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Energy consumption of traditional metal-halide and light-controlled fluorescent light fixtures at a gas station

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Overview

Existing metal halide light fixtures in the canopy and car wash of a gas station have been replaced by fluorescent light fixtures with digital ballast, connected to an external light controller and a light sensor[1]. The energy consumption and the power quality have been investigated over a period of time. This leads to increased insight into energy saving capabilities introduced in a building lightning course.

Wisconsin's focus on energy program

Wisconsin's Focus on Energy Program is a public-private partnership[2]. This partnership offers energy information and services to residential, business, and industrial customers throughout Wisconsin. Wisconsin's Department of Administration's Division of Energy contracts a group of firms which deliver those services. The goals of this program are to encourage energy efficiency and use of renewable energy, enhance the environment, and ensure the future supply of energy for Wisconsin.
The Milwaukee School of Engineering is among the primary organizations that make up the Focus on Energy program.

Objectives

Since an already existing system was replaced, several goals had to be accomplished in order to satisfy requirements of future projects:
- Energy consumption should be considerably less.
- A positive return on investment should be in the foreseeable future.
- The new system should be relatively easy to install (i.e. no new major conduits etc.).
- Light levels should not be reduced.
- Power quality should be enhanced.

Design considerations

To satisfy all goals, two major design decisions had to be made:
- Selection between a fully-automatic and manual system.
- Consideration of different types of illumination (metal halide, fluorescent, or other)

A fully-automatic system has been chosen for several reasons:
- A person usually cannot judge accurately when ambient light levels are low enough to justify additional illumination. Manual systems tend to be turned on very early during dusk and turned off late during dawn without any benefit of additional light but with considerable costs.
- Manual outside illumination systems are very often left on during day-light because the operator forgot to turn them off in the morning.

Fluorescent light fixtures have been chosen for several reasons:
- Energy consumption of fluorescent light fixtures is much smaller than that of traditional metal halide light fixtures.
- New fluorescent light fixtures are rated for sub-zero temperatures required for outside operation.
- New dimmable digital ballasts allow continuous power adjustments between 20% and 100%. Hence, a fully automatic system can be employed.
- Fluorescent light fixtures enclosed in housings with the exact same form factor than those of traditional metal-halide fixtures are available. This reduces cost of installation considerably, since new mounting brackets and conduits are not necessary.

Light control system

The light control system consists of a light controller, light sensor, and fluorescent light fixtures[1]. The light controller used for this project is shown in Figure 1.

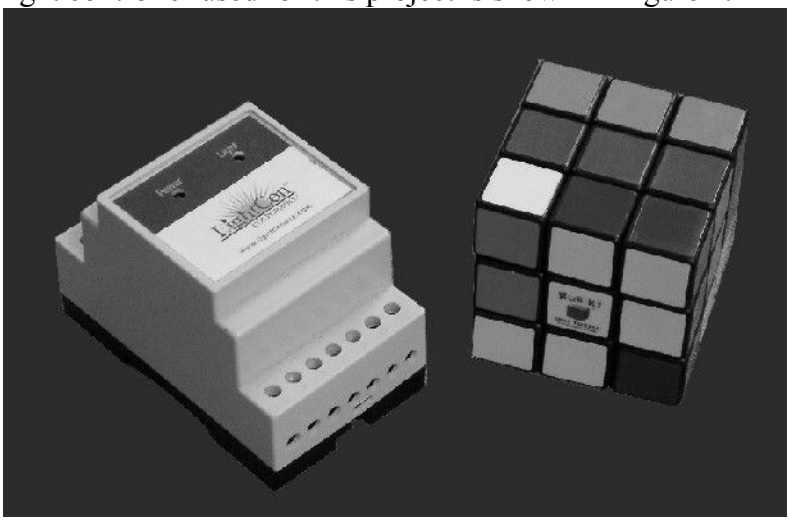

Figure 1: Light Controller

The light sensor is connected to the light controller and measures ambient light. The light controller controls the DALI (digital addressable lighting interface)[3] ballast in the fluorescent light fixture, shown in Figure 2.

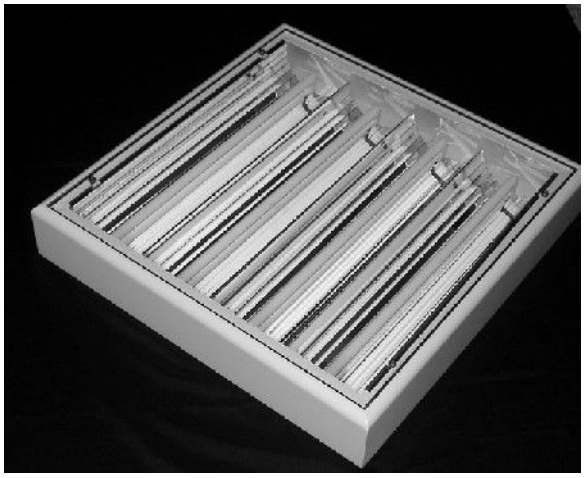

Figure 2: Fluorescent Light Fixture

The controller dims the fluorescent light fixture to maintain a constant total illumination, generally operating the light near a maximum during night hours, gradually dimming during morning hours, operating at a minimum level during daytime hours, and gradually brightening during the evening. The system used for this project is a completely automatic system[1].

This project uses fluorescent light fixtures which are designed primarily for gas station canopies. These fixtures house either two or four 55W compact fluorescent tubes and one or two digital ballasts. The entire fixture is dimmable by a DC voltage signal ranging between 1 and 10V. The fixture features 14 gauge aluminum housing, a 4mm tempered glass lens, and mirror finish reflectors. This controls light pollution or "side splash". The housing is IP54 rated to prevent moisture and bug intrusion[4]. The fluorescent light bulbs used for this fixture are claimed to have a life-time of up to four years when connected to an appropriate light control unit[1].

Gas station layout

The gas station used for this project had a typical layout as shown in Figure 3. The subject property is an Open Pantry-BP gas station / convenient store located in Delafield, Wisconsin.

Figure 3: Gas Station Layout

There are two canopies, one on each side of the gas station, each housing 18 overhead light fixtures. Each light fixture contained one 400W metal halide light source. The two canopies combined therefore have 36*400W = 14.4kW of installed light power. The layout of the fixtures on the canopies can be seen in Figure 4 and Figure 5.

Figure 4: Left Canopy

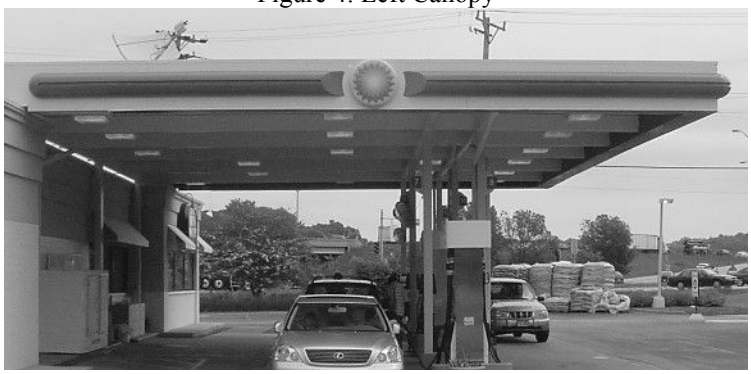

Figure 5: Right Canopy

Please note that on each side one of the existing metal halide light fixtures was not working due to a defective light bulb.
All original metal halide light fixtures of one of the canopies were replaced with 4x55W fluorescent light fixtures. A light control unit was installed in the interior of the convenience store next to the electrical panel box. The light sensor was mounted on the roof of the canopy.

The gas station also provided the services of a car wash. The car wash contained four 400W light fixtures, which provided full illumination 24-hours a day. The layout is shown in Figure 6.

Figure 6: Car Wash Layout

Two of the four metal halide fixtures were replaced with two 2x55W fluorescent light fixtures. The digital ballasts were connected to the light controller in the convenience store. A motion sensor was installed in the car wash and was connected to the light fixtures. This allowed reduction of the illumination if the car wash was not occupied.

Light level measurements

The light levels of each canopy light fixture and of each car wash light fixture were measured with a handheld light meter 1m above ground. Please refer to the appendix for detailed results of all measurements.

Canopies

For both canopies with metal halide fixtures the light levels ranged from 36footcandle(fc) to 80fc, averaging 59.1fc. After replacing the metal halide fixtures with fluorescent light fixtures the light levels ranged from 80fc to 125fc, averaging 96.5fc. This resulted in a 63.4% increase in light levels. Light levels were measured at 80% output of the light controller.

Car wash
Light levels in the car wash with metal halide fixtures ranged from 40fc to 75fc, averaging 57.8fc. After replacing two of the four metal halide fixtures with fluorescent fixtures the light levels ranged from 30fc to 40fc, averaging 34.5fc. This resulted in a 40% decrease in light levels. Again, light levels were measured at 80% output of the light controller.

Energy consumption
The energy consumption of each circuit for the canopies was measured Fluke 123 handheld power meters[5]. The set-up can be seen in Figure 7.

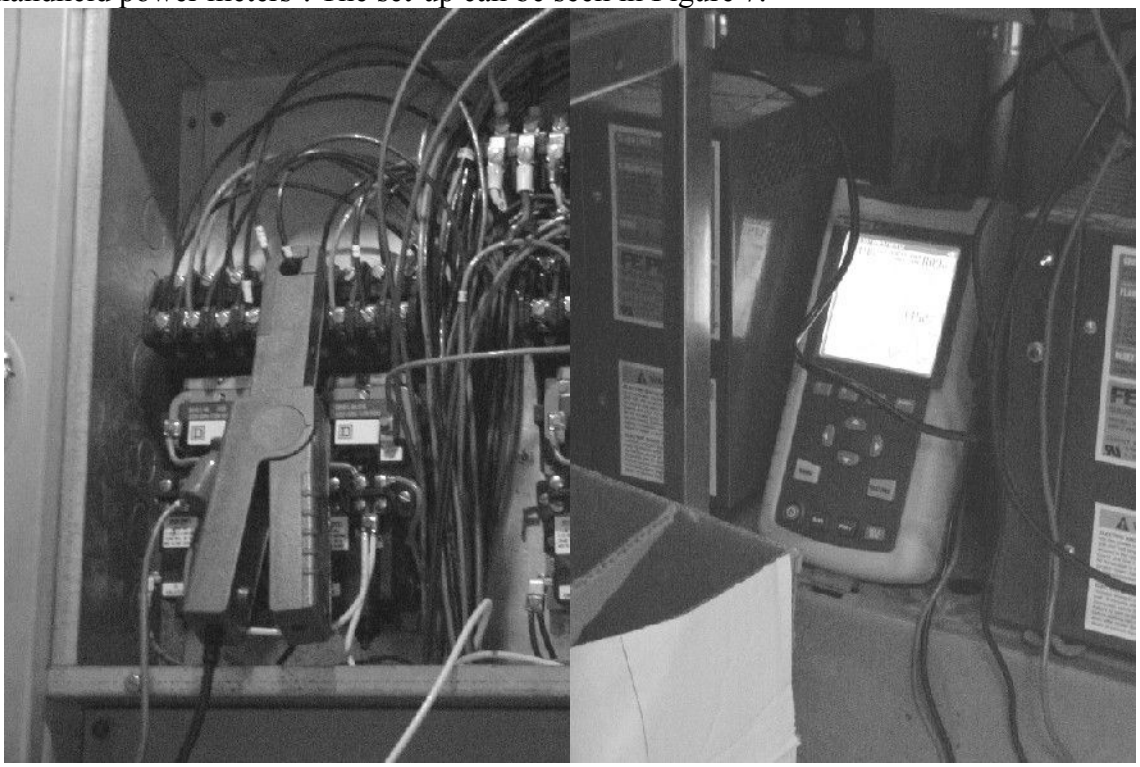

Figure 7: Set-up of Measuring Equipment

Metal halide light fixtures
The power consumption of the existing metal halide light fixtures ranged between 445W and 493W, averaging 471W per fixture. Using 8 dark hours for June 21st the energy consumption of the canopy was 128kWh per day. Using 15 dark hours for December 22nd the energy consumption of both canopies was 240kWh per day.
The existing metal halide light fixtures in the car wash consumed a total power of 1.685kW. Since the car wash was always illuminated the total energy consumption of all four metal halide light fixtures was 40.4kWh per day.
The minimum total energy consumption therefore was 169kWh per day (June 21st) and the maximum total energy consumption was 281kWh per day (December 22nd)

Fluorescent light fixtures

The power consumption of the fluorescent light fixtures averaged 141W. This resulted in a minimum energy consumption of 40.7kWh per day (June 21st) and in a maximum energy consumption of 76.3kWh per day (December 22nd).

The fluorescent light fixtures in the car wash averaged 97W per lamp. This resulted in an energy consumption of 9.31kWh per day, assuming that the car wash is always illuminated. The total power consumption of the fluorescent light fixtures of one circuit of the canopy over a 24-hour period clearly shows how the light controller controls total illumination. This can be seen in Figure 8.

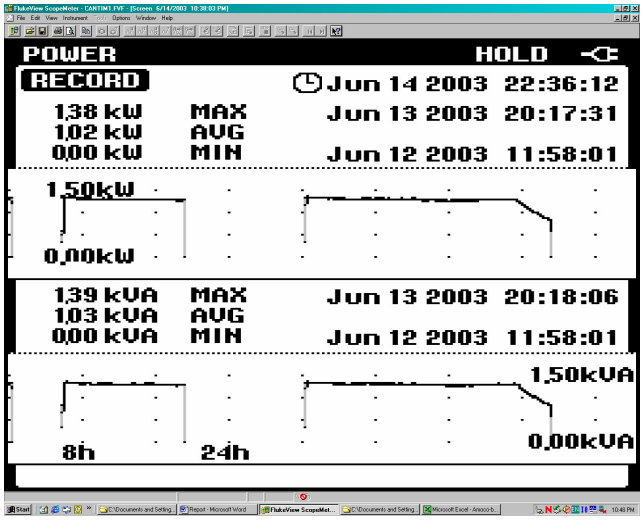

Figure 8: 24-hour power consumption of one circuit of the canopy

The total power consumption of the fluorescent light fixtures in the car wash over a 24-hour period can be seen in Figure 9.

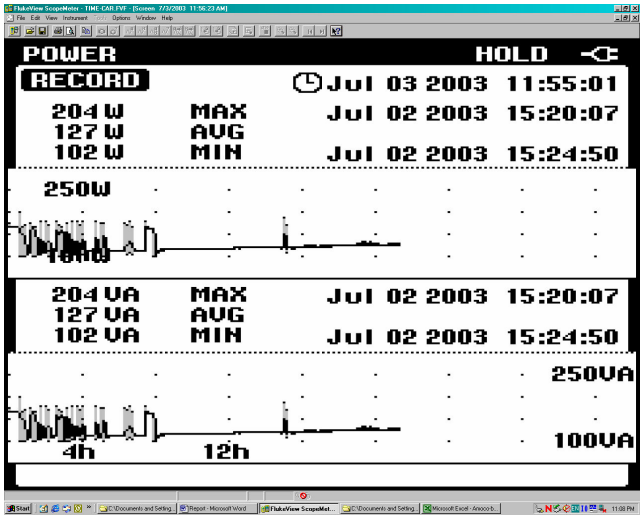

Figure 9: 24-hour power consumption of the car wash

Energy savings summary

Metal halide light fixture:	
Minimum monthly energy consumption canopy	128KWh
Maximum monthly energy consumption canopy	240KWh
Total yearly energy consumption canopy	2208KWh
Fluorescent light fixture:	
Minimum monthly energy consumption canopy	40KWh
Maximum monthly energy consumption canopy	76KWh
Total yearly energy consumption canopy	702KWh
Total energy savings for canopy	68%

Cost savings summary

Metal halide light fixture:	
Minimum monthly cost:	$ 410.46
Maximum monthly cost:	$ 683.46
Average monthly cost:	$ 546.96
Fluorescent light fixture:	
Minimum monthly cost:	$ 121.75
Maximum monthly cost:	$ 208.44
Average monthly cost:	$ 165.10
Cost savings:	
June 21st savings:	$ 288.71
December 22nd savings:	$ 475.01
Average savings:	$ 381.86
Annual cost savings:	$ 4582.37
Investments:	
36 fluorescent light 4x55W fixture @$340:	$12240
4 fluorescent light 2x55W fixture @$225:	$ 900
Light controller:	$ 1400
Installation $75 per fixture:	$ 3000
Installation of controller:	$ 500
Total investments:	$18040
Simple payback:	3.49years

Note: - all cost calculations assume $0.08 per kWh (provided by WE Energies customer service dept.).
- calculations do not take into account maintenance costs and life expectancies of the light bulbs

Measurement details
The following tables show the detailed results of all measurements.

Light levels metal halides:

Canopy 1:

#01: 60	#02: 60	#03: 60	#04: 60	#05: 36
#06: 30	#07: 75	#08: 75	#09: NA	#10: 65
#11: 80	#12: 38	#13: 40	#14: 40	#15: 50
#16: 60	#17: 70	#18:70		

Canopy 2:

#01: 70	#02: 70	#03: 65	#04: 46	#05: 36
#06: 30	#07: 80	#08: 80	#09: NA	#10: 70
#11: 80	#12: 48	#13: 42	#14: 70	#15: 42
#16: 60	#17: 70	#18: 80		

Carwash:

#01: 42	#02: 75	#03: 50	#04: 60

Light levels fluorescent light fixtures:

Canopy 1:

#01: 80	#02: 110	#03: 110	#04: 100	#05: 100
#06: 80	#07: 120	#08: 125	#09: 90	#10: 100
#11: 100	#12: 90	#13: 100	#14: 100	#15: 90
#16: 100	#17: 100	#18: 80		

Canopy 2:

#01: 80	#02: 100	#03: 100	#04: 90	#05: 90
#06: 80	#07: 120	#08: 110	#09: 80	#10: 100
#11: 100	#12: 80	#13: 100	#14: 100	#15: 90
#16: 100	#17: 100	#18: 80		

Carwash:

#01: NA	#02: NA	#03: 30	#04: 40

Power consumption metal halide:

Circuit 02: 1.335kW	circuit 06: 1.48kW
Circuit 12: 0.95kW	circuit 16: 0.463kW
Circuit 36: 1.41kW	circuit 38: 1.41kW
Circuit 40: 0.96kW	
Total power canopies: 8.008kW	Carwash: 1.685kW

Power consumption fluorescent light:

Circuit 02: 0.57kW	circuit 06: 0.422kW
Circuit 12: 0.417kW	circuit 16:
Circuit 36: 0.432kW	circuit 38: 0.429kW
Circuit 40: 0.273kW	
Total power canopies: 2.543kW	Carwash: 0.127kW

Acknowledgements
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Bibliography

[1] http://www.lightconusa.com/products.htm
LightCon Corporation
675 North Brookfield Rd Office: 1-262-786-5522
Brookfield, WI 53045 USA Fax: 1-262-786-5533

[2] http://www.focusonenergy.com/

[3] http://www.ecmweb.com/ar/electric_improving_workplace_lighting/
Improving Workplace Lighting with Digital Control System
Joseph R. Knisley, Senior Editorial Consultant, EC&M

[4] http://www.instrument.com/ctm/nema.asp

[5] http://www.fluke.com

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