimming. The Sacramento Municipal Utility District (SMUD) came face to face with the non-linearity problem during an advanced control lighting project study at Intel (SMUD 2013) when the evaluator's ex-post measurements did not verify a rigorous ex-ante effort on the part of the implementer. The savings discrepancy prompted another study (SMUD 2013) to investigate the less published power vs control signal performance curves for products across the market. The market studies research team relied on manufacturer sources, including interviews with product engineers and various request for the specification sheets. The final results uncovered that regardless of what the performance curve is, you need to know your system and make adjustments to control set points to take full advantage energy savings potential.

Introduction

Adoption of dimming ballasts for fluorescent lighting has steadily increased since they were introduced to the market, and their use has increased substantially after the update of California's Title 24 building code was released in January 2014. Dimming ballasts are incorporated into the following four types of lighting control strategies:

- **Daylight Harvesting** combines daylight and electric lighting to meet building lighting needs. The total amount of light in a space is constantly measured and the electric light levels are adjusted to meet the predetermined illumination level.
- **Occupancy Controls** dim lighting through the use of occupancy sensors. This strategy is used when completely turning off the lights during business hours may not be acceptable, such as lighting in corridors, stairwells, offices, warehouses, and assembly areas.
- **Task Tuning** allows end users to customize the desired illumination levels. These systems are typically used in large open floor plan cubicle offices and other spaces where the delivered illumination levels are higher than necessary.
- **Demand Response** ballasts use dimming functions to lower the light levels during peak hours upon request from the local utility. These ballasts generally can be controlled remotely via the Internet and may be connected with control systems that accept open automated demand response (OpenADR) protocols.

Our first involvement with dimming ballasts began during an advanced lighting controls project at Intel (SMUD 2013). The implementer had conducted a rigorous ex-ante calculation, but the evaluator measured the savings at about 5% less. While digging to see where the 5% savings went missing, SMUD took power measurements on a single fixture as it was dimmed and noticed the power at 80% light output and at 70% light output levels was about equal. After some more investigation we found that the ballast installed incorporates a two-step heated filament where the input filament heating voltage can be set to the low setting at full light output settings. As the ballast dims to lower light levels, it reaches a point where the required voltage to heat the lamp filament is not met. The ballast then switches to the high filament heating voltage setting, which is applied for the remainder of the curve (Figure 1).

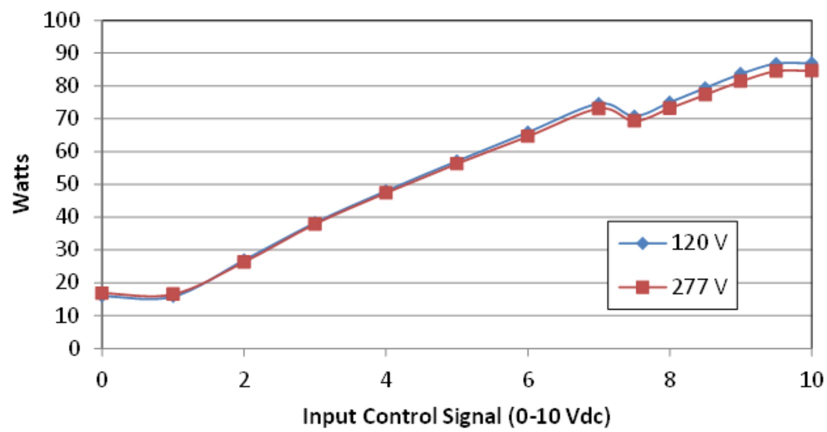

Figure 1. Dimming Ballast with Two Step Heated Filament Power vs Control Signal

We based ex-ante savings calculations on taking the percent light output as the ratio of power input for the various control signal settings. As shown in Figure 2, the light output vs control signal curve does not have the two step heated filament discontinuity.

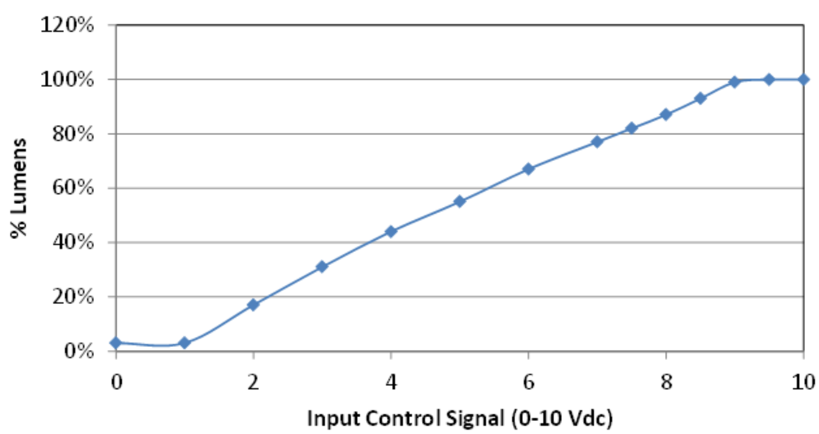

Figure 2. Dimming Ballast with Two Step Heated Filament Light Output vs Control Signal

After encountering this difference, we wanted to know how often this mistake is bound to be made. Is this the only product whose power vs control signal curve does not follow the light output vs control signal curve? To answer this question we initiated a product study.

Methodology

This product study was bound by multiple criteria to determine the market sample that best represented products that are similar to the ballasts installed at the Intel project. We wanted to know on a broader scale if, when using similar products, similar ballast performance differences were likely to occur.

Our first criterion was to include only continuous dimming ballasts since the ballasts for the Intel project were continuous dimming ballasts.

Our second criterion was that the dimming ballasts must utilize 0-10 Volt direct current (Vdc) controls. There are two branches of dimming ballast controls; 0-10Vdc and digital controls. We only looked at 0-10Vdc because digitally controlled dimming ballasts have a power vs control signal standard which prevents the problem that we encountered. Within 0-10Vdc controls a couple of wiring options exist, including two-wire, three-wire, and four-wire. We selected the four-wire option because the Intel project used that type of wiring. It is also the most applicable wiring option because the light level input signal can be provided by any type of control system. A wiring diagram of a four-wire ballast is provided in Figure 3.

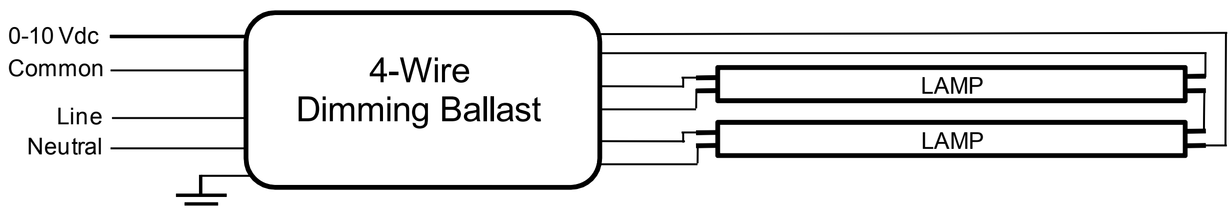

Figure 3. Wiring Diagram of Four-Wire Dimming Ballast

The third and fourth criteria we used were that the ballasts must be compatible with either 25W or 32W 4ft T8 fluorescent lamps, and they must be designed to operate with either 2-lamp or 3-lamp configurations. These criteria limited this research to ballast categories that encompass the largest portion of the market without selecting too many product types.

Thus, ballasts used for this performance comparison study have the following characteristics:

1. Full range continuous dimming
2. Four-wire controls (0-10 Vdc)
3. Compatible with 4 ft. T8 fluorescent lamps (25 W and 32 W)
4. Designed to operate 2-lamps or 3-lamps

With these criteria, we did literature research to identify a list of target products for which we wanted to acquire power vs control signal curves. We then built a network of contacts with each company that allowed us to engage in conversations about dimming ballast specifications; especially the unpublished power vs control factor specifications.

Products Evaluated

We were ultimately successful in obtaining information on a total of twelve products between four different companies.

Table 1 shows the products meeting the ballast selection criteria for each of the four companies (A, B, C, D) that were used in this study. Company A has multiple product options with different ballast factors. Ballast factor (BF) is the ratio of the lumen output of a fluorescent lamp for the evaluated ballast compared to the lumen output of the lamp on a reference ballast. The other companies did not have multiple products with different ballast factors.

Table 1. Product List

	Model	Dimming Range	Watts	# of Lamps	Voltage	Additional Options
Company A	1	100%-3%	32 W	2	120-277	Normal Ballast Factor
	2	100%-3%	32 W	2	120-277	High Ballast Factor
	3	100%-3%	32 W	3	120-277	Normal Ballast Factor
	4	100%-3%	32 W	3	120-277	High Ballast Factor
Company B	5	100%-5%	25 W 32 W	2	120-277	
	6	100%-5%	25 W 32 W	3	120-277	
Company C	7	100%-5%	32 W	2	120-277	
	8	100%-5%	32 W	3	120-277	
Company D	9	100%-3%	32 W	2	120-277	
	10	100%-5%	32 W	2	120-277	
	11	100%-5%	32 W	3	120	
	12	100%-5%	32 W	3	277	

Results

The results are split into two figures, one showing 2-lamp fixtures (Figure 4) and one showing 3-lamp fixtures (Figure 5). The normal ballast factor model from company A is the product that was used in the Intel project (Figure 4**)**. Company A is the only manufacturer using the two step method of filament heating, and it shows in both their normal and high ballast factor models. The normal ballast factor model shows the increase in power as the control signal drops from 7.5Vdc to 7Vdc. The high ballast factor model has a deadband where there is no drop in power as the control signal drops from 6Vdc to 5Vdc.

We have additional observations around the lower ends and higher ends of the spectrum. We expect to see deadbands around the lower ends, most notable on 2-lamp models from companies C and D (Figure 4). These lower end deadbands are not in as wide of a control voltage range for the 3-lamp models in Figure 5**.** We did not expect deadbands at the higher range of the control spectrum as seen from company B's 2-Lamp and 3-Lamp models in Figure 4 and Figure 5**.** For instance, the 2-Lamp does not have a reduction in power as the control signal is decreased from 10Vdc to 8Vdc, and the power reduction at 7.5Vdc is small. The 3-Lamp variation is less dramatic but follows a similar pattern.

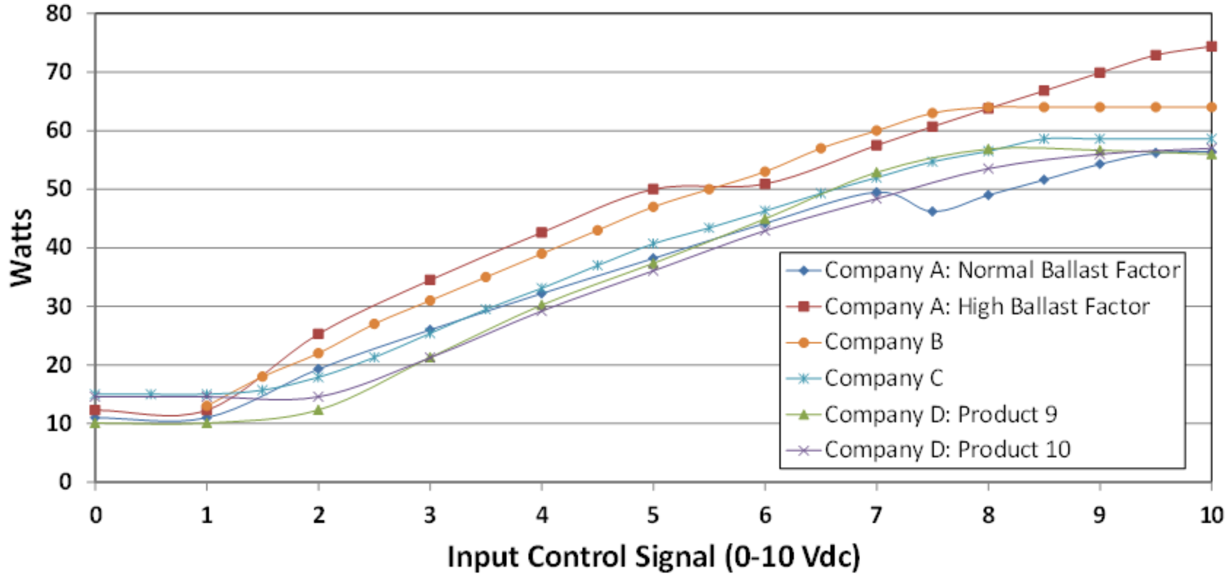

Figure 4. Dimming Ballast Summary: 2-Lamp

Company D only has one plot for 3-Lamp ballasts because they claim equal ballast performance for both 120 V and 277 V models (Figure 5**)**.

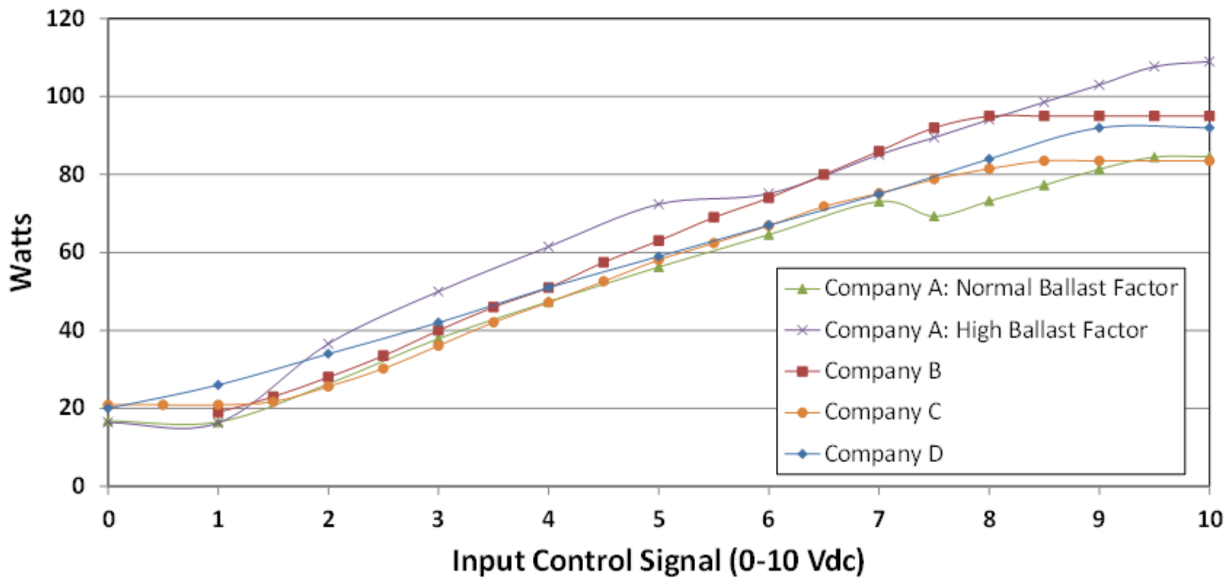

Figure 5. Dimming Ballast Summary: 3-Lamp

Conclusion

As a result of the Intel study (SMUD 2013) we asked the question; does Company A make the only ballast whose power vs control signal curve does not follow the light output vs control signal curve? The answer is no, there are multiple profile differences from multiple manufacturers that can cause lost savings potential. In the case of the Intel project, the implementer was able to reclaim savings by adjusting the task changing set point to 7.5Vdc instead of 7Vdc. For company B, implementers will need to be careful not to anticipate generating savings from a control signal reduction from 10Vdc to 8Vdc, as power is not reduced until the control signal is reduced past 8Vdc. These differences will not make or break a project but can be avoided with full knowledge of the system specifications and using that information to avoid system deadbands. The take home message from this study; know your system!

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