Influence of Conductors Losses in the Economic Analysis of Efficient Interior Lighting

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Abstract

In a modern society the lighting is present in day-to-day in almost all the sector of activity, particularly in light of large and small buildings. Electricity is an essential component to our way of life and a crucial factor in the competitiveness of companies. Considering the current global economic situation and the rising energy costs, all contributions to the reduction in energy consumption will be relevant, allowing the reduction of the energy bill of industries and domestic lighting. This study provides a new software application that compares and chooses the best investment in the acquisition and installation of efficient lamps. The equipment choice focuses on the following factors: cost, power consumption, reduction of losses in the cables, useful life and interest rate. The consumer can then decide in light of all the parameters of the lamps and its electrical installation.

Keywords: Energy management, decision support, efficiency Lighting, losses

1. Introduction

The current global economic situation and the rising energy costs, all contributions to the reduction in energy consumption will be relevant allowing the reduction, however small, of the energy bill of industries and in particular the families, increasing disposable income. This concern motivated a research direction in order to try to reduce the consumption, in view of the reduction of losses in conductors of an electrical installation, depending on the equipment used, including the lighting of interiors of homes domestic.

In power distribution networks, to final consumption, various aspects have been particularly highlighted: dimensioning of the section of conductor selection circuit to reduce power consumption and optimize operating distribution systems [1]-[3]; reduction of distribution losses by reducing reactive power optimization with capacitors placed in the distribution lines and layout optimization for radial distribution [4], [5]; use of the superconducting power transmission [6]; circuit design of industrial and residential electrical installations [7].

Also noteworthy is the study and development of efficient equipment in power consumption, in particular industrial induction motors [8], [9], to be responsible by much of the energy consumption, and efficient lamps [10] of the large industrial and domestic use.

Hence, this paper presents a new software application that compares and chooses the best investment in the acquisition and installation of efficient lamps in lighting interiors of buildings. The lamps choice focuses on the following factors: cost, power consumption, reduction of losses in the cables, useful life and interest rate.

The losses in the conductors will be analysed based on the current that passes throughout the electrical installation. A connection between optimal cables selection and the influence of efficient lamps will also be experimentally demonstrated, in addition to the simulation results, in view of an economic analysis.
2. Formulation

2.1 Identification of the Parameters

First, Physical parameters:

- Distribution boxes (Q);
  The distribution boxes are numbered from 1 (initial distribution boxes) to the total number of distribution boxes for the installation.
- Connections between distribution boxes;
  The connection of these distribution boxes is saved in a matrix that identifies the connection courses. The number contained in the matrix \([k,i]\) indicates the number of the respective output.
  \(k\): Distribution boxes that provide energy; \(i\): Distribution boxes that receive energy; \([k,i]\): Output of distribution boxes \(k\)
  - Length of output conductors in distribution boxes;
  - Section of output conductors in distribution boxes;

From the length and section, the resistance of conductors is determined for all outputs.

- Power of the loads connected to the electrical installation;
- Efficiency of the loads;
- Power factor of the loads;
- Daily load diagram (Figure 1).
- Daily load diagram of the lamps for economic analysis.

Operating parameters:

- Operating time of the electrical installation;
- Monthly operating days \((d)\);
- Months of annual operation \((m)\);
- Cost of electricity \((€)\).

The price of electricity is variable. The software allows the user to choose the tariff.

Figure 1 - Daily load diagram
2.2 Installation Characteristics

Figure 2 shows a typical installation with the respective parameters.

![Figure 2 - Scheme of the installation considered](image)

2.3 Calculations

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

- Load diagram associated to the output distribution boxes, adding the corresponding load diagrams. For example: the output "2" in "Q1" is the sum of output diagrams in "Q2".
- The currents in all conductors of the electrical installation, due to:
  - The initial load diagram (I1)
  - The load diagram of the efficient lamp (I2).
- Difference in cable losses (ΔP) in the conductors affected by the changed lamps (identified in bold in Fig.2), given by: (in all n ranges of the load diagram)

\[ \Delta P[k, i] = R[k, i](I_j)^2 - R[k, i](I_j)^2 \]  \hspace{1cm} (1)

- Profits from the variation of cable losses (G1), given by:

\[ G_1 = \sum_{j=1}^{n} (\Delta P[k, i] \ast d \ast m \ast €) \]  \hspace{1cm} (2)

- Profits from the variation of power equipment (G2), given by:

\[ G_2 = \sum_{j=1}^{n} [(P[k, i] - P2[k, i]) \ast d \ast m \ast €] \]  \hspace{1cm} (3)

- Total profits, given by:

\[ R = \sum_{j=1}^{n} \Delta P[k, i] \ast d \ast m \ast € + \sum_{j=1}^{n} [(P[k, i] - P2[k, i]) \ast d \ast m \ast €] \]  \hspace{1cm} (4)

3 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.

In this work, the VAL (net present value) 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.
\[ VAL = \sum_{k=0}^{n} \frac{R_k - D_k - I_k}{(1 + a)^{V}} + \frac{V}{(1 + a)^{n}} \]  \hspace{1cm} (5)

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.

4 Results

4.1 Simulation results

Fig. 2 shows the considered installation with the respective parameters, used in this paper as a case study. The load diagram is shown in Fig. 3. The power of each equipment is given by: heater [2,1], 1000 W; lamps [2,2], 3x100, 3x72 or 3x20 W; lamp [3,1], 100 W; inductor motor [3,2], 1000 W.

Fig. 3 - Load diagram

Fig. 4 presents the results of the new software application to the scheme of Fig. 2. The results compare an initial situation of normal incandescent lamps of 3x100 W, with halogen lamps of 3x72 W and other fluorescent compact ones of 3x20 W.

Figure 4 - Results of the software application
4.2 Experimental validation

Experimental measurements were performed at the beginning and at the end of the cables identified in Fig. 2 as A and B. With 3x100 W lamps, 6 W losses were obtained in A, while 1.4 W losses were obtained in B. With the more efficient lamps 3x20 W (option 2), 4 and 0.2 W losses were obtained instead in A and B, respectively.

The Figures 5 and 6 represents the experimental setup and measures made at laboratory in the cable A and B, affected for the substitution (initial situation).
The experimental results were analyzed based on the initial situation and the cost effective option (option 2) indicated in the simulation results, during one year of operation and with a price of 0.08 €/kWh (use and nighttime tariff).

From the data presented in the simulations using the new software application (Fig. 4), it can be seen that the total losses are equal to 0.467 € (2.0831 - 1.6158).

From the experimental results, it was observed that the initial losses were equal to 7.4 W (6 + 1.4), while the losses for option 2 were equal to 4.2 W (4 + 0.2). Thus, the reduction of losses is equal to 3.2 W. Considering that the installation operates under the same conditions of the simulations (5 hours a day, 365 days a year), the total losses are equal to 0.467 € (3.2 * 5 * 365 * 0.08/1000), validating the simulation results.

5 Conclusions

The losses in electrical installations, although small, are not null and can make a considerable difference in the economic evaluation, supporting the investment decision on efficient lamps, lighting in large buildings or a simple domestic housing. The results presented confirm that the VAL is superior when the losses are included, validating our study by simulation and experimental results. It also shows the importance of the application of computer simulations in real situations, allowing to analyze and choose effective solutions, making energy use more efficient by employing the integration of advanced technologies.

Bibliography


