EFFICIENT AND ADAPTIVE LED PUBLIC LIGHTING INTEGRATED IN ÉVORA SMART GRID

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ABSTRACT

Lighting accounts for 19% of electricity consumption worldwide and 14% in the EU [1]. In Continental Portugal an estimate of 19% of global energy consumption is related with general lighting systems [2]. EDP Distribuição, shortly EDP D, (EDP Group), Portugal, as the main Distribution System Operator (DSO) in Continental Portugal, operates the Street Lighting Network (SLN) with a total energy consumption of 1,5 TWh, 3% of Portugal´s global energy consumption. As a DSO, fully committed to respond to the energy efficiency demands, to ensure a sustainability growth of Quality of Service (QoS) and to answer the needs and expectation of clients, EDP D has been systematically upgrading the network with new efficiency technology and testing new emerging technical solutions to mitigate risk, namely, the impact in maintenance, management and operational process.

INTRODUCTION

EDP D operates around 4 millions streetlight luminaires with a total energy consumption of 1,5 TWh, which is about 3% of Portugal´s total energy consumption [2]. There has been a growth rate of 4% annually from 2005 to 2009. Due to good practices and new technologies, SLN´s consumption stopped having a growth trend.

STATE-OF-THE-ART

SLN is owned by municipalities and is managed by EDP D as concessions; the exception is Lisbon and very small villages managed by small operation due to historical reasons. Presently, the SLN is characterized by poles with 6 m, 8 m and 10 m height equipped with High Pressure Sodium lamps and ferromagnetic ballasts. There are also some Metal Halide and Mercury Vapour lamps and electronic ballasts in the network [3].

As a DSO fully committed to respond to the energy efficiency demands, ensuring a sustainability growth of QoS and to answer the needs and expectation of clients, EDP D has been systematically upgrading the network with new efficient technology and testing new emerging technical solutions, such as LEDs and Light Flux Regulators, to mitigate risk, namely, the impact in maintenance, management, and operational process.

The change of the predominant paradigm of increasing street light levels to provide well-being for the population is a key challenge to ensure that the European Union meets its ambitious climate and energy targets for 2020.

In the context of street light, EDP D is developing efforts to:

- Create a street lighting manual encompassing standards (e.g. CIE - International Commission on Illumination), energy efficiency, rational energy consumption and social benefits (considering all the costs and benefits of all stakeholders). This document aims to establish, as a reference, a series of technical parameters which should follow a street light project in order to achieve greater energy efficiency;
- Help Municipalities to implement new and more efficient street light solutions;
- Create technical and operational specifications: e.g. LED Luminaries and Light Flux Regulator systems;
- Upgrade crepuscular cells control to astronomical clock control and the traditional metering to smart metering;
- Overnight street light switch-OFF responding to municipalities requests;
- Test new innovative solutions, as Led luminaries, Light Flux Regulation systems and intelligent street lighting management systems associated to LED Luminaries.

Aligned with this scope, Continental Portugal has stopped the 4% annual growth rate of street light energy consumption since 2005 (Figure 1).

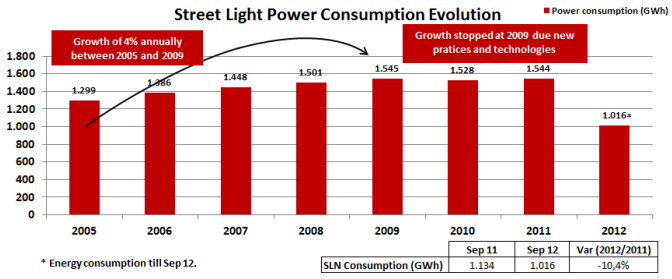

Figure 1 - SLN Power Consumption Evolution since 2005

Street Lighting Manual

EDP D is involved with governmental bodies and agencies, organizations with a role in lighting, and Portuguese Engineers Order to develop and promote a reference document for energy efficiency in street light. This document aims to establish, as a reference, a series of technical parameters which should follow a street light project in order to establish an energy efficiency classification for the street light project based in letter codes like the energy efficiency rating used in domestic electronic devices [4].

Technical installation and operation specifications

With the focus on energy efficiency, manufacturers are continually introducing innovative and original products in the market. To minimize the risk of installing such new equipment EDP D specified technical and functionality specifications and installation requirements, such as:

- Modular LED luminaires. The objective is to have modular parts to facilitate the replacement only of the failed component. These luminaires are an excellent solution to exchange discharge lamp technology with LED technology and furthermore ensure that replacement of these LED modules will also be possible after their lifetime or malfunction.
- Light Flux Regulator based on voltage regulation with operation and maintenance module. This module will permit the natural operation of SLN, namely the possibility to inspect the network during daylight and local remote to the system in a way to guarantee safety in all network operation.

Astronomical clock control

The main SLN control system is based on crepuscular cells control. This static ON/OFF control is based exclusively on surrounding light information. Astronomical clock control is becoming more and more popular, considering the high savings through precise switching ON of lighting at the right time (Figure 2). The ON/OFF switching is controlled by the sunrise and sunset table, which is permanently stored in the device memory. The user may modify the lighting duration, depending on local requirements, and may also set both switching delays (offset to delay sunset switch ON and forward sunrise switch OFF) and switch OFF circuits during night periods.

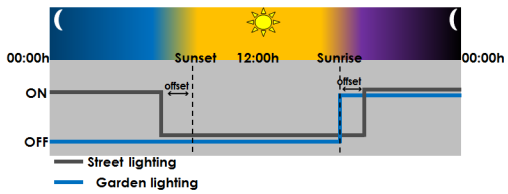

Figure 2 - Astronomical control example

At the end of 2012, Portugal´s public street lighting has 30.586 astronomical clocks controlling 177.544 street lights. This represents 49% of all SLN control systems.

Overnight street light switch OFF

In order to respond to municipalities requests, EDP D has started to optimize the efficiency of street lighting by switching OFF luminaires, in places where their light parameters were over dimensioned. To minimize social impacts, the main issue is to guarantee adequate lighting at junctions, crossings and high crime areas.
In terms of operation and maintenance, the population is informed by a sticker form placed in the pole, recognizing that lamp to be intentionally on OFF mode.

Presently, EDP D has switched OFF 123.705 street lights, representing, in round figures, 3% of total street light lamps.

Test new innovative solutions

The choice of the light source is very important in the overall street lighting project. Colour temperature, colour rendering index (CRI), luminous efficiency and lifetime are the most important characteristics when choosing a light source. Lighting design is not just illuminating a space but how we can provide the best light to people. Space “humanization”, that is, creating secure and comfortable spaces, is the main issue for the street lighting projector.

Considering parameters like lifetime, efficiency, CRI, possibility of implementing intelligent control systems, maturity, standardization and integration in luminaires’ manufactory, the LED technology has already shown that it is of primordial importance to general light and particularly to street lighting. Apart from long life, another benefit of LEDs for street lighting is their directed light. They emit light precisely where it is required, hence, less light is unnecessarily scattered and light pollution levels are reduced. Overall, less power is needed in order to properly illuminate the road.

The possibility of selecting the colour temperature in association with the CRI is very important to find the right balance between safety, comfort and energy efficiency. LED technology is the only that provide this. Cold white (>5000 k) and good colour rendering index (>70) help to make people feel safer. Warm white helps people to perceive spaces as more comfortable. Moreover, cold white LED is more efficient than the warm white LED.

In general, LED technology is already available mostly for urban and pedestrian areas. The replacement of existing street lamps with LED lamps is limited by the large initial cost, as well as the limited number (yet increasing) of manufacturers offering LED modules. Currently, most manufacturers only sell complete systems. The mass adoption of LEDs by luminaires’ manufactures and their technical benefits are leading to the publication of standards and recommendations from international standards association, namely to promote luminaires with modular

independent parts. As a consequence, price reduction is expected (Figure 3) [5].

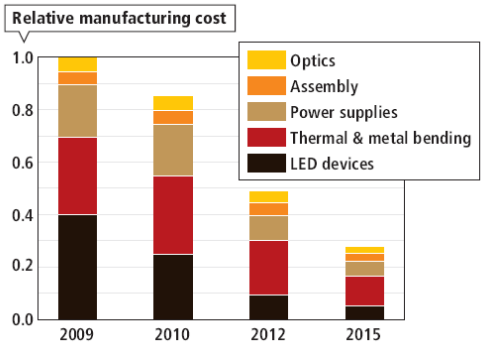

Figure 3 - LED Luminary estimated reduction cost

Due to the characteristics of LEDs, it is easier to integrate the concept of Smart Grid in SLN. In order to prove it, EDP D is implementing a pilot, explained in the next heading.

INTELLIGENT SLN MANAGEMENT SYSTEMS ASSOCIATED TO LED LUMINARIES

Introduction

One of the main reasons of energy waste in street lighting is illuminating, at nominal flux in periods without traffic or pedestrian activity. EDP D, in the scope of Évora InovCity (InovGrid Project), invited Arquiled (National partner) to develop an innovative and more efficient street lighting solution with widespread communication networks and artificial intelligence [6].

LED Luminaries

For the pilot, a prime area of Évora City was selected, the Sertório central plaza. The project comprised the substitution of 44 lanterns, all connected to a MV/LV Substation. As Évora is a Unesco World Heritage Site, it was developed a LED technology lantern, similar to the original shape, to preserve the historical street lantern-light design and characteristics. 67 W Arquihistoric model luminaries (equipped with 48 Osram Golden Dragon Plus LEDs) (Figure 4) were installed, replacing the existing High Pressure Sodium conventional luminaries with a total power consumption of 163,5 W (equipped with 150 W VSAP Lamp and a conventional ballast) (Figure 5).

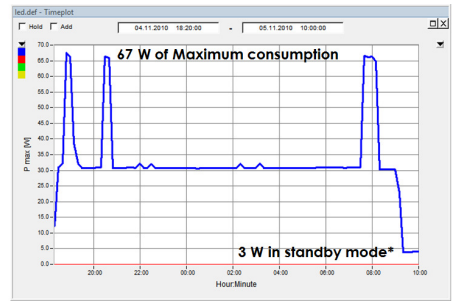

Figure 4 - New LED luminaire consumption

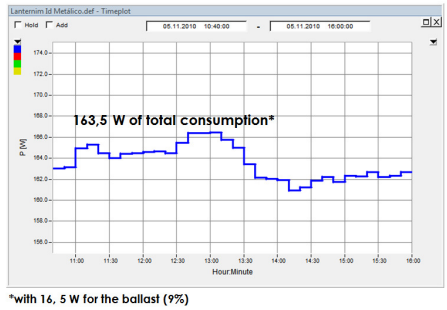

Figure 5 - Old VSAP Luminaries consumption

The Arquihistoric units include Arquiled's sensors (Thermal, Sun, Tractus and G Sensors) and Power Line Communication (PLC) system (Figure 6).

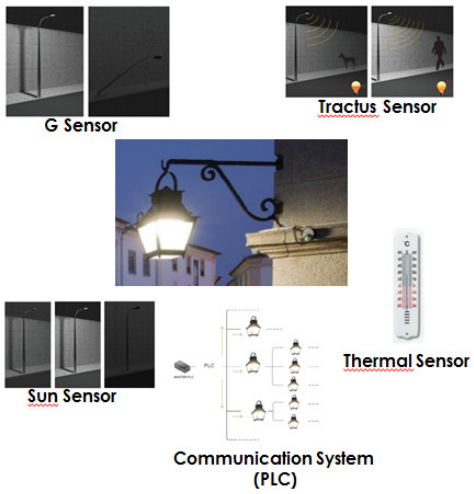

Figure 6 - Full intelligent historical lantern-light

One beneficial effect of LED is less light spillage (leading to higher system efficiency) and less light pollution due to a directional light output.

With the new LED luminaire, there is an almost full cut-off solution eliminating the upward light and a reduction of 42% of the luminous intensity at 90º (Figures 7 and 8).

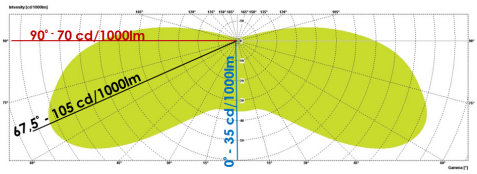

Figure 7 - Old VSAP Luminaire Light Distribution Diagram

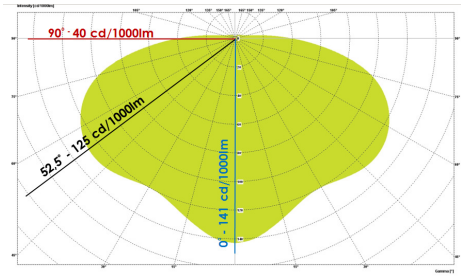

Figure 8 - New LED Luminaire Light Distribution Diagram

Dynamic and intelligent system

With dynamic and intelligent system, the luminaire has the capacity to manage the lighting flux profile concerning sensor information. The system was pre-configured with a maximum and a minimum lighting flux profile levels (black profile in Figure 9). In central plaza luminary (exclusive pedestrian area – Red profile in Figure 9), between 11:30 pm and 02 am, the lighting flux increase corresponds to cultural night activities typical in the plaza. In historical zone access roads (pedestrian and vehicle traffic – Green profile in Figure 9) from 11:00 pm the lighting flux decrease corresponds to the vehicle traffic reduction in the historical center of the city. In Pedestrian residential access roads (pedestrian traffic – Yellow profile in Figure 9) between midnight and 06:30 am the lighting flux follows the absence of pedestrian traffic in the road. After 06:30 pm till sunrise the light flux increases due to city's awakening.

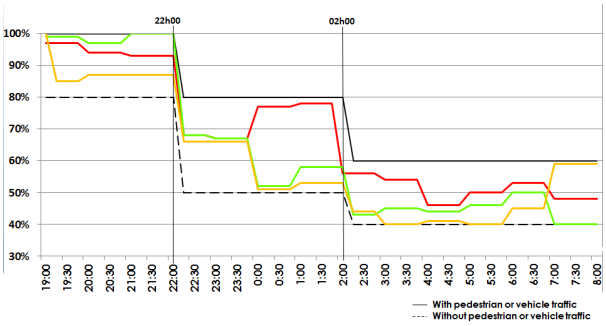

Figure 9 - New LED Luminaire Light Distribution Diagram

CONCLUSION

Data collected by the system has shown a decrease of about 68% of monthly energy consumption after the change, achieved by using LED technology with lighting flux set by traffic or pedestrian activity (Figure 10). With dynamic and intelligent system, the luminaire has the capacity to manage the lighting flux profile concerning sensor information, which allows real time centralized management of all street lights, providing adaptive road lighting without jeopardizing security, comfort and functionality. Also, analyzing the history of the consumption profile, it was possible to optimize the pre-configured lighting flux profile levels to achieve optimal balance between energy efficiency and security and comfort.

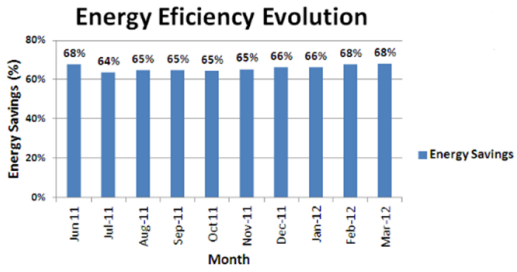

Figure 10 - Energy Efficiency Evolution of intelligent SLN management systems associated to LED Luminaries

In addition to energy savings, the existence of an intelligent grid has allowed the Municipality and the DSO to gain a better knowledge of the street light usage, improving service and maintenance activities.

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