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Study of Case for Energy Efficiency in Old Buildings

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Abstract. Now due to the lack of rains in Brazil, the efficient use of the electric power became an important subject. There are federal norms that regulate the production and commercialization of products that are energetically efficient. Besides the regulations, several operational and maintenance methods exist to increase the efficiency of the use of the energy. These methods can reduce the electric power losses in these equipments and to optimize the consumption. Another viable alternative for the reduction of the consumption of energy is the use of equipments energetically efficient. Using the efficient equipments, operating these same equipments correctly and promoting the maintenances in agreement with the needs, a great amount of energy can be saved. The consumers that save energy will also be reducing the amount of tributes to be paid in their electric power bills. This article makes a study on old buildings in Brazil and it analyzes through a case study, as we could save with the costs of energy of these buildings.

Key words
Old buildings, energy efficiency, efficient equipments.

1. Introduction

In our houses, in industries and in commercial buildings many times no there is a controlled use and efficient of the available electric power. And being taken into account the low levels of the reservoirs of the hydroelectric power stations in our country, through report published by the National Operator of the System, we cannot think about another way of saving energy not to be the one of the rational use of energy [1]. The politics of energetic efficiency are suitable so that there is not a rationing of energy or something of the gender. These politics inhibit the inadequate consumption and they promote a better use of the available resources. By definition of the Ministry of Mines and Energy, the energy efficiency consists of the relationship among the amount of employed energy of an activity and that made available for its accomplishment [2]. The promotion of the energy efficiency includes the optimization of the transformations of energy, and the transport and use of the energy resources, from their primary sources to its final use. They are adopted, as presupposed basic, the maintenance of the comfort conditions, of safety and of the users' productivity, contributing, additionally, for the improvement of the quality of the services of energy and for the mitigation of the environmental impacts [3]. In Brazil, specifically speaking, a program was created addressed to treat of the use of energetically efficient equipments called *"Programa Brasileiro de Etiquetagem"* (PBE), in 1984. After the creation of this organ and the beginning of the diffusion of the thought of reduction of consumption of energy, Brazil still went by a serious rationing of energy from the period among July of 2001 to February of 2002 [4]. In the specific case of PBE, its importance is linked to the Brazilian goals of economy of energy [5]. The adoption of politics of efficiency of the use of energy can reduce the consumption of energy in old buildings in even of 30% [6]. So that there is that reduction in the electric power consumption, some protocols should be following. These procedures seek to accomplish a complete analysis of the equipments and existent facilities in the construction and to suggest changes to be put in practice.
A form of evaluating if a building is efficient in relation to its consumption of energy is to accomplish an operational inspection of the equipments there installed. This is nothing else than a quantitative process that shows where the energy is being used and then it identifies points in that there is opportunity to reduce the consumption. This article shows how we can analyze buildings with more than 10 years of construction seeking to reduce the electric power tariffs through the use of procedures of energy efficiency.

2. Energy Efficiency and Conservation of Energy

We can define energy efficiency as being the relationship among the amount of energy consumed by certain equipment or apparel and the amount of energy indeed used by him to accomplish its objective (function) [7]. As larger the energy efficiency in an establishment, residence or industry, minor will be the final consumption of energy, the production level will be larger and this will generate a larger energy economy. The electric power losses are so much presents in the generation, transmission and electric power distribution as in our residences. The final

consumer of energy [8] shows that there are procedures that can be adopted to generate larger economy of energy.

- Buildings that use better the ventilation and the natural illumination;
- Electronic devices with reduced consumption of energy;
- Use of more efficient lamp;
- More efficient device for the heating of water;
- Project and control of power systems in general;
- Education and the understanding among the residents.

The measures mentioned above in spite of simple are of difficult implantation due to several factors. One of the main factors is the high implantation cost, since an equipment of larger efficiency possesses a higher price. Another factor to be taken into account is the incapacity of measuring the economical results obtained through the change of equipments. In spite of that the government is regulating more and more the use of energetically efficient equipments and addressing the consumer of energy to adopt practices of energy efficiency [9].

3. Factors that Increase the Losses of Electric Power

There are some factors that contribute in a significant way to the increase of the electric power consumption in any electric installation, be it residential, commercial or industrial. These factors don't depend on the ways of use of energy. They depend mainly on the correct planning and execution of an electric project. Below we listed some.

A. Joule Effect

The losses for Joule effect are more known by losses due the overheating of the electrical conductors of an installation. When a current electric flows through a resistor, this converts electric power in thermal energy. The resistor dissipates the energy in form of heat. This way the total potency of the system decreases. The heating of a resistor for the passage of a current is called of Joule effect [10]. When the amount of current that flows through a certain electric conductor exceeds the face value supported by the section of this conductor, it tends to produce a larger amount of heat, doing like this with that the amount of wasted energy be still larger. To reduce the Joule effect in an electric installation, it is necessary the correct dimensioning of the electric conductors of all of the circuits of this installation. One of the examples more common of losses for Joule effect in electric installations is the use of incandescent lamps. An incandescent lamp just uses about 8% of the energy provided for its nominal potency. The other 92% of the available energy are not used for the illumination of the environment and they are transformed in heat through the Joule effect.

B. Electric Current Leakage

The current leakage is the call "leak" of electric current. To facilitate the detection of that problem, the circuits should have a Residual Current Circuit Breaker (RCCB). That element disarms in the case of current leakage and, with that, it avoids shocks in people and damages in equipments. Besides avoiding the electric discharges, the RCCB aids indirectly in the economy of energy avoiding the current escape. The RCCB is a protection factor and, for that, its installation is obligatory particularly in circuits of sockets of humid areas, as bathrooms and kitchens. In nets without RCCB, what is not allowed, the main sign that current leakage exists is the electric discharge when catching apparels with metallic carcasses. Some simple actions can be taken to avoid the leakage of electric current. Below we described some.

- Appropriate dimensioning of the electric installation in relation to the established load;
- The use of appropriate materials during the assembly of the electric system;
- To avoid amendments, solders and improvised adaptations;
- The periodic maintenance in the electrical installations.

4. Evaluation of the Equipments of the Building

Knowing about the cares for economy of energy mentioned, we can study the possible substitution of the equipments installed in old buildings. We should monitor and to evaluate the durability and operational capacity of the equipments already installed, as circuit breakers, distribution boards, conductors, illumination and drive systems. In [11] we found an orientation on how to proceed for these evaluations.

A. Boards of Distribution

- To verify the state of general conservation: the boards of distribution dirties or rusty should receive corrective maintenance and all circuits of common use of the construction should possess system against overload and short circuit;
- To research the existence also of a general protection against over-currents and over-voltages. In the case they should be characteristic circuit breakers for this function;
- To discover the existence of a residual current circuit breaker (RCCB) so that, in case of leakage of current of a larger value than specified in project, it cuts the feeding of the circuits and make the protection in an appropriate way;
- To verify if protection exists against direct contact with the alive parts of the feeding

system, like this avoiding accidents with the energized part of the distribution board;
- To verify the existence of grounding bar possessing the due protection conductors;
- To analyze the place of installation of the distribution board, tends in view that should be positioned in place of easy access and operation so that, during maintenances, don't put in risk the pedestrians' integrity.

B. Circuit Breakers

- To verify the disarmament of the circuit breaker in an situation of overload or short circuit;
- To verify a possible intermittent disarmament of the circuit breaker;
- To analyze a possibility of no opening or closing of the circuit breaker;
- To discover if the mechanism of operation of the circuit breaker is not stable in a position (level intermediate, nor open and nor totally closed);
- To check if oxidation exists in the terminals of the circuit breaker (this does with that the resistance of the contacts increases);
- Presence of inoperative item in the circuit breaker.

C. Conductors

Through [12], in its item 8.3.1 (Conductors), the operation of any distribution board or electric equipment in a safe way requests an inspection in certain characteristics of the conductors there installed. The items to be verified are:

- State of insulation of the conductors and their fixation devices and support;
- Existence of signs of excessive heating, cracks, drying, lack of cleaning and identification of the spinning.

Besides these items it should be verified if the building possesses architectural, hydraulic and electric projects.

Starting from the projects it will be verified if the conductors meet the minimum dimensioning demanded by [8] and if the color of the conductors of neutral and of grounding (if grounding exists) are in agreement with the used technical norm (neutral in blue and grounding in green)

D. System of Illumination

A system of sensor of presence is a solution to be used for not spending a larger amount of energy than the necessary in the illumination of a building. The sensor enters in operation after an individual's recognition in the illuminated space and it works for an amount of defined time in its configuration, doing with that the lamp remains lit only the necessary time. Also, it is possible to accomplish the change of incandescent lamps for fluorescent and, depending on the situation, even for LED lamps, to reduce the consumption of energy with illumination. The fluorescent lamps provide a smaller expense of energy in relation to the incandescent lamps and the LED lamps consume energy to a smaller tax than the fluorescent lamps.

E. Motors for Elevators and Water Pumping

- Convenient charging of the motor: to verify if the charging of the motor is in agreement with its use. In case of no conformity in relation to the dimensioning of the load of the motor, the professional that will be accomplishing the inspection should suggest to the manager a resizing and make the change of the motor unit in subject;
- Adequate ventilation: to discover if the place where the motor is installed possesses a current of air or an escape place for the hot air produced by the motor. This so that the motor no overheating and looses performance;
- Control of the room temperature: to check if the temperature of the place where the motor is installed doesn't cross the temperature value specified in the operation manual. This temperature value shows which is the room maximum temperature in that the motor in subject can operate without performance loss;
- Voltage variations: This item can be satisfied by the correct electric power supply by the dealership of energy and also for the correct electric system of the building.
    - The dealership of energy should transmit a stable voltage without there is variation.
    - The facilities of the building should be sized so that there is not a voltage fall to the terminals of feeding of the motor, doing with that this executes an inadequate start-up.
- Degradation of the thermal insulators: the professional that it will be accomplishing the inspection and maintenance should check if the insulating materials of the motor are in acceptable state of operation. Besides verifying visually, it should also take into account some factors:
    - To check if overvoltages exist in the terminals of feeding of the motor;
    - To check if during the departure of the motor there are cases of overcurrents;
    - To see if the motor is installed at salubrious place, so that there is not penetration of particles that can form conductive bridges.
- Elimination of vibrations: the vibrations no programmed cause reduction in the

performance of the motor. So that this is verified, it is necessary some cares:

- To verify if the base of the motor is fixed in a satisfactory way;
- To check if excessive gaps exist in the motor bearings;
- To check if the alignment of the motor is correct;
- To analyze if the balancing of the rotating parts is correct.

- Lubrication of the motor bearings: the non lubrication of the motor bearings allows overheat the bearings and, consequently, it will cause the loose of useful life and the reduction of the motor performance. The professional should check the state of the lubrication of the motor bearings and to take the necessary measures.

The inspection and maintenance procedures should be made by specialized and qualified personnel [12].

5. Time of Return of Invested Capital

Before changing some equipment (motors, lamps), we should make an expense forecast and also a forecast of time of investment return on the invested capital (Payback). Tends in view that the life useful average of a motor is of 13.3 years [13] it is recommended to obtain a value of time of return of up to 48 months (4 years). The literature recommends a medium value of 24 months (2 years). Times superior or very close of the values of useful life of the motors in general are not accepted.

A. *Time of Simple Return for Electric Motors*

It is the necessary time so that the capital invested in the acquisition of the motor of high performance be paid in the form of monthly portions. Part of the value of these monthly portions will come of the economy of energy propitiated by the change of the motor.

$$T_{rs} = \frac{\Delta C_a}{\Delta E} \quad (1)[14]$$

$$\Delta C_a = Ca_2 - Ca_1 \quad (2)[14]$$

$$\Delta E = \Delta P_p * H * C_K \quad (3)[14]$$

$$\Delta P_p = P_s * 100 * (\frac{1}{n_1} - \frac{1}{n_2}) \quad (4)[14]$$

Where:
T_{rs} – Time of simple return in months;
ΔC_a – Additional cost in the acquisition of the motor of high performance;
C_{a1} – Acquisition cost of the standard motor;
C_{a2} – Cost of acquisition of the motor of high performance;
C_k – Cost of the kilowatt-hour (kWh) in R$ (*Reais*);
ΔE – Economy in Real a month;
P_s – Potency of the standard motor and of high performance (the two possess the same potency in this analysis);
n_1 – Performance in percentage, of the standard motor;
n_2 – Performance in percentage, of the high performance motor;
ΔP_p – Difference of losses among the standard and high performance motors (in kW).

A. *Time of Return Capitalized for Electric Motors*

The time of return can also consider a certain interest rate. Considering an interest rate i in percentile values, it is obtained the following value of time of capitalized return:

$$T_{rc} = \frac{\log\left(\frac{\Delta E}{\Delta E - \Delta C_a * \frac{i}{100}}\right)}{\log\left(1 + \frac{i}{100}\right)} \quad (5)[14]$$

T_{rc}– Time of Return Capitalized in Months.

B. *Time of Return for Investment in Lamps*

The same analysis should be made for the change of lamps, but being taken into account other important factors for these elements. In the moment of the choice of the lamps for the change we should choose a lamp model with brightness level similar to the lamp installed already at the substitution place. This calculation won't take into account an exact operation period of the lamps in each place of any condominium. The medium time of operation should be stipulated by the person in charge responsible of the maintenance of the lamps. Considering that the lamps operate for a period of 30 days in one month, we have:

$$C_{OL1} = \frac{P_{l1} * C_k * T * 30}{1000} \quad (6)$$

$$C_{OL2} = \frac{P_{l1} * C_k * T * 30}{1000} \quad (7)$$

$$V_E = C_{OL1} - C_{OL2} \quad (8)$$

$$V_{DCL} = C_{L2} - C_{L1} \quad (9)$$

$$T_{RIL} = \frac{V_{DCL}}{V_E} \quad (10)$$

The equations from 6 to 10 are adapted from [15]. Where:

30 – Value of days adopted in a month of operation;
P_{l1} – Potency of the lamp already installed;
P_{l2} – Potency of the lamp to be installed;
C_k – Cost of the kilowatt-hour;
C_{OL1} – Cost of monthly operation of the lamp already installed (R$);
C_{OL2} - Cost of monthly operation of the lamp to be installed (R$);
V_E – Value of energy saved monthly (R$);
V_{DCL} - Value of the difference of the cost among lamps (R$);
C_{L1} – Cost of installation of the lamp already installed;
C_{L2} – Installation cost of the lamp to be installed;
T_{RIL} – Time of Return of Investment for lamps in months.

6. Study of Case

The building used as base for the case study is the building Napoli, located in the Visconde of Guarapuava Street, number 3185, in the city of Curitiba, Paraná, Brazil. The condominium counts with an approximate number of 150 consuming units. The building has 33 years old. The building is in a good conservation state and it maintains their regular maintenances. After a specialized and accredited professional to have

accomplished the inspections suggested by this article, were obtained the following results:

A. General Board of Distribution

- The condition of conservation of the board of general distribution is good: it possesses identification, it is with light dirt, it possesses the identification of the present circuits;
- The general board possesses protection device against the direct access to live parts of the electric installation;

The board of general distribution doesn't possess a good location because it is located in a corridor. And for its operation it is necessary to interdict the access door to the garage of the building.

B. Circuit Breakers and Conductors

For the circuit breakers and conductors it was observed that:

- Devices inoperative, damaged or with limited operation were not found;
- There is no grounding conductor for the sockets. All the sockets are single-phase and the grounding conductor used in the circuits of the building is the neutral conductor;
- An appropriate coloration exists for the conductors of neutral and of phase. Reminding that the building doesn't possess grounding system.

The minimum section demanded for [7] for conductors it is being accomplished (illumination #1,5mm2 and Sockets of General Use #2,5mm2);

C. Systems of Illumination

In all the floors of the building the illumination was totally shown functional. It didn't present switches with bad operation, burned lamps or system of sensor no functional. Besides, the building possesses 110 lamps. All of them are fluorescent lamps.

D. Motors for Elevators and Water Pumping

The maintenances are periodic and they are accomplished monthly by authorized professionals. The motors were lubricated and well attached. It is still worth to emphasize that the conductors of feeding of the motors are correctly sized as well as the motors are properly sized for their functions. Another important factor for the good acting of the motors was the ventilation of the house of machines. The two motors are housed at a spacious place, very well clean and airy, what contributes to their good operation and for the increase of their performance.

E. Change of Lamps

For the change of the fluorescent lamps for the LED model it was observed that, through the calculations, there was an economy of R$0.55 per lamp in the cost of monthly operation, see Table 1. Still reminding that tends the values of the lamps, quoted for the month of September of 2015, the time of return for the investment in the change of the lamps would be of, approximately, 14 months.

Table 1 – Economy Values for Lamp Changes.

Economy Values for Lamp Changes	
Economy in monthly operation per lamp	R$0,55
Return of investment	14 months

F. Change of Motors

Accomplishing the economy forecasts for the change of motors, it can be considered an economy of electric power superior to 550 kWh a month. This represents more of R$ 400.00 of monthly economy (at that time U$ 1.0 = R$ 2.7). The esteemed time of simple return was of 19 months. And the time of capitalized return was approximate in 35 months, see Table 2.

Table 2 – Economy Values for Motor Changes

Economy Values for Motor Changes	
Energy Economy per month	550 kWh
Economy value per month	More than R$ 400,00

G. Total economy of Energy and Taxes

There was a reduction in the sum of the values of consumption of energy after the Change of Motors and Change of Lamps. Consequently, this causes a reduction of the tributes due to economy of energy. All of this reduction in energy consumption can provide a monthly economy of more of R$ 500.00 in the electric bills of the condominium. This represents about 30% in relation to last bill of electric power of the condominium, see Table 3.

Table 3 – Economy Values of energy and Taxes

Economy Values of Energy and Taxes	
Economy value per month	More than R$ 500,00
Percentage reduction in relation to last bill	About 30%

7. Conclusion

We observed that it was possible to obtain a good economy of energy using methods of preventive maintenance and techniques that propitiate energy efficiency. The methods of preventive maintenance show that usually in old electric installations, there are focuses of current escape because of the use of inadequate equipments.

The Residual Current Circuit Breaker (RCCB) is an element of extreme importance to avoid the current escape. Consequently its use can provide a substantial decrease of the electric power consumption. Another important point standing out is the correct sizing of the conductors of the energy system. With the changes of technologies, the habits of consumption of a family also change and consequently the electric installations can be obsolete. These changes can be visualized in the periodic preventive maintenances of the system of energy. Conductors well sizing carry out their functions without there is loss of energy for the increase of the Joule effect. It was also verified that in old buildings, in most of the cases, there is the presence of equipments of low energy efficiency, generating in this way a larger consumption of electric power. The use of equipments of high energy efficiency can diminish the electric power consumption and, consequently, the payment of tributes. Besides the installation of more efficient equipments, the electric power consumption can stiller be reduced if established education politics that motivate and correct the residents of condominiums as for the aspect of the consumption conscious of electric power. Finally, we could verify an economy of almost 30% in relation to the current expenses of electric power with the application of our proposal. These details can be visualized in our Study of Case Section that was presented above

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