ENERGY INDEX EVALUATION OF BUILDINGS IN FUNCTION OF THE EXTERNAL TEMPERATURE

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ABSTRACT

In Brazil, the energy crisis and the scarcity of financial resources to build new plants have increased the interest in saving energy. Buildings are responsible for using a vast amount of energy. To implement actions to save energy in old buildings, it is necessary to measure its energy efficiency. It is difficult to analyze the consumption of energy because of a great amount of variables. Even if there are some fixed variables, the external environment affects strongly the energy use. This paper presents a study, which searches an index of specific consumption with the external temperature. The present work took as base a acclimatized artificial building analyzed through simulation in the Energyplus and compared with measured values. The results collated by means of mathematical modeling had been adjusted for the considered index.

INTRODUCTION

The energy crisis in the 70's decade and recent crises in the sector of energy distribution in Brazil had increased the importance of the energy conservation programs. The increasing consumption of electric energy became more critical. The principal problems are: the scarcity of public monies to invest in new generation plants beyond the ecological impact caused by them.

The energy consumption is increasing in each year. Currently on countries search to save energy in distinct ways, either through equipment modernization that consumes less, design the buildings better or consider renovation in existing buildings.

The electric energy is the principal energy source used in Brazil (BEN, 2002). The buildings are responsible for an important amount of this consumption. The importance of the design of an architectural project, that has not only taken in consideration the implantation, the form, the facades, dimensions of openings, the materials to be applied, but also the climatic conditions of the region.

The knowledge of the climatic condition is not only excellent in the elaboration of a project but also a

determinative factor of final energy consumption. In the countries where the hot and humid climates predominate, there is much difficulty in keeping the levels of comfort in the constructed environment, mainly in the summer. In the projected buildings, HVAC system is a practical alternative, however it causes significant rise in the final energy consumption. In this case, the operation of the HVAC system varies with the external climatic conditions. The rise of external temperatures will increase the load necessary to neutralize the indoor environment. This will prove that the external temperature affects the energy consumption.

An energy performance index is a measuring tool, which makes it possible to compare two different levels of energy use in the provision of a particular type of service. It is usually obtained by dividing the energy use by one or more normalizing factors (Baird 1984).

In buildings, that execute many activities, the attainment of an energy index that can assist in the energy accompaniment is not an easy task. Indexes as the AEUI (Area Energy Use Index) and the PEUI (Person Energy Use Index) are widely used in Brazil, however, they do not contribute to energy use. One of the reasons for which these indexes do not present good results is the variation of the consumption used for the variation of the external temperature for buildings with HVAC systems. For these cases, it is necessary to use an index that has taken in consideration the temperature variation. This work presents the studies carried through for the proposal of the index of consumption normalized for the temperature (Normalized Energy Use Index-NEUI).

A case study using a real building will be presented in this paper. Also it will be represented an analyses of actual data and the comparison with some simulations carried through the computer program Energyplus. Through this index it is possible to compare the energy use without temperature effect and making it possible to evaluate the save energy program in other building energy systems.

CASE STUDY

The case-study building is located in Brazil, in the central region of Belo Horizonte city, South Latitude 20º (Fig. 1).

Figure 1 Building's Location in city and country

This is the administrative building of CEMIG (Energy Company of Minas Gerais State). It is a region of tropical climate, with hot and rainy summer and cool dry winter. The building has 35,000.00 m^2 of area, distributed on 21 floors being 16 floors type, 1 covering, 1 to reception area, 3 reserved subterraneous floors to the Energy System Operation Center of the company, the machine's house of the central air conditioning air, and the garage. The building possesses a rectangular form (40.70 x 33.20m). The four facades have similar covering aspects and ratio. It has as volume form a prism with structure in concrete covered glass forming a continuous panel. It possesses vertical blinds in all facades (fig. 2).

Floor type possesses 1.351,00m2, being separated by thick partition walls of 1,60m of height in beige color. Each type floor possesses in the center 6 elevators, 2 bathrooms and a pantry. The shell of building is composed of concrete. The total height is 4,00m and lowered with aluminum plates in beige color, getting a final height of 2,55m. The floor is coated with plates of carpet in gray color. All window frames are in aluminum, composed of double glass, which has aluminum blind between glasses. A gray protective film, little reflexive, coats the external glass. The artificial illumination is composed by fluorescent lamps of 28W, the total amount of 39.6kW for each floor (fig. 3).

The equipment is basically microcomputers, printers and faxes responsible for a power installation of 55kW in each floor type. There are 2.500 employees working in that building. In each floor there are 135 ones.

The employees work routine is Monday to Friday, 8:00 am to 6:00 pm (fig. 4). On the weekends, the building is almost closed. The central air conditioning acts on all the floors and works between 5:00 am to 7:00 pm. It was set up for each floor a temperature around 23º Celsius. The daily activities are essentially administrative. The sources of energy variation used are the air conditioning and the use of the elevators.

Figure 2 Northeast Facade

Figure 3 Type floor

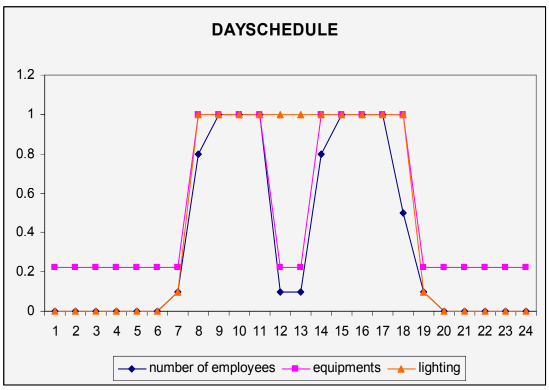

Figure 4 Day Schedule during the weekday

BUILDING ENERGY PERFORMANCE INDEX

The search of a building energy performance index, that can allow comparisons of energy use during a year, has extended for many years. Many works indicate the difficulty of getting a representative index since the daily tasks in office buildings do not have representative impact in the energy use (Yannas 1996, Lam et. al 1997).

In industry, a growth of the production changes directly the energy expense, while growth of the production in the administrative area represents little in energy expenses and is considered fixed. There are two common indexes that have been used in buildings, but both cannot help the efficiency energy performance evaluation. Thus, this paper presents a new index called NEUI that can supply this necessity.

Area Energy Use Index (AEUI)

For buildings, many specialists use the Area Energy Use Index (kWh/m2) to analyze the energy use. However, as this variable (area) is fixed, it does not serve as reference to analyze the variation of the energy use during a year. Because divide this consumption for a constant does not assist in the analysis.

This index can help to verify trend of electric equipment growth in the installation, or either, density of energy consumption by area. An automated company, which uses computers intensely, printers, copying, coffee, pots, machines, must have a bigger consumption than one with more manual service. The comparison of similar companies (for example the same group), therefore, supplies indications on wastefulness degrees. However, for a study of energy efficiency and for monthly accompaniment this index is useless.

Person Energy Use Index (PEUI)

Person Energy Use Index (kWh/person), as well as the Area Energy Use Index, assists in the study to compare energy expenses between similar companies. This index does not help show the agreement of the causes of the energy expense increase since the energy expense can increase without the addition of new employees.

Normalized Energy Use Index (NEUI)

The buildings that use HVAC systems suffer direct effect from the variation of temperature. This amount has been studied, but its effective use is not verified due to difficulty of establishing an index. There are two forms of studying the effect of the temperature in the energy expense. The first one is through the analysis of actual data and second through simulation. In this work the analysis carried through will be presented under both views.

THE SIMULATION

The simulation has been done with only one floor type, as similar floors compose the most part of CEMIG's building. The database of climate is hourly and composed by the TRY-Test Reference Year (1995). Simulation data can be seen below (Tab. 1 and Tab. 2).

	Wall	Floor	Ceiling	Carpet
Roughness	Medium Rough	Medium Rough	Roughness	Very Rough
Thickness (m)	0,1	0,15	0,15	-
Conductivity (W/m-K)	1,75	1,75	1,75	
Density (kg/m3)	2400	2400	2400	
Specific Heat (J/kg-K)	1000	1000	1000	
Absorptance: Thermal	0,9	0,9	0,9	0,9
Absorptance: Solar	0,7	0,7	0,7	0,7
Absorptance: Visible	0,7	0,7	0,7	0,7
Thermal Resistance (m2-K/W)				0,211648

Table 1 Simulation data

	Window shade	Window glass
Solar transmittance		0,845
Solar Reflectance	0,7	0,078
Visible transmittance		0,899
Visible reflectance	0,5	0,077
Thermal hemispherical emissivity	0,9	0,84
Conductivity {W/m-K}	221	0,9

Table 2 Simulation data

Infiltration rate was not considerate because the window frame is whole closed. The HVAC system was considerate ideal. They had been considered in the simulation a scale of public entrance to the building based on actual measurements made on electronic roulettes of the building. Amongst the existing equipment in the building, it was only entered the most representative like computers, videos and printers. The elevators had not been considered, because of its complexity.

The outputs of the simulation are the energy consumption of the equipment and the HVAC system. The building daily energy consumption was calculated. The equipment daily consumption (kWh/day) is always the same for any month, because there is no variation of daily routine between months. The energy consumption of the HVAC system varies monthly in function of temperature variation and the solar radiation.

NORMALIZED ENERGY USE INDEX-NEUI

Using the output of the Energyplus, it is possible to calculate the NEUI. It can be calculated using the equation below.

$$NEIU = \frac{Energy}{function(temperature)} = \frac{kWh}{day * k(t)} \quad (1)$$

As each month has a different number of days, the used energy consumption is the daily month consumption, or (kWh/day).

As no changes have been simulated in the building routine during the months, the equipments daily energy consumption is constant for all months. The climate is the unique condition that changes during the year in the simulation. Considering that only the temperature variation changes the energy use, it is possible to obtain a function of temperature *k(t)* that returns 1 for *NEIU* for any month. This is not true, because there are other climate variables that affect the energy use, like solar radiation and air velocity. However temperature is the most important one and it is easier to be measured too. Then, to eliminate the effect of that variable in the energy use the index NEUI can be used. As the temperature changes constantly during the day, it uses the monthly average temperature to calculate the temperature of the month. In this case, we have the temperature of each hour of all months. Using the calculated energy consumption for each month and the monthly average temperature it is calculated *factor k* for each month. Figure 5 represents the *k* values versus the average temperature. The equation of *factor k* in function of the average temperature is obtained using linear regression, as shown in figure 5.

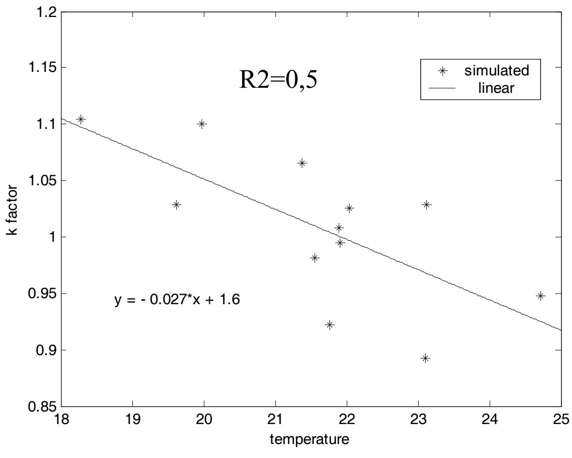

Figure 5 –K factor (Simulated data)

Figure 8 presents the daily energy consumption and the NEUI. Both are presented in normalized values to allow comparison. It can be seen that, the first index (kWh/day) has the same variation profile as the average temperature has, figure 7. The coldest months spend less energy than hottest ones.

The second index is the NEUI which can be seen is more constant. That is the idea of this index. The effect of temperature is eliminated and the energy use of the months can be compared searching for other causes of variation. The small NEUI value is 0,96, which represents a variation smaller than 4% in an actual case cannot be considered as a real variation, as the limitation of the index. In other words, the responsibility of this 4% index variation in other climate changes that is usually not used in the normalization process.

K FACTOR FOR A REAL CASE

Using the same reasoning to an actual data for the same building, the *k factor* is calculated. Using the linear regression the best equation to represent the *actual k factor* is calculated. To compare it with the *simulated k function* both are presented in the same figure (fig. 8).

The building is fed by three lines of distribution. The energy consumption is measured by three equipment of measurement (E1, E2 and E3). The air conditioning system is distributed for the construction and is fed by these three measurers.

To verify the influence of external temperature in energy consumption of building to calculate the factor K, it is necessary two analyses. The first one considers the total energy (sum of the equipments' energies) and relates this consumption with temperature (equation 2). In the second one, it is verified the relation between the consumption of each measurer with the temperature (equation 3). The curve y1 of figure 6 was calculated from the first analysis and the curve y2 from the second one.

In the first one, the sum of the three values is considered in the regression process, the data is presented in Equation 2.

$$data_1 = \begin{bmatrix} (E^1 + E^2 + E^3)_{January}, t_{January}) \\ \\ (E^1 + E^2 + E^3)_{December}, t_{December}) \end{bmatrix} \quad (2)$$

where

E^1 – Energy consumption measured by equipment 1

E^2 – Energy consumption measured by equipment 2

E^3 – Energy consumption measured by equipment 3

$t_{January}$ – January average temperature

In the second one, each measured value is associated with each average temperature period (each month has three values), the data is presented in equation 3.

$$data_2 = \begin{bmatrix} (E^1_{January}, t_{January}) \\ (E^2_{January}, t_{January}) \\ (E^3_{January}, t_{January}) \\ \\ (E^3_{December}, t_{December}) \end{bmatrix} \qquad (3)$$

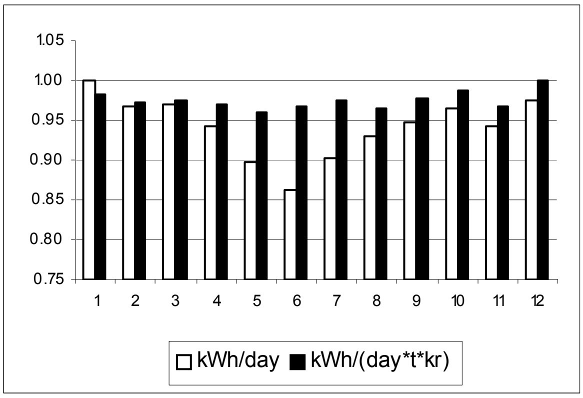

Figure 6 – Energy index comparison

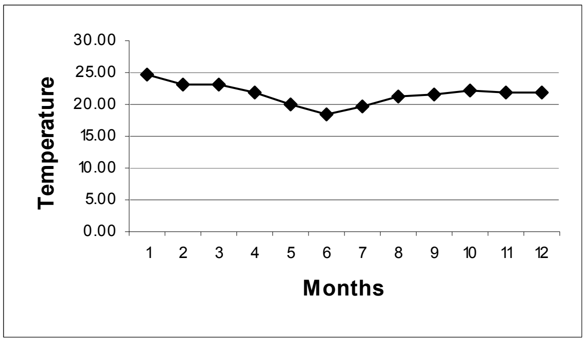

Figure 7 – Average temperature

It can be seen in figure 8 that the equation obtained using the simulated data is located between the two equations obtained with the actual data for the considered interval. They indicate clearly the strongest influence caused by temperature in energy consumption. It can be seen that the functions are very similar, although many equipments are not considered in the simulation (elevator, etc).

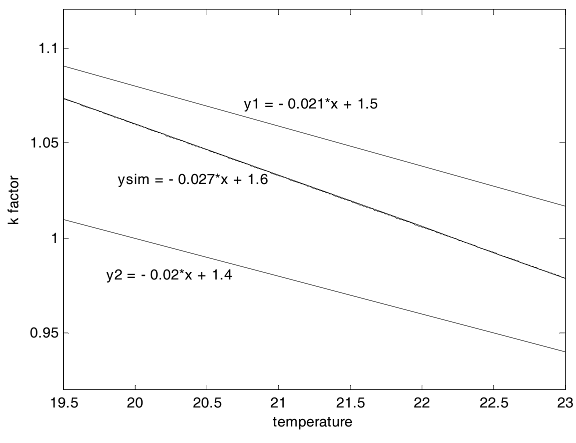

Figure 8 – K factor (actual data)

CONCLUSIONS

This paper presents a new building index energy performance that can allow the management engineer to follow the energy use during the months. There are many variables that change all the time during a normal routine day. Using an index that normalizes the data in relation of temperature it can be possible to compare the amount of energy used in hot months with the amount used in cold months without the concern of the temperature. The management engineer can control some other variables, like number of users inside the building and so on and then increase work quality. The simulation and actual data shows that the index presents a good improvement of the analysis

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