Demonstration of Controllable High Bay Lighting in a Warehouse

EPRI and the Tennessee Valley Authority (TVA) demonstrated three commercial technologies at four sites in Energy Efficiency Demonstration 2.0. This demonstration was of a controllable induction high bay lighting system in a warehouse in Tennessee. Energy Efficiency Demonstration 2.0 focused on commercial customer applications where significant energy savings could be achieved.

Background

Illuminating large open spaces with ceiling lights higher than standard offices and rooms is typically categorized as bay lighting. Common bay lighting applications are warehouses, manufacturing facilities and big box retail establishments. High bay lighting refers to lighting above 25 feet. Bay lighting applications typically use High Intensity Discharge (HID), standard or High Output (HO) fluorescent lighting. HID sources are the most commonly used and HID bay lighting is roughly 10% of the total energy used for lighting annually.

EPRI has been evaluating the equivalence and use of plasma, light emitting diode (LED) and induction lighting as replacements for HID and fluorescent technologies in the bay lighting market space. Research by EPRI and others has shown that these alternative lighting solutions offer energy savings of 30-70% over HID and fluorescent products depending on the wattage, product and application considered.

Induction lighting is an older lighting technology, but recent advancements have allowed it to expand to higher wattages than previously possible. An induction high bay fixture typically includes an external electronic ballast that produces high frequency alternating current that inductively stimulates mercury vapor inside a circular fluorescent lamp. (see Figure 1).

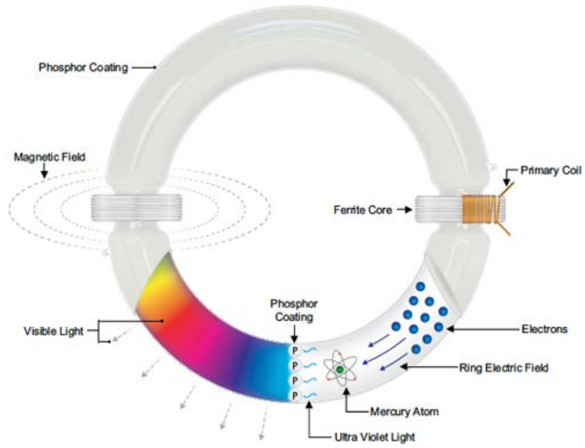

Figure 1. Schematic of induction lighting technology operation

Unlike HID technologies, induction is an instant-on technology, so there is light the instant that power is applied. Induction is also capable of instant restrike so it can be restarted immediately if the lamp loses power. Induction lamps are rated for 100,000 hours of life, although the induction ballast lifetime is typically 50,000 hours. If the fixture was left untouched for 50,000 hours it would quadruple the amount of time before maintenance was required compared to the current maintenance schedule for the HID fixtures.

Demonstration Overview

This study was a demonstration of a controllable induction high bay lighting system to determine the effectiveness of the integrated control system at delivering lasting energy savings. The demonstration site was a large warehouse located at the

Knoxville Utility Board in Knoxville, TN that housed utility transformers and contained approximately 54 lights.

Twenty non-networked metal halide lights were replaced with 20 dimmable 400-watt induction lights. Figure 2 shows a close-up photograph of an induction fixture and an HID fixture.

Figure 2. Photo of induction fixture (right) and HID fixture (left)

Half of the fixtures were installed in the central bay with 40-foot ceilings and the other half were in a side wing with 30-foot ceilings. The technology included a wired network connection that enabled individual fixture communication and controllability via motion and daylight sensors. The networked control scheme was hardwired so that the fixtures could be programmed and monitored for maximum energy savings. The demonstration began with baseline illuminance measurements of the existing lighting to evaluate the change in light levels resulting from the switch in lighting technologies. A separate monitoring system was then installed to collect energy data. The demonstration ran for approximately two years.

Results

Once the induction lights were installed, the high color temperature of the induction lights was immediately apparent when compared to the remaining HID lights (see Figure 2). In addition, while the HID lights had a distinct buzzing noise, the induction lights had no audible sound.

Figure 3. Photo showing shift in color temperature

The primary focus of the demonstration was to test the ability of the integrated control system to deliver additional energy savings. The demonstration consisted of three control configurations:

A: Induction fixtures controlled by breakers in ON/OFF fashion

B: Induction fixtures controlled by scheduling with manual override possible

C: Induction features controlled by sensor inputs and scheduling

A series of measurements were taken to gather illuminance measurements. Baseline measurements were taken immediately after the induction lights were installed. Measurements were taken after the induction lights had been operating for 100 hours and after 6 months. After six months, there was a noticeable decline in illuminance but the occupants remained satisfied with the lighting levels. Measurements taken at the beginning of control configuration C showed a further decline in the illuminance of the induction features. A final illuminance measurement taken about one year later showed further declines in illuminance, although the occupants were still satisfied with the light levels.

In control configuration A, the differences in lamp consumption for the HID vs. induction lights was monitored. The lamps were controlled with ON/OFF switches. The 9

HID lamps that were monitored consumed 20 kilowatt hours (kWh) more per day than the 20 induction lights. The induction lights on average provided energy savings of 63% per fixture.

Control configuration B consisted of running an automatic daily schedule on the induction circuit while the HID circuit was controlled by a switch. The programming was enabled by a tablet connected to the fixtures communication loop via Ethernet. The three breakers that controlled the induction lights in control configuration A were disabled by taping over the switches with duct tape. Because the breakers were covered, the warehouse workers left on the HID circuits continuously throughout control configuration B. This resulted in total collected energy savings that were likely higher than would be experienced in most retrofit installations. The research team believe that the energy savings of 63% per fixture measured during control configuration A would be similar to the energy savings in control configuration B if the workers would have cycled the lights.

Control configuration C continued the automated schedule for the induction lights but added daylighting controls and motion sensors for the central bay, but not the side wing. Figure 4 shows the dimming results throughout the day. Several times a day, clouds caused the lamps to spike back up to compensate for reduced daylight. The level of demand savings averaged about 1 kW.

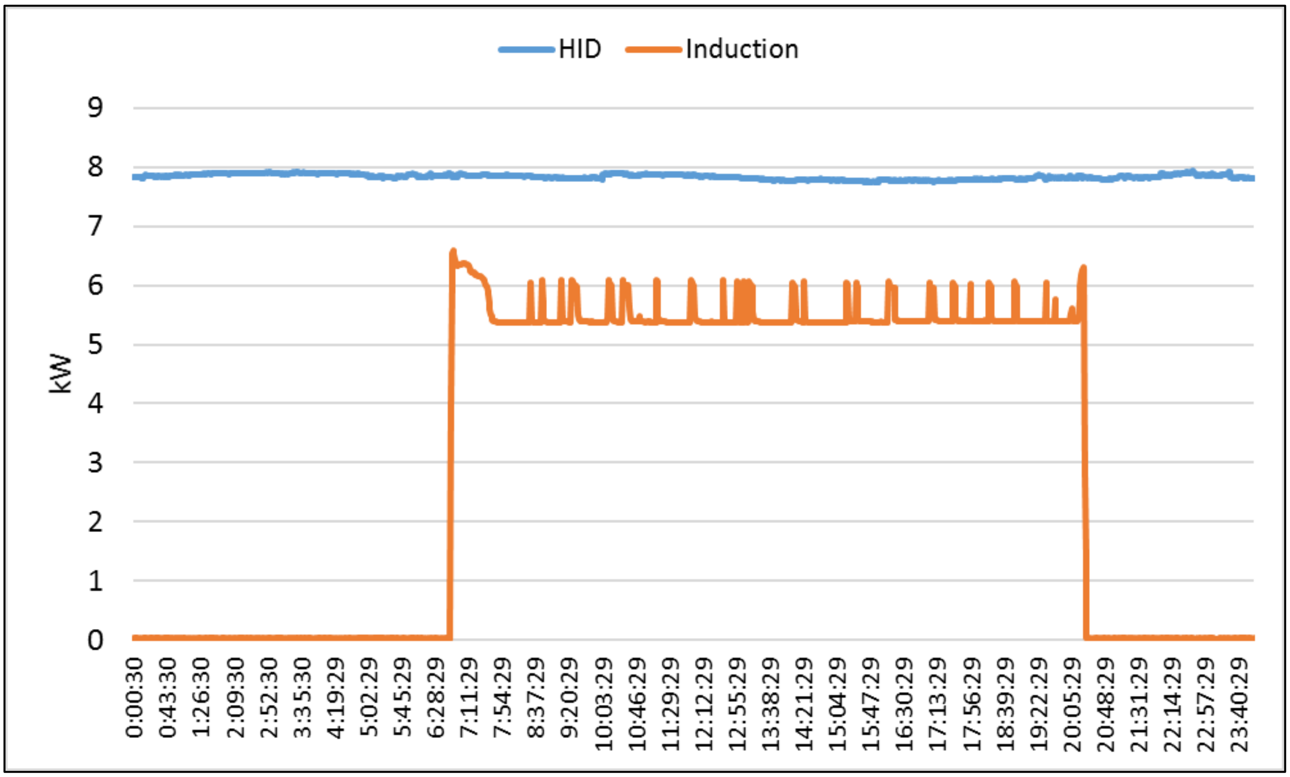

Figure 4. Control configuration C when operating with scheduling and daylight sensors

The situation with the HID circuit breakers being covered with duct tape continued in control configuration C. As in control configuration B, the collected total energy savings was likely higher than would be experienced in most retrofit installations. However, noticeable energy savings would have still occurred had the HID fixtures been cycled as they had been historically.

Summary

Data collected by EPRI during all three control configurations showed notable energy savings between the HID and induction circuits, although these collected savings may be higher than would normally be experienced in retrofits since the HID circuits remained energized throughout control configurations B and C. Feedback from the warehouse workers also indicated that the induction lights provided sufficient light levels.

Overall the demonstration showed that energy savings of 60-70% are attainable through the combination of advanced lighting technologies and networked controls. Although the total savings percent will vary based on applications, noticeable savings are possible. Warehouse applications like the one in this demonstration have the potential to achieve consistent, reliable energy savings results when combining daylighting sensors with dimmable, efficient lighting technologies such as induction lighting.

One of the major findings was that having a schedule for the lights eliminated the times that the lights were left on overnight or on weekends when the warehouse was unoccupied. In contrast, the HID lights were constantly left on. This led to significant energy savings on the order of 50%. In addition, energy savings can be achieved by dimming the lights in direct response to incoming sunlight, although users must be trained to adjust the lighting levels.

Table 1 shows the adjusted energy savings using control configuration A as a baseline. The table shows significant energy savings for the induction fixtures compared to the HID fixtures as well as the energy savings that resulted from the use of scheduling and daylight sensors. These savings were achieved for both control configuration B and control configuration C.

Table 1. Energy savings using control configuration A as a baseline

	Control Configuration	
	B	**C**
Total savings per fixture	68.3%	69.9%
Savings per fixture using scheduling/daylight sensors	4.8%	6.4%

Further Information

*Energy Efficiency Demonstration 2.0: Results of Four Demonstration of Three Commercial Technologies (*3002009947).

Energy Efficiency Demonstration Final Report (1025437) and *Energy Efficiency Demonstration: Executive Summary* (1025438).

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