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LED TRAFFIC LIGHTS: AIMING ENERGY CONSERVATION IN THE BRAZILIAN SCENE

[1]Mário Cesar do Espírito Santo Ramos & [2]Mário Cesar Giacco Ramos

[1]University of São Paulo.
São Paulo - Brazil.

[2]University of Mogi das Cruzes,
São Paulo - Brazil.

[1]Corresponding author: mcesr@usp.br

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ABSTRACT

This paper aims to evaluate the technical and economic feasibility of the LED lamps used in traffic lights. LED's are one of the most promising options for the future of general lighting. With small dimension, useful life of 100,000 hours, high reliability, without emission of ultraviolet and infrared, have been used in numerous applications such as signaling systems in general. Using LED technology has been possible to verify the disappearance of the "ghosting effect", when occurs the false impression of a light bulb being improperly connected, avoiding many accidents. The replacement of conventional incandescent lamps by LED technology has advantages as durability and energy saving. The case study presented two intersections in a large Brazilian city: intersection 1 (with incandescent technology) and intersection 2 (with LED technology). Measurements were made using a three-phase energy analyzer, installed at each measuring point during a week. Economic analyses were applied, demonstrating the fast return on investment for the LED technology. Measurements demonstrated that the power consumption of the LED lamp is 12 times smaller than the incandescent lamp and the replacement of technology is highly feasible.

KEYWORDS: LED traffic light, useful life, energy saving, return on investment.

INTRODUCTION

In Brazil, there are still thousands of intersections traffic lights that use old conventional technology with incandescent lamps.

The incandescent lamp is made by a transparent glass bulb containing chemically inert gas and a tungsten filament that reaches incandescence due to electric current.

The useful life of an incandescent lamp is based on a number of lamps tested under controlled conditions, where this value is determined at that instant of 50% of the tested lamps remain on.

However, the average nominal life test hasn't the same value in terms of service, because the vibration, voltage fluctuations and other environmental influences, shortens the average life of the lamp.

Table 1 shows the types of incandescent lamps still used in conventional traffic lights in Brazil.

Power [W]	Voltage [V]	Luminous Flux [lm]	Useful Life [hours]
64	127	665	3000
100	127	1260	3000

Table 1: Incandescent lamps used in conventional traffic lights.

On the other hand, the Light Emitting Diode consists of a semiconductor. Its structure is formed by a crystal combined with elements from columns III and V of the periodic table of chemical elements. When activated by a very low current, the junction element emits light at a defined wavelength.

The main benefits of the LED lamp are energy saving, low periodic maintenance and better visualization (Binduhewa, 2001).

The high efficiency LED, due to its good performance, has been used in the manufacture of the LED lamps, which are made up of tens or hundreds of LED's, a lens responsible for the uniformity of the brightness and an AC/DC converter (Akanegawa et al, 2001).

The LED lamp is both economic and technical good investment; it reduces energy consumption about 88% (Hernandez, 2011).

The useful life of LED lamp is approximately 100,000 hours. This means that in normal conditions, the substitution decreases reducing maintenance costs significantly (Ibrahim et al, 1998).

The fact of having a long life conveys to the user a certain rely in the equipment. According to some manufacturers, the probability of LED fails during its useful life is approximately 0.3%, same under different climatic conditions.

According to the United States Institute of Transportation Engineers, the LED lamp ensures the security of the message communicated to users until the burning out of 20% of all LED's. Thus, it is possible to say that this technology represents an additional safety for drivers and pedestrian (Liet al, 2011).

Tests conducted by the Department of Transportation of the State of California - CALTRANS indicated that,both in field and laboratory, light index of reflection when the sun is behind the observer is 50% lower on LED lamp when compared with incandescent technology, eliminates the false impression of a light bulb being improperly connected (ghosting effect), avoiding many accidents.

In the United States, the LED lights also provide energy savings, approved by drivers and pedestrians. According to the drivers, the LED lamps are brighter than incandescent lamps, with no significant difference in color.

Some U. S. cities like San Diego and Philadelphia were the first to use this technology. The capital expenditures were paid in two years.

Figure 1 shows the LED traffic lamp, where:

1. Electric module.
2. Fresnel lens.
3. Prismatic lenses.

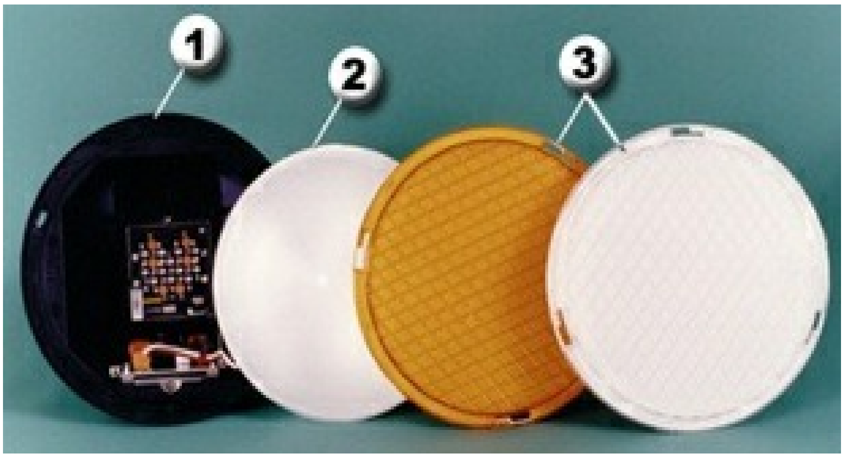

Figure 1: LED traffic lamp (Cobrasin, 2012).

Figure 2 shows the electric module details, where:

1. Board with LED's.
2. Electric module.

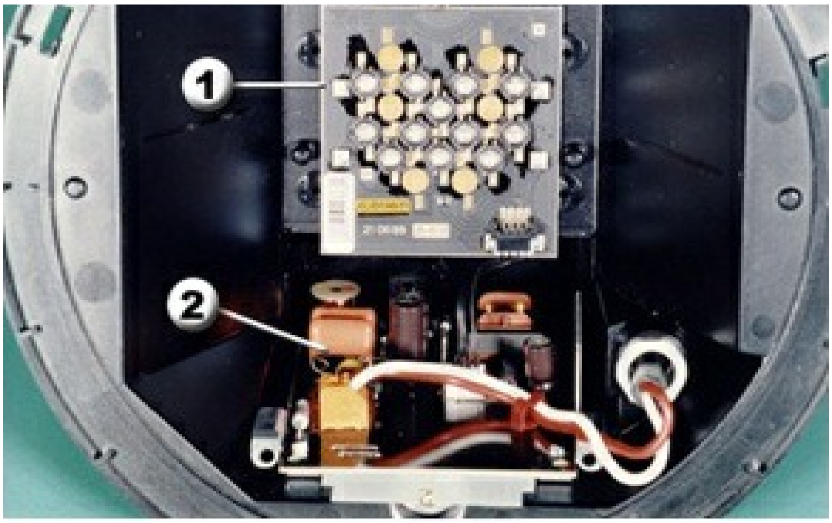

Figure 2: Electric module details (Cobrasin, 2012).

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CASE STUDY

This case study shows two intersections in a large Brazilian city: intersection 1 (Incandescent technology) and intersection 2 (LED technology).

Measurements were made using a three-phase energy analyzer, installed at each measuring point during a week.

Equipments were programmed to measure the following variables: date, time, voltage, current, active power, reactive power, apparent power and power factor.

Figure 3 shows an intersection that uses conventional technology (Incandescent):

Figure 3: Conventional technology.

- Number of incandescent lamps: 21
- Voltage variation: 114.18 V (min); 120.31 V (max)
- Active power variation: 940.62 W (min); 1,263.28 W (max)
- Power factor: 1.00
- Power interruptions: 0
- Measuring time: 10,025 minutes
- Energy recorded: 201 kWh
- Estimated monthly energy consumption: 867 kWh

Figure 4 presents the measurements performed in the incandescent technology.

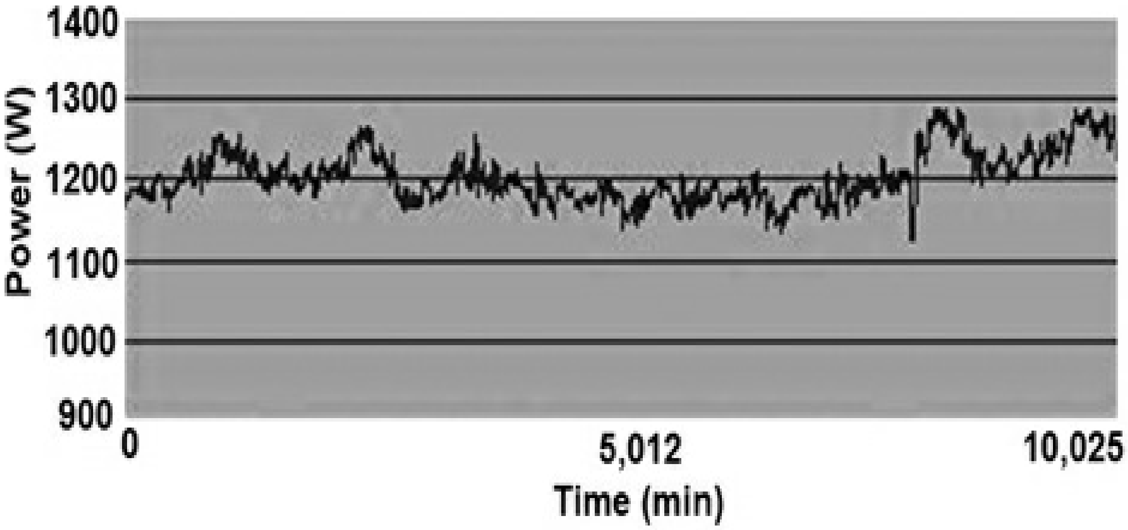

Figure 4: Measurements results (incandescent technology).

The new values of useful life and light intensity of an incandescent lamp, when supplied by a different voltage from the nominal value, can be calculated using the Equations (1) and (2):

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$$\tau = \left(\frac{U}{U_o} \right)^{-12} .\tau_o \qquad (1)$$

Where:

τ- New useful life value when supplied by a voltage U.

τ_o- Useful life value when supplied by a nominal voltage Uo.

U - Voltage of the supply network.

U_0 - Nominal voltage of the lamp.

$$J = \left(\frac{U}{U_o} \right)^{3,5} .J_o \qquad (2)$$

J - New value of the light intensity when supplied by a voltage U.

J_0 - Light intensity when supplied by a nominal voltage U_o.

The monthly consumption per lamp was 41.28 kWh.

Figure 5 shows an intersection that uses LED technology.

Figure 5: LED technology.

- Number of LED lamps: 88
- Voltage variation: 230.56 V (min); 240.25 V (max)
- Active power variation: 373.43 W (min); 467.96 W (max)
- Power factor: 0.84
- Power interruptions: 0
- Measuring time: 12,855 minutes
- Energy recorded:93.54 kWh
- Estimated monthly energy consumption: 314.34 kWh
- Monthly energy consumption per lamp: 3.57 kWh.

Figure 6 presents the measurements performed in the LED technology.

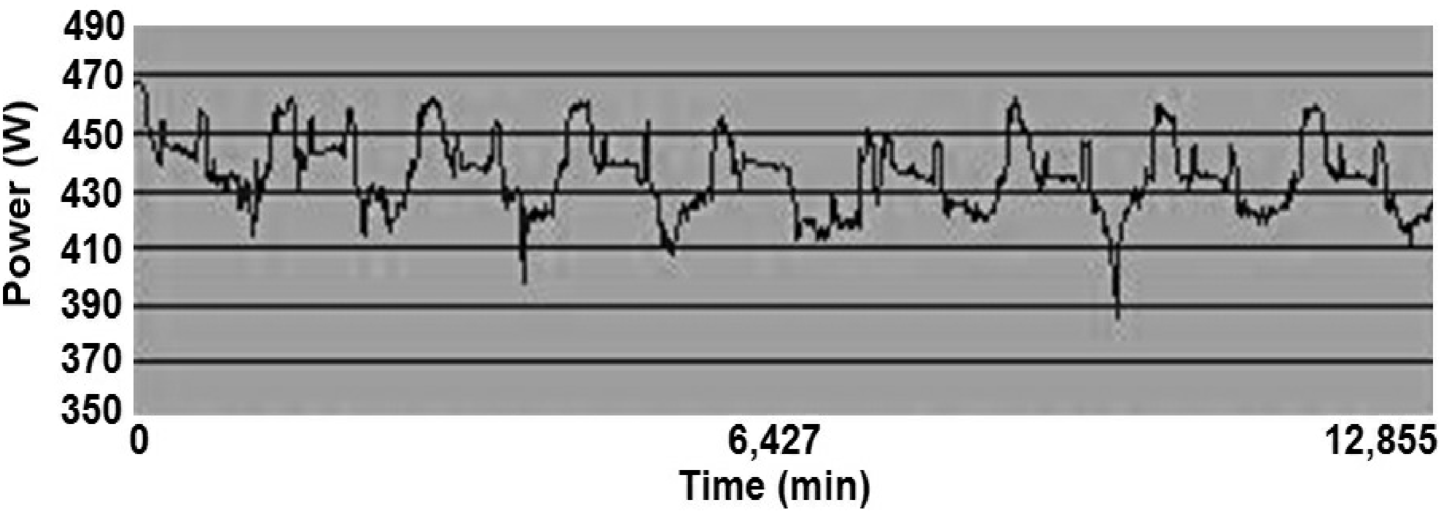

Figure 6: Measurements results (LED technology)

ECONOMIC ANALYSES

Table 2 Shows the replacement costs of incandescent lamps during the analysis period.

	Incandescent		LED
Power (W)	58		5
Useful life (hours)	3000		100000
Price (US$)	2		250
Cost of substitution (US$)	0		0
Total (US$)	2		250
Analyze Period (years)	11		11
Internal Rate of Return (%)		14	

Table 2: Replacement costs of incandescent lamps.

Table 3 considers the operating costs of US$ 30 related to the replacement of each lamp, according to data provided by the traffic engineering in the city where the study was conducted.

	Incandescent		LED
Power (W)	58		5
Useful life (hours)	3000		100000
Price (US$)	2		250
Cost of substitution (US$)	30		30
Total (US$)	32		280
Analyze Period (years)	11		11
Internal Rate of Return (%)		43.1	

Table 3: Replacement costs of incandescent lamps during the analysis period considering substitution.

CONCLUSIONS

According to measurements performed at intersection 2 was possible to prove the high potential of energy savings using the LED technology.

It observed that, even on sunny days, the use of the LED lamps provided an excellent luminosity.

LED's are one of the most promising options for the future of general illumination. With small dimension, useful life of 100,000 hours, high reliability, without emission of ultraviolet and infrared,has been used in numerous applications such as signaling systems in general, and currently in decorative lighting systems too.

The useful life of an incandescent lamp with double filament in continuous operation is approximately 3,000 hours, but this value can decrease drastically in cases of intermittent operation.

Using LED technology was verified the disappearance of the "ghosting effect", when occurs the false impression of a light bulb being improperly connected, avoiding many accidents.

Another great advantage of the LED technology is the warranty from 4 to 8 years, offered by some manufacturers.

In order to reduce the initial costs of substitution of the incandescent lamps, an alternative is to buy only the LED lamp, consider that it is inserted perfectly in the involucres door-focuses of the existing traffic lights.

Economic analysis applied demonstrating the fast return on investment for the LED technology.

Measurements demonstrated that the power consumption of the LED lamp is 12 times smaller than the incandescent lamp and the replacement of technology is highly feasible.

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