JOINT TRANSPORTATION RESEARCH PROGRAM

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Cost- and Energy-Efficient (LED, Induction and Plasma) Roadway Lighting

Introduction

The Indiana Department of Transportation (INDOT) is getting a lot of interest from vendors pushing the new lighting technologies, such as light emitting diode (LED), induction, and plasma light sources, for roadway lighting applications. Before adopting the new lighting technologies, INDOT needs to determine if the new lighting technologies meet required light output and if they are cost effective. Moreover, it is necessary for INDOT to establish standardized guidelines for evaluating the new lighting systems.

Surveys were conducted to identify the perceptions of state departments of transportation (DOTs) and local cities towards the new lighting technologies and their experiences in use of the new lighting technologies. High pressure sodium (HPS) HPS, LED, plasma, and induction luminaires were evaluated for both conventional and high mast lightings. Illuminance measurements were made to determine the light performance with the existing lighting infrastructures. Electric currents were measured to determine the energy consumptions. Life cycle costs were computed to determine the cost-effectiveness and payback periods for the new lighting luminaires.

Findings

Roadway Lighting Surveys

LED lighting technology is probably the most attractive new lighting technology for DOTs, followed by the induction lighting technology. Local cities seem very receptive to new lighting technologies and are also more attractive to LED lighting than to induction and plasma lighting technologies.

The main reasons for DOTs and local cities to adopt new lighting technologies include maintenance saving, energy saving, and better light performance. Federal grants have also played a role for local cities. The main barriers for DOTs to adopt the new lighting technologies are the concerns about light level, luminous efficacy and savings unconvincing.

The average service life expected by DOTs is approximately 13, 15, and 10 years for LED, induction, and plasma lighting, respectively. The average life cycle cost (LCC) is approximately \$80, \$70, and \$122 for LED, induction, and plasma lighting, respectively. Induction lighting was perceived to have the longest service life and the plasma lighting to have the greatest LCC.

In use of the new lighting technologies by DOTs, the main issues include light performance, electronic driver, and surge protection. Early failures were observed for induction luminaires. Issues also arose with the installation, particularly with use of the existing poles. Many DOTs are looking forward to some kind of national guidance from AASHTO or FHWA. Several DOTs are in the process of developing LED lighting specifications.

Field Installation

For Phillips RVM LED, every aspect was user friendly. The fixtures are lighter and easier to hold and level. For GE ERS4 LED, the fixtures are a

solid unit and the internal access was user friendly. For Stray Light Tesla II plasma, the fixtures were easy to install and level. The electrical connections are also very user friendly and easy to access. For EcoLuminator induction, the fixtures were heavier and difficult to install. The terminal block was difficult to access.

Light Distribution

In conventional lighting, All LED, plasma, and induction luminaires produced measureable illuminance. HPS, GE LED and Philips LED luminaires produced oval-shaped lighted areas and the Horner LED and EcoLuminator induction luminaires produced circular lighted areas. The illuminance measurements demonstrated a double-hump distribution for the GE LED luminaires and a single hump distribution for all other new luminaires. Compared to HPS 250W luminaires, the GE LED 258W luminaires were capable of producing a larger lighted area and the Philips LED 270W luminaires were capable of producing an equivalent lighted area in terms of the area size. The areas lighted by the Horner LED 200W and EcoLuminator induction 200W luminaires were both smaller than the areas lighted by the HPS 250W luminaire. The areas lighted by the HPS 400W luminaires are greater than those lighted by all LED luminaires and the plasma 295W luminaires. In high mast lighting, both HPS 1000W and SoLtice 392W LED luminaires produced a symmetrically lighted, circular area covered with illuminance measurements 100% greater than 0.20 foot-candles.

Illuminance Metrics

Compared to HPS 250W luminaires, GE 258W and Philips 270W LED luminaires produced similar minimum illuminances, and Horner LED and EcoLuminator induction 200W luminaires produced smaller minimum illuminances. The maximum illuminances produced by all LED and induction luminaires are greater than those by HPS 250W luminaires. The GE LED produced the greatest average illuminance and the Horner LED produced the smallest average illuminance. The average illuminance produced by the Philips LED is close to that by the HPS luminaires. The illuminance uniformity ratio produced by Philips LED is close to that by the HPS 250W luminaire. The illuminance uniformity ratio produced by the GE LED luminaires is greater than that by the HPS 250W. The illuminance uniformity ratios produced by both the Horner LED and EcoLuminator induction luminaires are much greater than those produced by the GE LED, Philips LED and HPS luminaires.

Compared to HPS 400W luminaires, both LED and plasma luminaires produced smaller minimum, maximum and average illuminance values. The illuminance uniformity ratios produced by the LED and plasma luminaires are greater than those by the HPS luminaires. Both GE and Philips LED luminaires produced greater average illuminance and smaller illuminance ratio values than the Horner LED and Stray Light plasma luminaires.

For high mast lighting, the SoLtice 392 E LED luminaires produced smaller illuminance levels but better uniformity than the HPS 1000W luminaires.

The rankings through field observations by the SAC members agreed well with the field illuminance measurements and indicated that the new

lighting sources produced sufficient light levels and GE and Philips provided better light performance in terms of light level and uniformity.

Power Metrics

The measured electric currents for LED, plasma and induction luminaires varied around 1.0 A, regardless of the lamp watts, and are less than the electric currents for not only the HPS 400W luminaires, but the HPS 250W luminaires as well. For high mast lighting, the electric currents for the LED 392W luminaires are much less than those for the HPS 1000W luminaires.

Compared to the HPS 250W luminaires, the calculated energy saving is 12% to 20% for LED luminaires, 12% for the 295W plasma luminaire, and up to 25% for the 200W induction luminaire. Notice that the GE LED, Philips and Stray Light plasma luminaire sizes are all greater than the HPS 250W luminaire. Compared to the HPS 400W luminaires, the energy savings produced by the new luminaires varied between 44% and 52%. For high mast lighting, the energy consumed by the SoLtice LED 392W luminaires is 70% much less than the by the HPS 1000W luminaires.

Life Cycle Costs

The lower life cycle costs of the alternative lighting devices are attributed to their relatively lower electricity usages and longer lamp/emitter replacement cycles. All of the alternative new luminaires, including LED, plasma, and induction, are more cost effective than the existing 400W HPS lights under various discount rates and lamp replacement cycles. In comparison with the existing 250W HPS lights, only the 200W induction luminaire among the six alternative lighting devices is more cost effective. For high mast lighting, the 392W LED luminaires are more cost effective than the 1000W HPS luminaires. With the huge difference in electricity usages between the 392W LED and 1000W HPS luminaires, the LED luminaires will break even within 4 years.

The discount rate and the lamp/emitter replacement cycle affect the life cycle costs as well as the return periods as shown in this study. An MS Excel based worksheet, INDOT Lighting LCCA, has been developed in this study. The software makes it easy for INDOT engineers to perform life cycle cost analysis. The software can be used beyond this study by INDOT to conduct life cycle cost analysis for new lighting systems. It is recommended that the software be used to conduct thorough cost evaluations for possible new lighting systems in addition to other types of field evaluation.

Implementation

It is recommended that GE 258W, Philips 270W, and Horner 200W LED luminaires may be used to replace the HPS 250W luminaires with the existing lighting poles. The GE 258W and Philips 270W LED luminaires may also be used to replace the HPS 400W luminaires.

It is recommended that the Stray Light plasma 295W luminaires plasma may be used in lighting applications for minor streets, residential areas, and parks. However, special care should be exercised about the quality of luminaire products to avoid early failure and lighting layout to produce satisfactory light performance.

While the induction lighting has the potential to achieve great energy savings, its early failures make induction lighting not live up to expectations. It is recommended that at present, more field evaluation is needed.

It is recommended that the SoLtice LED 392W luminaires may be used to replace the HPS 1000W luminaires in high mast lightings with the existing lighting poles.

It is recommended that the further efforts should be made by manufacturers to enhance the light uniformity for roadway lighting applications with the existing lighting poles.

There is no urgent need to change the lighting design criteria at present to adopt the new lighting technologies for roadway lighting applications. Field application data on the long term performance and reliability is still needed for future revision of the design criteria for the new lighting technologies.

Early indications are that the new lighting sources are inherently energy-saving, particularly for high mast (area) lightings.

Manufacturers shall warrant the LED and plasma luminaires to be free from defects in materials and workmanship for a period of at least 8 years for conventional roadway lighting. For high mast lighting, the current warranty of 5 years provided by the manufacturers should be sufficient to protect the investment.

Appropriate technical specification should include but are not limited to the following aspects:

Lamp/Luminaire

- Photometric properties: lamp watts, initial lumen, CRI, CCT, light distribution type
- Performance: lumen maintenance, service life
- Safety: UL1029, UL1598
- LM-79, LM-80 and ANSI C78.377 tests and reports
- IP rating: IP65 or better (ANSI C136.25)

Electrical

- Voltage
- Power factor
- Surge protection: IEEE/ANSI C62.41
- Ballast sound rating: A
- Electromagnetic Interference (EMI): Class A (Title 47 CFR Part 15)
- Photo electric sensor

Housing

- Vibration resistance: 2G or better (ANSI C136.31)
- Material: Die cast aluminum housing (A360)
- Slipfitter mount: Adjustable ($\pm 5^\circ$) for leveling
- Wildlife instruction protection

Others

- Materials: RoHS compliant
- Upward light output ratio (ULOR) rating: 0
- Temperature rating: -40°C ~ 50°C
- Warranty: 8 years for conventional lighting, and 5 years for high mast lighting

Recommended Citation

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