Evaluation of influences of the external temperature in the building energy consumption

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ABSTRACT

Forward of the shortage of energy resources, the rational use of the energy started to be a subject of great relevance. In the last years, the countries come taking conscience of this and searching alternatives to optimise the energy use. For constructed buildings, the alternative is to use installations efficiently. In this purpose, a pos-occupation evaluation becomes necessary to know the building performance and then helps an energy management. In countries of hot climate, the external temperature affects the thermal building performance and its energy consumption. Thermal inertia is a building factor that gives attenuation in the thermal load transferred into the building due the outdoor climatic. The time delay and the damping of the heat transference caused for thermal inertia cause delay in time response of the HVAC system and in the energy impact. This work searches the relationship between the building energy consumption and the external temperature. Analysing simulated and actual data it can be seen how the external temperature affects the energy consumption. Using that information it is possible to obtain an normalised energy performance index.

1. INTRODUCTION

The electric energy is the principal energy source used in Brazil (BEN, 2002). The buildings are responsible for an important parcel of this consumption. Because of that the architectural project, has to consider the form, the façades, dimensions of windows, the materials, but also the climatic conditions of the region.

The knowledge of the climatic condition is excellent in the project elaboration as well as determinative factor of final energy consumption. In the countries where the hot and humid climates predominate, a great difficulty in keeping the levels of comfort in the constructed environment exists, mainly in the summer. In the projected buildings already, 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 bigger the external temperature, the bigger will be the load necessary to neutralize the environment.

An energy performance index is a measuring tool, which makes possible to compare the 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 office buildings, 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 follow the energy use. One of the reasons for which these indices do not present good results is its dependence of external temperature for buildings with HVAC systems. For these cases, it is necessary to use an index that has taken into 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).

Analyses of simulated and actual data will be presented. Through this index it is possible to compare the energy use without temperature effect and making possible to evaluate the results of save energy actions.

2. 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. Both cannot help the efficiency energy performance evaluation.

For buildings, many specialists use the Area Energy Use Index (kWh/m2) to analyse the energy use. However, as this variable (area) is fixed, it does not serve as reference to analyse the variation of the energy use during a year. This index can help to verify trend of electric equipment growth in the installation, or either, density of energy consumption for area. An automatized company, which uses computers intensely, printers, copying coffee pots, machines, must have a bigger consumption that one with more manual service. The comparison of similar companies (for example of 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 (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 assist in the agreement of the causes of the energy expense increase among months since the energy expense can increase without that employee's number modifies.

The buildings that use HVAC systems suffer direct effect from the variation of the temperature. This amount has been very 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.

3. THE SIMULATION

The case-study building is located in Brazil, the central region of Belo Horizonte city (South Latitude 20º). It is a region of tropical climate, with hot and rainy summer and cold and dry winter. The building has 35,000.00 m2 of area, distributed in 21 floors (40.70 x 33.20m). The four façades have similar covering aspects and ratio. It has as volumetric form a parallelepiped with structure in concrete and covering in glass forming a continuous panel. It possesses vertical blinds in all façades (Fig. 1).

The employees work routine is Monday to Friday, 8:00 to 18:00 h. In the weekends, the building is almost closed. Central conditional air acts in all the floors and works between 5 to 19h. It can be selected for each floor one different temperature set point, most of all turning around 23º. The daily activities are essentially administrative. The sources of variation of the energy use turn around conditional air and of the request of the use of the elevators that vary with the flow of occupants and visitors in the building.

3.1 Time delay time and damping of heat transfer

To analyse the time delay and the damping of the heat transference caused for thermal inertia it has been simulated the building with all the important characteristics. It has been used the Energyplus software. Figure 1 presents the outdoor and indoor temperatures. In this case, there are no equipments and people inside building. The indoor temperature follows the outdoor one. There are a time delay and a magnitude damping. The magnitude damping is approximately 26%. The time delay is difficult to be seen in this figure. It is calculated by the cross-correlation between these temperatures. Figure 2 presents the results. The maximum of the cross-correlation curve give us the time delay that is approximately 20minutes.

Each building will have a different time delay time and the damping of the heat transfer-

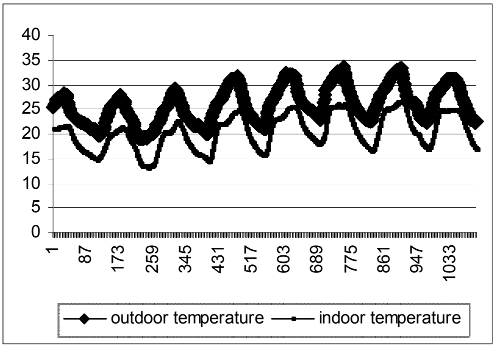

Figure 1: Simulated case results.

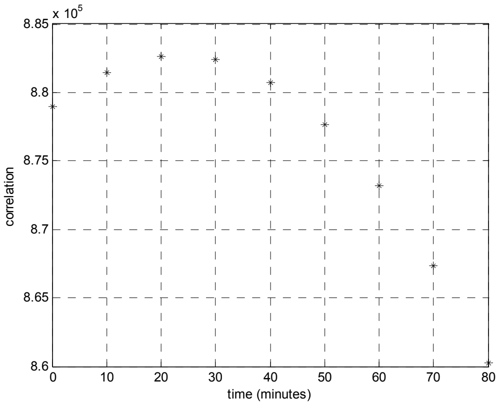

Figure 2: Cross-correlation between outdoors and indoors temperatures.

ence depending on its thermal inertia. It is important to determine because the HVAC system suffers the temperature effect with the time delay time imposed by the building thermal inertia.

3.2 Comparing the indices

Using the simulated building it is possible to compare the energy performance index in a clear way. In a real case, the energy use changes in the way that sometimes it is difficult to determine the causes. The simulated case can provide a clear analysis, because it is possible to analyse only the climate effects in building. It has been simulated a year of a building with the HVAC system. It is known that it is very difficult to compare different months energy uses because of climate changes. The energy consumption of the HVAC system varies monthly in function of temperature variation and the solar radiation Because of that the index that tries to normalise the energy index in relation to temperature could be very interesting for energy manager.

Figure 3 presents an energy index kWh/day and a normalised by the temperature kWh/(day*degree). The first one indicates clearly that the hot months (August to March) consume more energy in HVAC system, and the cold months consume much less energy. The second index tries to normalise the first index dividing it by the mean temperature. It can be seen that it is not a good normalisation procedure because the relation between the energy and temperature is not as simple.

3.3 Normalized Energy Use Index-NEUI

This paper presents a index called Normalized Energy Use Index. Using the output of the Energyplus, it is possible to calculate the NEUI. It can be calculated using equation 1.

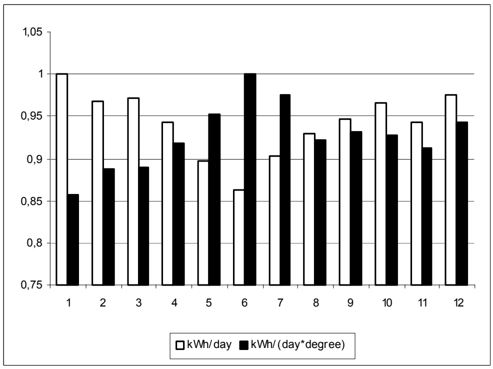

Figure 3: Energy performance index.

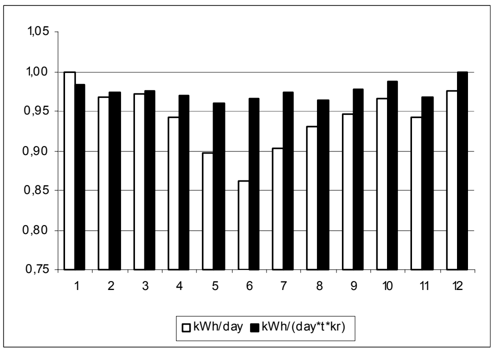

Figure 4: Energy performance index.

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

where:

t: is the monthly mean temperature,
$k(t)$: function of t.

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

Because 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 conditions that change 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. It is not true, because there are other climate variables that affect the energy use, like solar radiation and air velocity. But the temperature is one of the most important one and it is easier to measured too. Than, to eliminate the effect of that variable in the energy use, the index NEUI can be used.

As the temperature changes during the day, to calculate the temperature of the month it is used the month average temperature. In this case, we have the temperature of each hour of all months. The *factor k* is calculated by linear regression using the month energy consumption and average temperature, equation 2.

$$k = -0.027t + 1.6 \quad (2)$$

Where t is the monthly mean temperature.

Figure 4 presents the daily energy consumption and the NEUI. Both are presented in normalized values to allow the comparison. It can be seen that, the first index (kWh/day) has the same variation profile as the average temperature has. Cold months spend less energy than hot months, as expected.

The second index is the NEUI. It can be seen that its value is more constant. That is the idea of this index. The temperature effect 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 that 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 responsible of these 4% index variation is the other climates variables that is not used in the normalization process.

4. K FACTOR FOR A REAL CASE

Using the same reasoning to an actual data for the same building, the *k factor* is calculated. The better equation to represent the *actual k factor* is obtained by linear regression. For the actual building data the equation is presented in equation 3.

$$k = -0.02t + 1.4 \quad (3)$$

Other four buildings, those have HVAC systems, have been considered in this analysis. These buildings are located in the same city but in different points. It can be seen that a very similar equation is obtained for *k factor* again, Figure 5.

Then it can be affirmed that for buildings located in this city this *k factor function* can be used to normalize the energy index and allow the search for building energy efficiency by helping the management engineer to follow the energy use.

5. CONCLUSIONS

This paper presents a discussion about the temperature effect in building energy consumption. It is proposed 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 changes all the

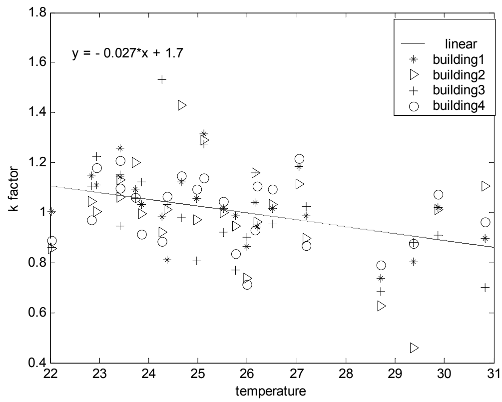

Figure 5: K factor for other buildings.

time during a normal routine day. But using a index that normalize the data in relation of temperature it can be possible to compare the energy use in hot months with cold months without the concern of the temperature. The management engineer can control some other variable, like number of person inside building and so on and than increase the quality of his work.

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