Decision Support in the Investment Analysis on Efficient and Sustainable Street Lighting

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Abstract. In recent years there has been a series of documents such as the European Strategy 20-20-20 to address the issue of energy efficiency in various sectors of activity. The objective is to reduce 20% of energy consumption, 20% of GHG emissions (Greenhouse Gases) and 20% of the energy consumed from renewable sources. Public lighting participates with 2.3% in global electricity consumption, so all contributions to the reduction in energy consumption will be relevant. Decision support in the investment analysis on efficient and sustainable street lighting allows a better use of the installed power. Hence, this paper deals with the reduction of losses in cables of a street lighting installation, depending on the luminaire used, presenting both simulation and experimental results. The economic choice of cables losses will allow improving the efficiency of the street lighting in general, providing also an optimal cost/benefit relationship. Moreover, real-time data acquisition systems of the equipment's consumption can be integrated into a collective awareness system.

Keywords: Street lighting, decision support, sustainable energy, efficiency lighting, losses.

1 Introduction

This study presents a new software application under development that compares and chooses the best investment and experimental validation in the solutions of installations of street lighting. The choice of efficient street lighting is related to the following factors: price, power consumption, reduction of losses in the conductors, useful life, and interest rate. The losses in the conductors will be analysed based on the current which passes throughout the electrical installation. The analysis allows various possibilities, allowing you to choose the analysis of a specific individual point of light, replace the existing technology on a street or in a selected group of streets or make replacement or control all luminaires installed simultaneously; investment analyses and advises more efficient.

Energy efficiency and consumption reduction in electrical installations and equipment have been the subject of investigation and research, from energy production to final consumer, public (predominantly street) lighting participates with 2.3% in global electricity consumption [1], energy-efficient programs in this field are very welcome, since possibilities for energy savings in street lighting are numerous and since some of them enable reductions in electricity consumption of even more than 50%.

The cable losses analysed regularly throughout the transport and distribution of energy [2-3], are often overlooked as a component of the cycle of lighting systems, and a means available to save energy and improve the overall performance of the installation in street lighting. Consumption reduction in electrical installations and lamps has been the subject of research, particularly in the aspects of economic choice of conductors section [4] and improving the efficiency lamps [5]. It is intended to connect these two aspects of the research, including on the economic analysis the influence of efficient lamps and losses caused by them in the installation of street lighting.

2 Relationship to Collective Awareness Systems

The electric grid is a massively interconnected network used to deliver electricity from suppliers to consumers. The electricity networks can intelligently integrate the behavior and actions of all users connected to it. In this sense, the parameterization of an installation of street lighting, associated with a data acquisition system in real-time consumption of the lighting, can be integrated in a collective awareness system. Associate software allows the decision maker to choose the purchase of efficient equipment to enable to improve energy efficiency, reduce carbon footprint, increase the security of energy supply and, last but not least, diminish the bill to be paid from production, transport, distribution and use of energy, thus linking objects, people and knowledge in order to foster new forms of social and business innovation.

The future development of the IoT will be especially relevant for energy efficient communication and energy-aware systems. In the service-based IoT applied to the production, transport, distribution and use of energy, all service providers are interconnected. A deregulated energy market, characterized by the growing use of decentralized energy systems and the increasing complexity of interactions between providers and consumers cannot be realized without an adequate IoT infrastructure,

Decision and policy makers will be able to base their actions on real-world, real-time data. Households and companies will be able to react to market fluctuations by increasing or decreasing consumption or production, thus directly contributing to increased energy efficiency, benefitting of the future collective awareness system in order to have better informed decision making and the effective involvement of the customer and sustainable energy systems.

3 Development

3.1 Identification of the Parameters

Physical parameters:

- Knot Connection (CK);
- Connections between knot Connection;

- Length of branch conductors in knot Connection;
- Section of branch conductors in knot Connection;

Load parameters:

- Power of the loads connected to the electrical installation;
- Efficiency of the loads;
- Power factor of the loads;
- Daily load diagram;
- Daily load diagram of the lamps and system control for economic analysis.

Operating parameters:

- Operating time of the street lighting installation;
- Monthly operating days (d);
- Months of annual operation (m);
- Cost of electricity (€);
- Interest rate

3.2 Installation Characteristics

Fig. 1 shows a typical installation with the respective parameters.

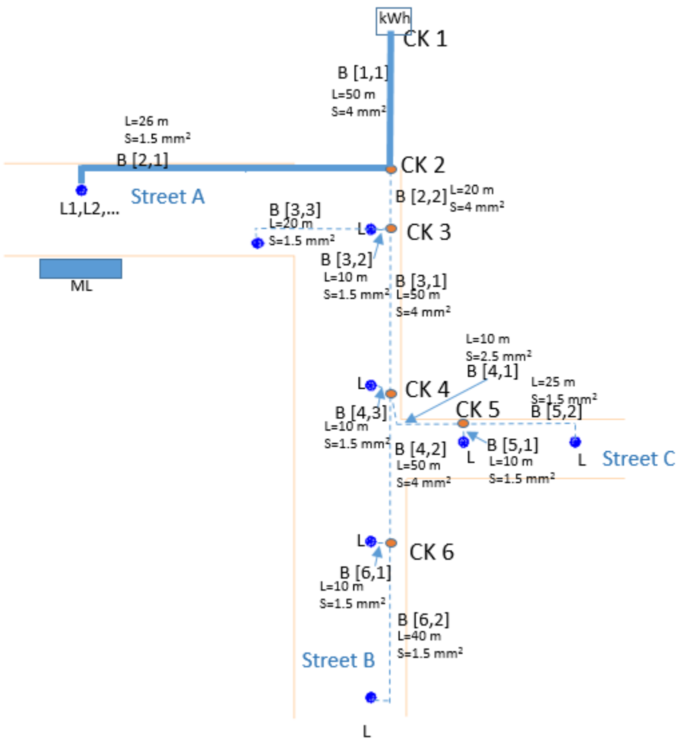

Fig. 1. Scheme of an installation.

3.3 Calculations

After inputting the parameters and load diagrams, the following calculations are made:

- Determination of the load diagram associated to the branch knot Connection, adding the corresponding load diagrams.
- The currents in all conductors of the electrical installation due to:
  - -Initial load diagram (I_1)
  - -Load diagram of lamps efficient (I_2).
- Difference in cable losses (ΔP) in the conductors affected by the changed equipment (identified in bold in Fig.1).

$$\Delta P[k,i] = \int_0^{24} R[k,i](I[k,i]_1)^2 d_t - \int_o^{24} R[k,i](I[k,i]_2)^2 d_t \quad (1)$$

- Profits from the variation of cable losses (G1).

$$\Pr ofit1 = \sum_{j=1}^{n} (\Delta P[k,i]j) * d * m * € \quad (2)$$

- Profits from the variation of power equipment (G2).

$$\Pr ofit2 = \sum_{J=1}^{n} [(P1[k,i]j - P2[k,i]j)] * d * m * € \quad (3)$$

- Total profits.

$$R = \sum_{j=1}^{n} \Delta P[k,i]j * d * m * € + \sum_{j=1}^{n} [(P1[k,i]j - P2[k,i]j)] * d * m * € \quad (4)$$

4 Economic Evaluation

Economic analyses are conducted to allow a rational selection of the solution to be taken during the investment decision, which should be based on a number of comparisons and analyses.

The methods can be grouped into:

- Static methods: simple payback time.
- Dynamic methods: net present value, internal rate of return and payback period.

In this work, the VAL (net present value) or the payback period (PP) is used, which is computed from the sum of the annual cash-flows for a given annual interest rate. The interest rate is indicated by the investor according to the desired profitability.

$$VAL = \sum_{k=0}^{n} \frac{R_k - D_k - I_k}{(1+a)^k} + \frac{V}{(1+a)^n} \quad (5)$$

with:

R - Net profit;
D - Operation cost;
I - New investment;
n - Years of useful life;

V - Residual value for the old equipment;
a - Annual interest rate.

$$PP = ln\frac{100\,W_{el}C_e}{100\,W_{el}C_e - iC_{inv}} - ln\frac{100+i}{100} \tag{6}$$

with:

W_{el}- Electricity savings; Ce- Electricity cost; W_{el}Ce-Net profit

C_{inv} - New investment; i - Annual interest rate

5 Results

5.1 Software developed

The developed software is intended to embrace a greater number of situations analyses. Thus, it is possible to analyze the efficiency simultaneously in the whole installation or in a particular street, as the example shown in Fig. 2. Here is analyzed the C Street, where it replaced luminaires 426.6W (lamp + ballast) by luminaires with using bi-power ballasts with an investment of € 51.5, decreasing to 310.6 W in half the time of use; this is due to flow reduction allowed by the use of the street in the late evening. It is also possible the analysis of specific individual lighting points as presented in the next section in terms of simulation and experimental verification.

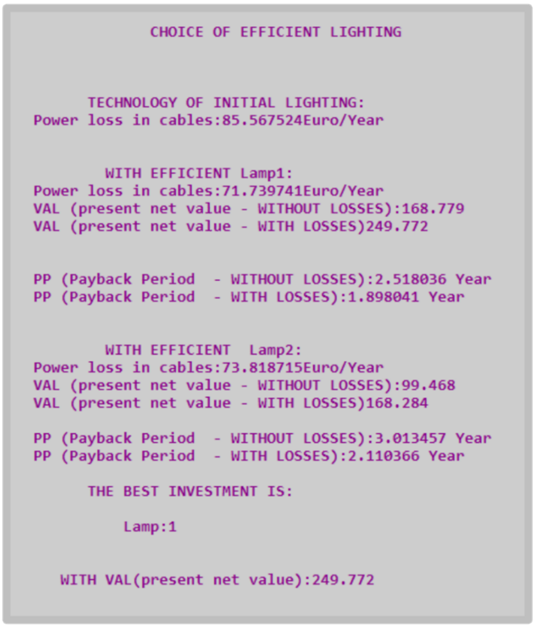

Fig. 2. Results of the software application for the street C.

5.2 Simulation and experimental results

The load diagrams are shown in Fig. 3 with the power of each luminaire and lamps B[3,2], B[2,3], B[4,3], B[5,1], B[5,2], B[6,1], B[6,2], 100 W;
Fig. 4 presents the results of the new software application considering that the branch B [2,1] feeds a spotlight to illuminate and highlight the building's facade. The objective will be to replace this with a more efficient spotlight (LED) including in the analysis the losses in the conductor sections marked in Fig.1 with the respective parameters, used as a likely example.

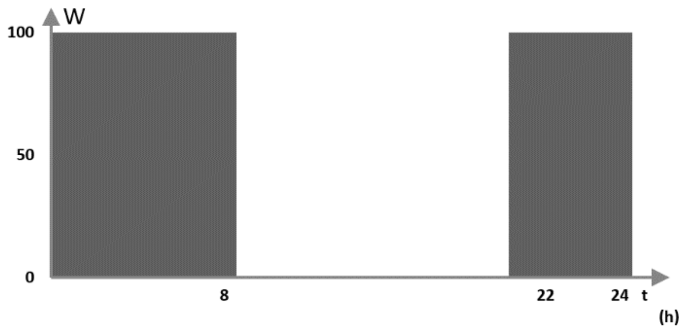

Fig. 3. Load diagram B[3,2], B[2,3], B[4,3], B[5,1], B[5,2], B[6,1], B[6,2].

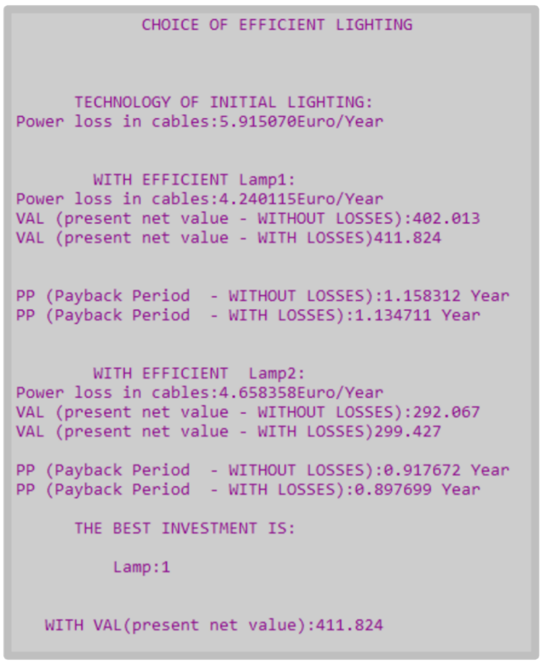

Fig. 4. Results (Experimental) of the software application

The results compare an initial situation, in the branch B[2,1] with one spotlight and halogen lamp of 240 W, with a spotlight LED of 30 W (90 €) and another spotlight and fluorescent compact lamp of 96 W (10€), equivalent in terms of lighting.

5.3 Experimental validation

The experimental setup can be seen in Fig. 5.

Fig. 5. Experimental setup.

Laboratory measurements were performed at the beginning and end of the cables identified as bold in Fig. 1. With 240 W spotlight, 10 W losses were obtained. With 30 W LED spotlight (option 1), 5.83 W losses were obtained in B[1,1]. Figure 6 represents the measurements made at laboratory in cable B[1,1].

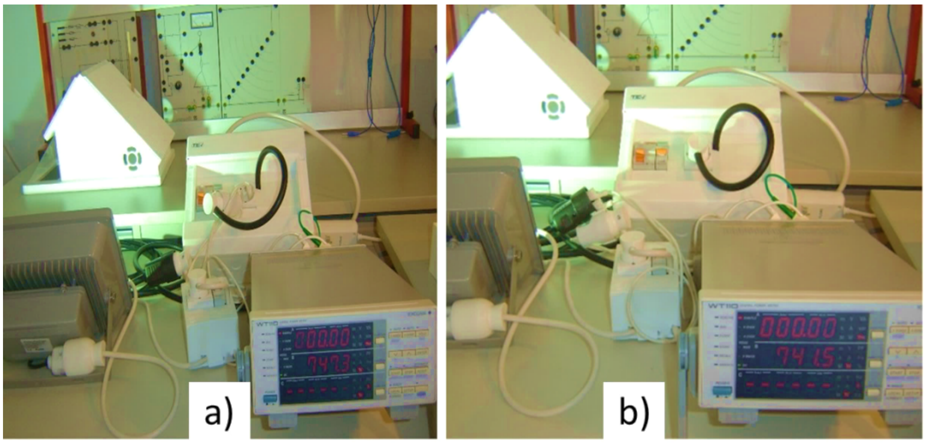

Fig.6. Measure in the branch (cable) B[1,1], option 1 [a)begin; b) end].

6 Analysis of Results

The experimental results were analyzed based on the initial situation and the cost effective option indicated in the simulation results, during one year of operation and with a price of 0.10 €/kWh, considered normal on average in street lighting. From the data presented in the simulations using the new software application (Fig.4), it can be seen that the total losses in branches affected by the substitution are equal to 1.6749 €. From the experimental results, the reduction of losses is equal to 4.13 W (41%). Considering that lighting works 11 hours during night period, operating under the same conditions of the simulations, the total losses are equal to 1.6742 €, validating the simulation results.

7 Conclusions

The work presents a software support in choosing luminaires and control systems for street lighting installations, in cases of projects of new or remodelled total, partial, or an individual spotlight. Losses in street lighting installations although small are not null and can make a considerable difference in the economic evaluation, supporting the investment decision. The use of software to support the designer, allows analysing and choosing effective solutions, thus avoiding the use of technologies and experiences from which there is no certainty of economic profitability. The incorporation of technologies in energy efficiency is a promising market segment in the future, and there will be an increased usage of wireless devices for remote data monitoring, where all devices will be interconnected and able to interact within collective awareness systems.

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