Influence of conductors losses in consumer's installations on the selection of efficient electrical equipment

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Abstract. Considering the current global economic situation and the rising energy costs, all contributions to the reduction in electricity consumption are relevant, allowing the reduction of the energy bill of industrial and domestic users. Hence, this paper deals with the reduction of losses in cables of an electrical installation, depending on the equipment used, presenting both simulation and experimental results. The paper provides a new software application that compares and chooses the best investment in the acquisition and installation of electrical equipment. The equipment choice focuses on the following factors: cost, power consumption, reduction of losses in the cables, useful life and interest rate.

Key words
Conductor losses, electrical equipment, sustainable energy, efficiency, consumption reduction.

1. Introduction

In a modern society, electricity is present day-to-day in almost every equipment we use, either at work or in leisure time, from the most sophisticated machine to the simplest appliance. Associated with the use of this equipment is the consumption of electricity. Electricity is an essential component to our way of life and a crucial factor in the competitiveness of companies.

In the future the consumer will no longer be passive, becoming an active element throughout the chain of production and consumption of energy. This requires that the consumer has available tools that help making optimal decisions, taking into account the characteristics of the electrical installation.

World energy usage is estimated to increase 38.6% by 2030, so there are increasing demands from customers.

In power distribution networks, two aspects are relevant: a) dimension of the section of conductors, selected to reduce power consumption and optimize the operations [1]-[3], b) reduction of distribution losses by reducing reactive power, with capacitors placed in the distribution lines [4], [5]. Also important is the development of efficient electrical equipment in power consumption, particularly related to industrial induction motors [6], [7].

This paper analyses the losses in the conductors of the installation of a given consumer, contributing to the overall efficiency of the electrical system. The losses in the conductors are analysed based on the current that passes throughout the installation. A connection between optimal cables selection and efficient equipment is experimentally demonstrated, in addition to the simulation results using a new software application.

2. Problem Formulation

A. Parameters Identification

Fig. 1 shows a typical installation with the respective parameters, while Fig. 2 presents the corresponding experimental setup.

1) Physical parameters

• Distribution boxes (Q);
The distribution boxes are numbered from 1 (initial distribution box) to the total number of distribution boxes for the installation.
• Connections between distribution boxes;
The connection of the 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. Fig. 3 illustrates the connection matrix.
• Length of output conductors in distribution boxes;
• Section of outputs conductors in distribution boxes;
From the length and section, is determined the resistance of the conductors for all outputs.

2) 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 equipment for economic analysis.

3) Operating parameters:
• Operating time of the electrical installation;
• Monthly operating days (d);
• Months of annual operation (m);
• Cost of electricity (€).

B. Calculations

After the installation is characterized, with load diagrams and operating parameters, the software is updated for the whole installation, determining the energy losses caused by the loads and the VAL (net present value) of the investments, and allowing the consumer to make efficient investments.

1) Load diagrams

The load diagrams associated to the output distribution boxes are shown in Figs. 4-6. In this case, the output "2" in "Q1" is the sum of outputs diagrams in "Q2".
2) **Net profit**

- The currents in all conductors of the electrical installation are associated with the:
  - Initial load diagram \(I_1\);
  - Load diagram of the equipment \(I_2\).
- The difference in cable losses \(\Delta P\) in the conductors affected by the changed equipment (identified in bold in Fig. 1) are given by:
  \[
  \Delta P = R(I_1)^2 - R(I_2)^2
  \]  
  (1)
- Profits from the variation of cable losses \(G_1\) given by:
  \[
  (G1) = (R(I_1)^2 - R(I_2)^2) \cdot d \cdot m \cdot €
  \]  
  (2)
- Profits from the variation of electrical equipment \(G_2\) given by:
  \[
  (G2) = (P_1 - P_2) \cdot d \cdot m \cdot €
  \]  
  (3)
- Total profits, given by:
  \[
  R = [R(I_1)^2 - R(I_2)^2] + (P_1 - P_2) \cdot d \cdot m \cdot €
  \]  
  (4)

3) **Economic Evaluation**

In this work, the VAL 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.

\[
VAL = \sum_{k=0}^{n} \frac{R_k - D_k - I_k}{(1 + a)^k} + \frac{V}{(1 + a)^n}
\]  
(5)
where \(R\) is the net profit, \(D\) is the operation cost, \(I\) is the new investment, \(n\) is the years of useful life, \(V\) is the residual value for the old equipment, and \(a\) is the annual interest rate.

### 3. Simulation and Experimental Results

#### A. Simulation Results

The load diagrams of the electrical equipment used in the installation shown in Fig.1 are provided in Figs. 7 to 11. We opted for constant load diagrams and temporal coincidence for a better understanding of the results.

Fig. 12 presents the results of the software simulation. The results compare an initial situation of a normal incandescent lamp of 3x100 W, with a fluorescent compact lamp of 3x20 W.

#### B. Experimental Results

The installation assembled at the laboratory corresponded to Fig.1, measuring power at the beginning (Fig. 13) and end (Fig. 14) of the conductors identified in bold. The power difference corresponds to the losses.

Changing from 3x100 W lamps to 3x20 W (Op2) provides a 43.2% reduction on power losses, which is significant.

Hence, the experimental results validate the simulation results, showing that Op2 is the most cost effective option. On a yearly basis, and for large industrial installations, the savings can be substantial and make the difference for the user.
4. Conclusion

The losses in consumer’s installations can make a considerable difference in the economic evaluation of efficient and sustainable electrical equipment, supporting the investment decision within smart grid environments. The results presented confirm that the VAL is superior when the losses are included. The simulations results, obtained by using a new software application, are validated with experimental results. A 43.2% reduction on power losses can be obtained, which is significant.

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