A Pilot Project of Street Lighting Telemanagement in a Smart Grid Environment

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Abstract—**This paper aims to demonstrate a new concept for the street lighting area in a Smart Grid environment. It presents a developed electronic device, which allows control and Telemanagement functions of the street lighting system, through a Mesh ZigBee network. Besides, it presents the achieved results with the deployment of a pilot project where high-pressure sodium lamps were replaced by LED lamps equipped with the developed device.**

Index Terms—**Smart grids; street lighting; Telemanagement; ZigBee networks; energy efficiency.**

I. INTRODUCTION

Street lighting is essential for cities infrastructure and plays a significant role in the modern life, since an adequate street lighting contributes to community life quality, allowing the citizens to enjoy the public space during the night hours.

Street lighting correspond approximately 4.5% of the energy consumption in Brazil [1], even though more than 60% of the street lighting points are high-pressure sodium (HPS) lamps[2], which are recognized by its efficiency and wide useful life.

However, the control system of street lighting is not efficient [3]. What determines the turn on/turn off schedules is the natural light hours, by switching on and off the lamps via photoelectric relays, in a decentralized manner. This kind of control is not reliable since it is very usual to find street lamps turned on during daytime and turned off during the nighttime, causing energy waste or not fulfilling its purpose.

Street lighting Telemanagement systems may provide a centralized control architecture, allowing selective control and dimming actions. It also may generate reports and alarms [3][4]. The main idea of centralized control comes from old times, as presented in [5] where a remote control system was deployed in the New York City in 1926.

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Modern Telemanagement systems aim to ensure that the lamps turn on in the proper time making use of astronomical clocks and georeferenced information of each street lighting point, in order to determine the sun rise and sun set times [6] – [8].

Some researchers used presence sensors for turning on/off and dimming purposes, triggered by a person or vehicle detection [9][10] or using pre-defined commands, controlling the systems via ZigBee, GPRS, 6LoWPAN, or PLC wireless network [11] – [13].

Combining Telemanagement techniques with street lighting LED lamps contribute significantly to energy efficiency. Traditionally used in electronics circuits, the recent evolution of the LED technology make possible their use in street lighting [13]. The main advantages of LED lamps are: (i) long lifetime, 50,000 hours; (ii) high color rendering index (CRI); (iii) high luminous efficiency [4]. Some projects have shown great results, like in [8]. [12] and [14], where Telemanagement systems were combined with LED lamps, achieving up to 68% of energy savings [8].

This paper focus on the application of new technologies for street lighting. It presents a newly developed street lighting meter with Telemanagement functionalities, and the results of a pilot project deployed inside a university campus in the city of Curitiba, Brazil. All the developments were carried withing the Brazilian National Electricity Agency (ANEEL) R&D program, financially supported by Light SESA.

The rest of the paper is organized as follows: Section II presents the measuring device, developed for monitoring and controlling each street lighting point, Section III shows the details of the pilot project, such as the location, the luminous study and the ZigBee network and, finally, Sections IV and V bring the results and final considerations of the pilot project.

II. Street Lighting Meter

A street lighting meter was developed focusing on the application of smart grid functionalities in the street lighting context. The street lighting meter developed has the following functional and electrical characteristics:

A. Electrical characteristics

- Nominal Voltage: 220VAC;
- Operational Voltage: 220VAC ± 20%;
- Maximum Load: 1800 VA without power factor correction and 500 VA with power factor correction, according to Table 1 of ABNT NBR 5123 standard (Brazilian standard for photoelectric relays and receptacles for lighting) [17];
- Power Measurement Accuracy: 2%;
- Start measuring current: 0.4% of nominal current for active energy and 0.5% of nominal current for reactive energy;
- Closing and reclosing of luminaire using internal relay;
- Monitoring system of luminaire state, e.g. burned lamp or malfunction of the reactor;
- Photoelectric sensor.

B. Functional characteristics

- The calculation of energy is the module of energy measured by the meter element;
- The equipment has local memory to store energy measured and events logs;
- Malfunction detection of the luminaire; as irregular activation during a day, burned lamp or switch without schedule command. All events generate specific alarms that are sent to the central system controller through ZigBee communication network (IEEE 802.15.4);
- Allows activation of the lamp using photoelectric sensor or remote control through the ZigBee communication network;
- When using LED lamps, is possible change the luminosity through dimmer control;
- Allows actions of energy efficiency, e.g. turn on / off or dimering luminaires overnight;
- Allows read and write remote configurations of data and parameters.

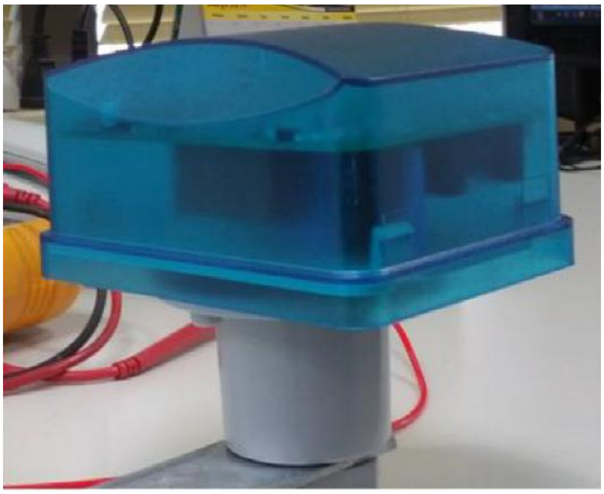

Fig 1 – Street Light Meter connected on the standard base of the conventional photoelectric sensor.

Fig 2 – Connection base of the Street Light Meter

C. Mechanical design

For this project, a specific casing was developed to accommodate all components and the supply circuit diagram of photoelectric relays of the Led and conventional luminaires. Fig. 1 shows the street lighting meter housing connected to a standard basis for photoelectric relays and Fig. 2 shows the connection base. One may verify that the application of this street light meter is relatively simple through the replacing of a conventional photoelectric sensor. The plug connector follows the ABNT NBR 5123 standard.

D. Communication System

A ZigBee communication module (IEEE 802.15.4 standard) was used in the communication system due to its low

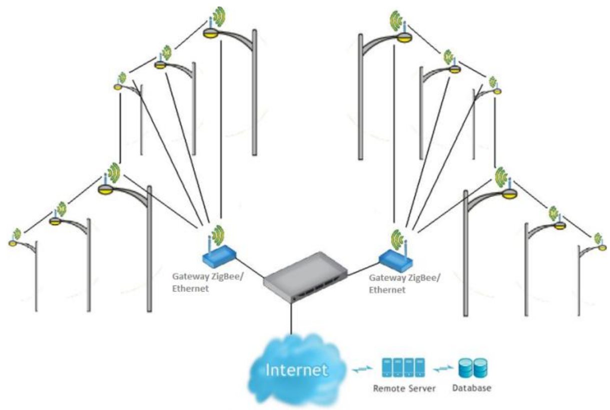

Fig 3 – Mesh network architecture for street light meters.

power consumption characteristic. The meter, through this ZigBee module, forms a mesh network together with other street lighting meters, i.e. a network with decentralized dynamic topology. Fig. 3 illustrates the concept of a ZigBee network for the street lighting meter application, where it is possible to verify the routes communications between the devices on a meshed network up to the ZigBee/Ethernet gateway. According to characteristics of mesh network, the gateway also assumes the role of network coordinator.

E. Control system

The hardware of street lighting meter was based on a conventional electronic meter designed in the Light Smart Grid program, the same program that supported its development. The specific features were increased so that the meter may control the lamp.

For dimming control, it was necessary to include a PWM/Analog converter module. This module generates voltage output between 0 – 10VDC, according the pulse width input. This variable output is connected to the LED luminaire driver, allowing the variation of to light flow based on the pulse width input.

The diagram of Fig. 4 illustrates the wiring necessary to connect the street light meter on the LED luminaire driver.

F. Street Light Meter X Photoelectric Sensor

Fig. 5 shows the comparative between the street light meter and a conventional photoelectric sensor. The plug connectors are the same. Therefore, it is possible to disconnect the conventional photoelectric sensor in the field and connect the street lighting meter, without any further changes needed.

Then, with the simple replacement of the conventional photoelectric sensors and the installing of a ZigBee/Ethernet gateway, it is possible to create the proposed Telemanagement network of street lighting meters.

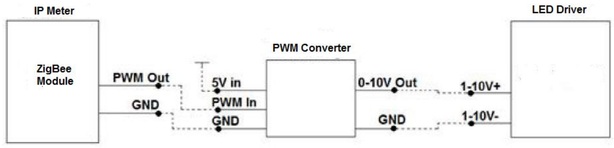

Fig 4 – Diagram connection between street light meter and LED luminaire driver.

More information about the street lighting meter can be found on [15].

Fig 5 – Street light meter with final product compared with the conventional photoelectric sensor.

III. PILOT PROJECT

Aiming to test the new concepts of Telemanagement for a street lighting system, a pilot project was developed on the campus of the Federal University of Paraná, in Curitiba, Brazil.

A. Pilot Area

The place chosen for the pilot was a parking lot area, with approximately 4,800 m². Originally with two poles lighting of 12 m high, each one contacting four high-pressure lamps of 400

W. The green square in 6 indicates the parking lot area, and the red circles the pole lighting. Fig. 6 shows a picture of the area.

Due to the presence of lots of trees around the parking lot, and the lamps being placed above them, the lighting conditions were inadequate. Measurements on the site indicated a luminance in order of 4 lux, which is not acceptable, according to Brazilian street lighting standards [16].

The pilot project was designed not only to test the new technology concepts, but also to improve the parking lot lighting conditions. By doing so, 12 new pole lighting, with six meters high were installed to substitute the old ones, as indicated in Fig 7 (A) and Fig 7 (B).

B. Luminous Study

This new pole lighting placement is different from the older project due to recommendations from a developed lighting case study.

Fig 6 – Parking lot area view from Google Maps.

In such study, this new pole lighting distribution, which used 16 new LED luminaries of 67 W, provided a medium luminance of approximately 17 lux. Considering also a depreciation of 15% of the luminous flux. Each pole lighting at the borders has one LED luminaire (Fig.8), and the central pole lighting has two luminaries (Fig. 9).

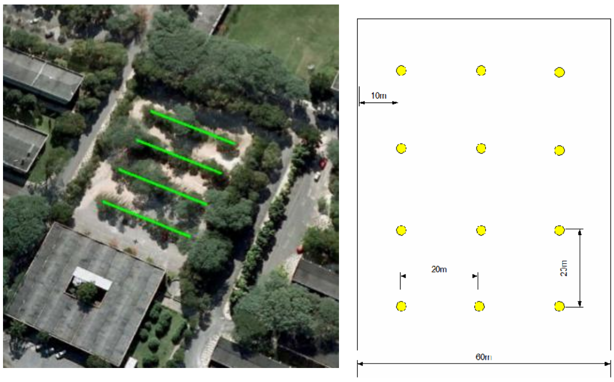

Fig 7 – Local of installation of new pole lightings (A) new pole lighting distribution (B)

C. ZigBee Network

In order to create a ZigBee network to carry on the wireless signals from the LED luminaires to the control base, it was necessary to install five additional measuring devices on conventional luminaires. This way, the signals generated by each measuring device find a routing route among the other devices until an internet gateway, as presented in Fig 10.

IV. Results

After the deployment of the new pole lightings, LED luminaries, measuring devices and the gateway, was possible to evaluate the results.

The new pole lighting distribution and new LED luminaires, provided good improvements with respect to luminous effects, as seen in Fig. 11 and Fig. 12, showing an *ex-ante* and *ex-post* photo.

Following the procedures of the Brazilian standard [16], some measures with a luminance measuring device were collected at some points of the parking, to evaluate the new medium luminance. An *ex-ante* measurement indicated a medium luminance of 4.74 lux, as mentioned before. The *ex-post* measurement, at the same points, indicated a new medium luminance of 33.58 lux.

Nevertheless, it is important to point out that this comparisons analyzed within the developed project and were not sufficient to infer about the luminous or energetic efficiency of the LED technology. Mainly because of the very different conditions, such as the pole heights, the cleaning of the lamps, some luminaries, among others.

Fig 8 –Border pole lighting with one LED luminaire

Another indirect result is the energy savings. Considering that the light system stays on during 12 hours per night, in one year it would consume 4,695 kWh. The old system had an estimate consumption of 14,016 kWh per year. Therefore, the LED may present a reduction of 66%.

Fig 9 –Central pole lighting with two LED luminaires

For this project, 36 street lighting meters were used, 20 installed on luminaires with metal halide lamp and 16 on LED luminaires. The remote monitoring was carried out through Hemera, a Telemanagement system developed by "CAS-Tecnologia", a partner company in the Smart Grid Light Program. The interface of the Telemanagement of the Hemera can be seen in Fig. 13.

V. FINAL CONSIDERATIONS

This paper presented the developments and results achieved in an R&D Project, focusing on Smart Grid applications in the area of street lighting.

It was shown the development of a new electronic device, the street lighting meter, which was fundamental in the process of deploying a Telemanagement system. The equipment was designed with the required functions to allow monitoring and control of each street light luminaire, creating a wireless ZigBee network, allowing long distance commands and a smart operation.

The pilot project was carried out on a university campus, and not only contributed to testing the concepts of Telemanagement, but also enhanced the luminous conditions of the parking lot. Improving the security of the students and professors, and helping the university saves energy.

Fig 10 – Position of each measuring device and the routing routes for communication with an internet geteway

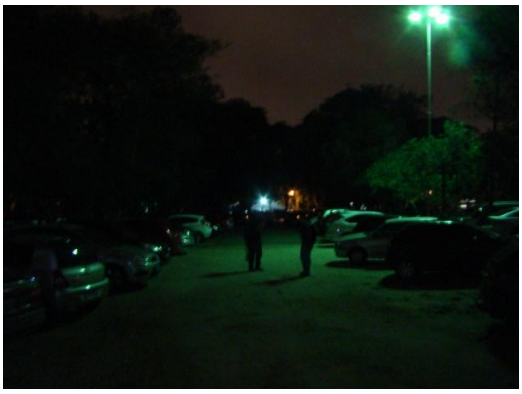

Fig 11 – *Ex-ante* photograph

Fig 12 – *Ex-post* photograph

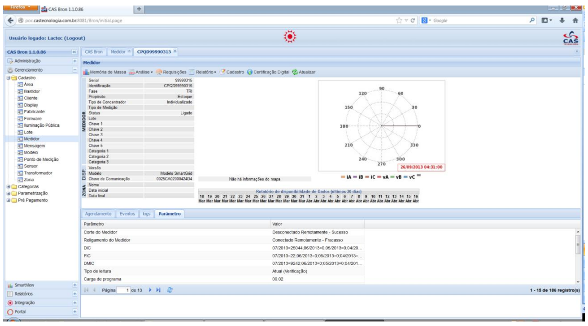

Fig 13 – Telemanagement interface of Hemera to manage all street light meters.

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