Implementation of LED Roadway Lighting

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Research Project
Final Report 2016-17

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16. Abstract (Limit: 250 words)
In September 2011, MnDOT installed 10 LED and 10 HPS luminaires along a trunk highway. MnDOT employed data-logging meters to gather hourly electrical operational characteristics relative to both types of light sources. A light meter was used to collect lamp color temperature data and identify changes in the specified color temperature as the LED luminaires aged. This document presents the collected data.

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EXECUTIVE SUMMARY

SEH collected data regarding the operating characteristics associated with the Relume VUE™ LED Roadway Fixtures installed in 2011. We have prepared the following observations and assumptions:

- The collected data, observations and assumptions are representative of the Relume VUE LED luminaires installed at the test site in 2011. This information does not represent any subsequent Relume products or internal components.
- When considering only operating wattage, the Relume test LED luminaires presented a 22.5% energy savings over MnDOT's traditional High Pressure Sodium (HPS) luminaires.
- When considering both energy and maintenance savings, the return on investment for the Relume test luminaires could be as soon as 6.5 years.
- At the end of the testing period it was determined that the luminaires may not be delivering acceptable lighting levels due to a reduction in color temperature.
- The data-logging meters provided acceptable data and performance prior to damage to the underground circuiting.
- The data-logging meters collected data that appeared to be consistent and unique to the respective LED and HPS circuits that were monitored.
- The data-logging meters monitored circuits that contained numerous luminaires. If one or a combination of luminaires operated erratically, the collected data would be affected if the conditions were present at the exact time of the collection, which occurred once every hour.
- Because the lighting branch circuits had common connections at the main breaker, there was the potential for the meters to collect anomalies and operating characteristics from other circuits that were energized from the same cabinet.
- Relume offered a warranty of seven years. The luminaires are still under warranty. MnDOT could investigate to determine whether the luminaires could be replaced under the conditions of the warranty.
- Current LED luminaires operate at nearly twice the efficacy (lumens per watt consumed) than the Relume or similar LED luminaires from the 2011 production year.

CHAPTER 1: PROJECT OVERVIEW & OBJECTIVE

On September 27, 2011 MnDOT installed 10 new LED roadway luminaires to determine if the application of current LED lighting technology reduced energy consumption, lifecycle and maintenance costs while providing appropriate light levels and visibility for roadway safety. A test site was selected along Trunk Highway 61 in Saint Paul to allow for the review of both LED and HPS luminaires concurrently.

The primary consultant task associated with this project was to collect luminaire operational data on a quarterly basis consisting of system electrical and luminaire color temperature operating characteristics associated with 10 LED and 10 HPS luminaires. Evaluation of the collected data was not part of the consultant project task.

MnDOT collected independent photometric data for both LED and HPS luminaires within the test site.

Figure 1.1 Service Cabinet photo

Figure 1.2 Cabinet Deadfront photo

CHAPTER 2: SYSTEM & EQUIPMENT CONFIGURATION

The LED luminaire selected for the evaluation by MnDOT was the Relume "VUE V400 Roadway Fixture". The luminaire operates at approximately 240 watts. Initial photometric calculations indicated that this luminaire would generate roadway lighting levels similar to that of MnDOT's current 250-watt (approximately 310 operational watts) HPS roadway luminaire.

See Appendix A for Relume VUE V400 LED Luminaire details.

Ten LED luminaires and 10 HPS luminaires are the only devices energized from their respective multi-wire branch circuits. Two additional independent HPS lighting circuits, a contactor coil, a photocell and two data-logging meters are also energized from the same service cabinet. All devices operate at 240 volts line-to-neutral.

Figure 2.3 Meter Configuration photo

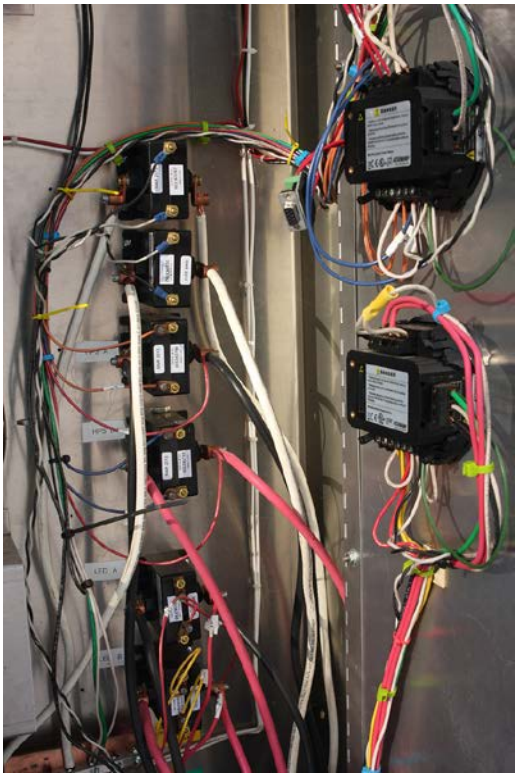

Figure 2.4 Current Transformer photo

Two 240/480 volt multi-wire branch circuits were established to energize the LED and HPS luminaires. In this configuration, the LED circuit is independent of the HPS circuit, and each circuit uses a two-pole circuit breaker as overcurrent protection. Each multi-wire branch circuit consists of two current carrying conductors and one grounded (neutral) conductor. This configuration constitutes two 240-volt circuits in each multi-wire branch circuit. Both the LED and HPS circuits are configured in the same fashion. Both circuits share common connections at the main circuit breaker and the neutral and ground bussing.

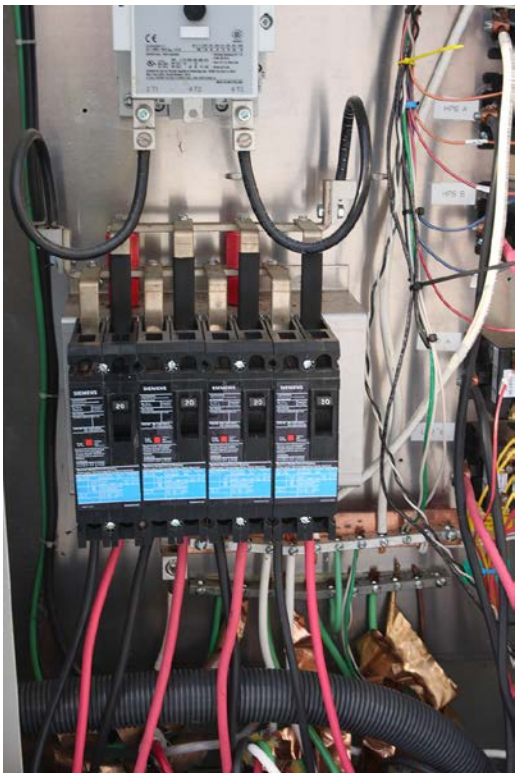

Figure 2.5 Breaker Configuration photo

The circuits are configured to operate nightly via a photocell and contactor mounted in the test site service cabinet.

Two Accuenergy “Acuvim II” data-logging meters were installed in the test site service cabinet that enabled the LED and HPS circuits to be monitored independently and simultaneously through the use of current transformers placed in-line with the respective branch circuit conductors. Data was downloaded to a laptop quarterly for in-office processing.

See Appendix B for Accuenergy Acuvim II Power Meter Data.

CHAPTER 3: POWER METER COLLECTION PARAMETERS

Meter data was collected quarterly for both HPS and LED circuits by a qualified electrician and downloaded onto a laptop computer. Collected data includes the following:

- Voltage
  - Line to Line (A to B)
  - A to Neutral
  - B to Neutral
- Current
  - A Current
  - B Current
  - Neutral Current
- Watts
  - A Watts
  - B Watts
- Power Factor
  - A
  - B
  - Average for A & B
- Total harmonic Distortion
  - A Volts
  - B Volts
  - A Current
  - B Current
  - Neutral Current
- Individual Harmonics for A, B and Neutral
  - 3rd, 5th, 7th, 9th, 11th, 13th and 15th

See Appendix C for Collected Power Meter Data.

3.1 Power Meter Data Downloads

The initial meter data logs were downloaded after 13 days of operation to observe the results and to determine if any operational parameters needed to be modified or added. The meters where initially programmed to log the parameters every 15 minutes. After our review, it was determined that additional parameters would be added to the data collection routine to provide a more thorough view of the lighting system operation. In addition, the logging schedule was modified to log the parameters every 60 minutes in order to reduce the overall amount of data collected.

The meters collected pertinent information for both the HPS and LED circuits. This data will enable the evaluation of operating conditions, such as the unique harmonics generated by the LED and HPS systems.

The data collection routine operated as expected until November 25, 2014. Data logs indicate a loss of current to one of the LED line-to-neutral circuits. On December 10, 2014, current was lost on one of the HPS line-to neutral circuits. After this time, the indicated operation of both HPS and LED lighting circuits became erratic. We suspect these circumstances are a result of damage to the underground circuiting by a utility equipment operator digging adjacent to the lighting service cabinet.

CHAPTER 4: COLOR TEMPERATURE DATA COLLECTION

Luminaire color temperature data was collected quarterly by a technician using a MnDOT furnished Minolta CL-200A Chroma Meter. Color temperature readings were measured by placing the meter's sensor at approximately seven feet above grade, directly under each respective luminaire. It was the initial intent of the project to measure color temperature for both LED and HPS luminaires; however, the HPS luminaires were excluded due to their color temperature being below 2300 Kelvin, which is the bottom limit of the measurement range of the Minolta CL-200A Chroma Meter.

See Appendix D for Minolta CL-200A Chroma Meter Data.

4.1 Color Temperature Data Review

At the time when the LED luminaires were installed, the manufacturer's published color temperature specification was 6000 Kelvin. Color temperatures in this range are perceived as having a slight blue or "cool" color. This color temperature was selected due to its high lumen output. Per the manufacturer's specifications, it would produce the highest average horizontal footcandle levels along the roadway when compared to the manufacturer's other options of 4500 and 3500 Kelvin.

The collection of color temperature readings began July 31, 2013, 22 months after the luminaires where installed. Nine site visits were conducted to collect color temperature readings.

Upon review of the first set of color temperature readings, it was observed that the rendered color temperature of each LED luminaire had diminished an average of 715 Kelvin from the 6000 Kelvin that was published by the manufacturer. The color temperature continued to diminish throughout the testing period. By the final readings, 24 months later, the average color temperature of each luminaire had diminished an additional 565 Kelvin, for a total average loss of 1280 Kelvin per luminaire.

See Appendix E for Quarterly LED Luminaire Color Temperature Readings.

CHAPTER 5: SYSTEM OPERATIONAL ISSUES

The lighting system encountered the following operational problems at various times during the test period:

- Several LED luminaires were non-operational or partially operational as observed during the scheduled color temperature readings.
- One pole was lost due to a knockdown during a vehicle accident.
- Only one LED luminaire remained fully operational for the duration of the test period (as observed during the nine site visits).
- One luminaire operated with only half its available LED arrays for the majority of the test period.
- The majority of the lighting system failed to operate during the final third of the test period when the underground distribution system was damaged by nearby digging operations.
- Meter data was erratic and incomplete for the final third of the test period due to damage to the underground wiring and possible subsequent damage to the luminaires, current transformers and data-logging meters.

CHAPTER 6: LED AND HPS LUMINAIRE OPERATIONAL CHARACTERISTICS

The LED manufacturer provided a photometric report that indicated the luminaire would perform with similar output and light distribution as MnDOT's standard HPS luminaire. This performance enabled a one-for-one replacement of existing HPS luminaires without a reduction in roadway lighting levels.

See Appendix F for Relume 400 Photometry.

As installed, the new LED luminaires operate at a published 240 watts. The typical 250-watt HPS luminaire operates at approximately 310 watts when the additional load of the ballast is added to the load of the onboard 250-watt HPS lamp. The LED luminaire operates with a 22.5 percent energy savings when compared to that of the existing HPS luminaire - a savings of approximately $36.50 per year, per luminaire. If we consider the cost of LED luminaire to be approximately $1,000.00, and subtract the cost of a typical HPS luminaire that it replaces, it would take approximately 17 years to see a payback for energy savings alone.

Maintenance savings also play a significant role when considering conversion to LED luminaires. The LED manufacturer states that the luminaire would operate for 21 years before it fails to deliver acceptable roadway lighting levels. If we assume that no luminaire maintenance is required during this period, a savings of approximately $65.00 per year, per luminaire, would be realized. It would take approximately 10 years to see a payback for maintenance savings alone. When maintenance and energy savings are combined, the payback to cover the additional cost of the LED luminaire would be approximately 6.4 years.

Unfortunately the LED luminaires within the test system did not perform as published. The primary issue was the loss of color temperature. The initial photometric report relied on the color temperature of 6000 Kelvin to deliver the required roadway lighting levels. With a drop of nearly 1300 Kelvin, we would expect the measured roadway lighting levels to drop as well and possibly fall below MnDOT's required levels.

CHAPTER 7: CONCLUSION

Relume was among the first manufacturers to offer LED luminaires able to produce acceptable initial light output and light distributions that were suitable for roadway lighting applications. Since the time these luminaires were installed, LED luminaire technology and the associated light output, efficiency and reliability have improved dramatically. MnDOT and other agencies have now adopted LED roadway lighting as a standard application.

The Relume VUE luminaire is no longer in production. Its successor and other manufacturer's LED luminaires of that vintage have evolved into reliable, high performance luminaires suitable for current roadway lighting needs.