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APLICACIONES INDUSTRIALES

Energy savings from occupancy based control of the fan coil unit speeds: a case study

Ahorro de energía mediante control por presencia del ventilador del acondicionador de aire: caso de estudio

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RESUMEN/*ABSTRACT*

The guest spends a considerable time out of the hotel room but he usually keeps working the highest speeds of the fan coil unit. These units are frequently overlooked as a potential source of energy savings. On the other hand, with real time occupancy measurements and simple control algorithms high degree of energy saving is possible t obtain. In this work was analyzed the guest behavior towards the fan coil unit speed. The possible energy saving to obtain, if during the absence of the guest the 2nd or the 3rd speed of the fan coil unit is switched to the 1st, was calculated. The selected fan coil speed is proposed as an indicator of guest comfort. An occupancy based control that acts over the fan coil unit speed, when the guest is not in the room, is recommended for hotel rooms.

Key words: energy savings; occupancy based control; fan coil unit; hotel; HVAC.

El huésped pasa un tiempo considerable fuera de su habitación hotelera pero usualmente mantiene funcionando las velocidades más altas del aire acondicionado. Estos equipos son frecuentemente subestimados como fuentes potenciales de ahorro de energía. Por otra parte, con mediciones en tiempo real de la presencia del huésped y simples algoritmos de control un alto grado de ahorro de energía puede lograrse. En este trabajo fue analizado el comportamiento del huésped en relación a la velocidad del aire acondicionado. Fue calculado el ahorro de energía a obtener si durante la ausencia del huésped de la habitación se conmutasen la 2da o 3ra velocidad del aire acondicionado a la 1ra. Se propone utilizar la velocidad del aire acondicionado seleccionada por el huésped como indicador de su confort. Se recomienda emplear en las habitaciones hoteleras un control por presencia que actúe sobre la velocidad del aire acondicionado cuando el huésped no esté presente.

Palabras clave: *ahorro de energía; control por presencia; hotel; HVAC; unidad de aire acondicionado.*

INTRODUCTION

Energy efficiency in buildings is today a prime objective for energy policy at regional, national and international levels [1]. Particularly, the lodging sector is notorious for its high, and sometimes irrational, energetic consumption [2]. In Caribbean Hotels, due to the high temperatures, the climatization takes around the 65% of the total electric consumption [2], and in several Cuban touristic lodging companies this consumption represents 8 to 20 % of the total running costs [3]. Hotel guest rooms account for 40 to 80 % of energy use in the hospitality industry so they may hold great potential for cost savings [4].

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User activity and behavior is considered as a key element and has long been used for control of various devices such as artificial light, heating, ventilation, and air conditioning [5]. While occupancy prediction leads to small energy savings [6], with real time occupancy measurements high degree of them is possible just using simple control algorithms [7]. In fact, [6] and [7] assert that high energy savings without sacrificing comfort are possible with only occupancy measurements. The occupancy based control (OBC) is a well developed concept and from the 1990s has been indicated for hotels and other public buildings with short term and variable occupancy [8]. Occupant behavior is one of the major factors influencing building energy consumption and contributing to uncertainty in building energy use prediction and simulation. Its understanding is insufficient both in building design, operation and retrofit. Although there has been growing research and applications in this field, there are still significant challenges and opportunities [9]. Recent papers, in both theoretical and practical way, have focused on OBC for improving energy efficiency in several types of building rooms [6-8, 10, 11].

That hotel room guests often leave their air conditioning equipment running during their absence is something known and reported [10]. Fan coil units (FCUs) are frequently overlooked as a potential source of savings, although several hundreds to thousands of them may be in a single building. Furthermore, they usually employ low efficiency fractional horsepower motors (typically 60 % efficient) [12]. For around ten years, techniques as variable speed drive (VSD) have been used for retrofitting on FCUs [12], however using high efficiency equipment, is an opportunity that has not been correctly exploited worldwide [13].

This paper was focused on the FCU speed the guest left turned on when he was out of the room. The objective was to study the guest´s behavior toward FCU speeds, to quantify the energy savings possible to obtain if during guest´s absence to turn down the highest FCU speeds, as well as to propose the late as a useful OBC strategy for those installations with less efficient FCUs. It is also proposed to consider the selected FCU speed as a guest comfort satisfaction indicator.

MATERIALS AND METHODS

The study was carried out in the “Paradisus Río de Oro” hotel in the northeast of Cuba utilizing the installed there Sauter EY2400 Provi+ building management system (BMS). With that system we were able to gather information about the guest presence and the selected by him FCU speed.

In case the guest is absent, the installed there room OBC sets back the temperature set point from 24 ºC to 28 ºC but takes no action over the selected FCU speed. The electric power that can be saved by slowing down the FCU speeds is represented in equation (1) considering, that the power consumed by the FCU motor will increase with the third power of its revolutions [14].

$$P_1 = P_2 \times \left(\frac{N_1}{N_2} \right)^3 \tag{1}$$

Where: P is the electric power and N the rotation speed.

The first step was to know how many rooms were affected by this particular guest behavior. A total of 82 rooms were randomly selected for the survey. As a result, almost 43 % of them had selected on the second or the third FCU speed when the guest was not in the room (Table 1).

Table 1. Room occupancy and FCU speed state

Room occupancy and FCU speed	Qty.	%
Guest present	30	36.6
Guest not present (none or 1st speed)	17	20.7
Guest not present (2nd speed)	12	14.6
Guest not present (3rd speed)	23	28.1
Total	**82**	**100.0**

In second place, it was necessary to estimate for how long the client is outside the room. Five rooms were randomly selected and continuously monitored for 24 hours. The historical data of room occupancy was recorded using the BMS (fig. 1) and placed in table 2. It was calculated that the client is out of the room for about 9 hours and 18 minutes a day (9.3 in decimal representation), which is more than the third part of the day.

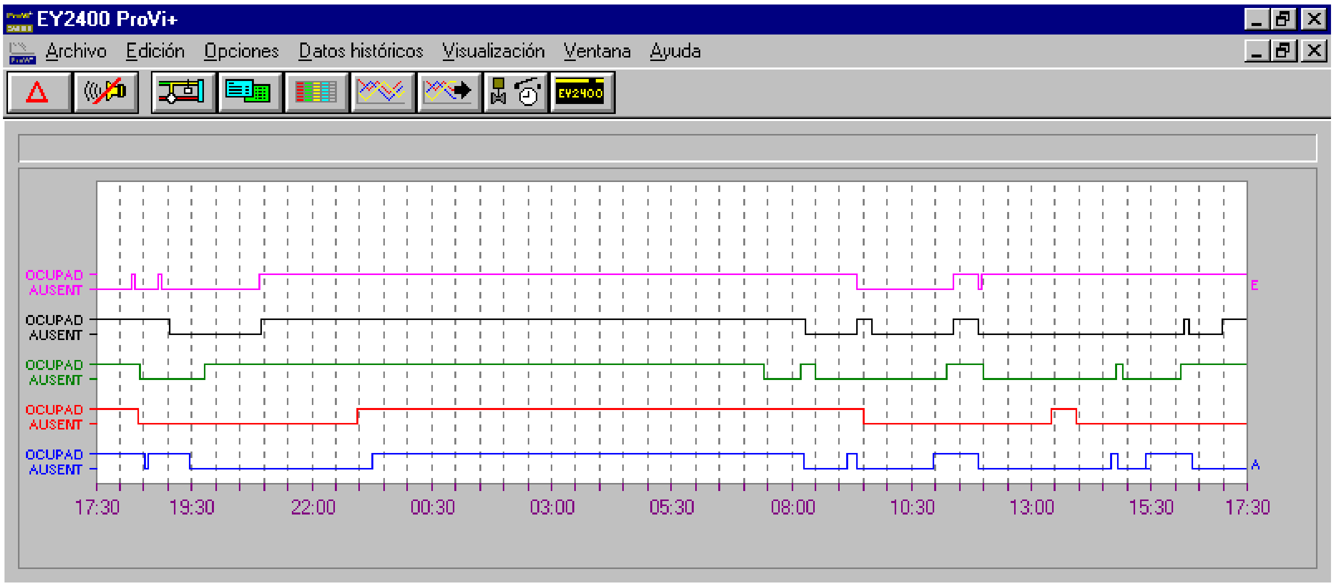

Fig. 1. Room occupancy in 24 hours (high level means guest present; low level means he is not).

Table 2. Average guest absence time

Room	Hours of guest absence per room (hh:mm)							Total
A	0:05	3:45	0:55	1:35	2:45	0:30	1:05	10:40
B	4:35	3:55	3:35					12:05
C	1:20	0:45	2:45	2:45	1:15			8:50
D	1:55	1:00	1:40	4:20	0:40			9:35
E	0:45	0:30	2:00	2:00	0:05			5:20
						Average hours		**9:18**

The energy savings by commuting the 2nd or the 3rd FCU speed to the 1st when the client is out of the room can be calculated using the following equation (2):

$$E = NTH \times HA \times D \times HD \times H3 \times \Delta P_{III-I} + NTH \times HA \times D \times HD \times H2 \times \Delta P_{II-I} \quad (2)$$

Where:

E - Energy savings (in kWh).

NTH - total hotel guest rooms.

HA - Hotel occupancy in one year (1=100%).

D - Number of days to include in the calculus of E.

HD - daily hours of guest absence (in hours).

H3 - Number of rooms without guest and with 3rd speed (%).

H2 - Number of rooms without guest and with 2nd speed (%).

ΔPIII-I - Electric power difference between 3rd and 1st FCU speed (in kW).

ΔPII-I - Electric power difference between 2nd and 1st FCU speed (in kW).

The equation (3), shows a simplified version of the equation (2):

$$E = NTH \times HA \times D \times HD \times \left[\left(H3 \times \Delta P_{III-I} \right) + \left(H2 \times \Delta P_{II-I} \right) \right] \quad (3)$$

Using the equation (3) the energy saving for the 298 room hotel, in a month and with an occupancy level of 80 % was calculated. The differences in power of the FCU speeds were calculated from their technical datasheets (ΔPIII-I = 0.136 kW and ΔPII-I = 0.037 kW).

$$E = 298 \times 0.8 \times 30 \times 9.3 \times [(0.281 \times 0.136) + (0.146 \times 0.037)]$$

$$E = 2.9 MWh$$

RESULTS AND DISCUSSIONS

As said before, 43 % of the rooms had selected on the 2nd or the 3rd FCU speed when the guest was not in the room which is a considerable amount of them. On the other hand, 9.3h of guest absence is more than the third part of the day. So, both facts imply a potential source of power savings. In one month, the hotel consumes 196 MWh of electric energy; then, the calculated energy savings of 2.9 MWh is about 1.5 % of this monthly consumption. Although 1.5 % could be considered a small figure, its value depends on the other building load energy losses, as pool, restaurants, kitchens, conference rooms, boutiques, disco and so on. In a hotel with none of these mentioned spaces the energy savings percentage will be higher.

What makes the guest to select one or another FCU speed is something not defined but related with his perception of comfort. When the room is too hot, is a common behavior that the guest puts the FCU at full speed, on the contrary, when it is too cold he slows down the FCU speed. So, the guest sees the FCU speed as another room temperature control, rather than an indoor air quality one. Following this analysis we propose to interpret FCU speed off as “comfort unwanted”, the lowest FCU speed as “high comfort satisfaction”; middle speed can be seen as “comfort satisfaction” and the highest speed as “comfort dissatisfaction”. Therefore, monitoring the selected FCU speed could bring immediate information about the guest comfort satisfaction.

CONCLUSIONS

The guest behavior towards the fan coil unit speed was studied. Keeping on the highest FCU speeds during guest absence was a behavior that affected almost the half of the rooms for about a third part of a day. Consequently, acting over the FCU speed when the guest is not in the room, will help in saving energy. In this sense, switching down the FCU speeds during guest absence is a recommended algorithm to be used in a typical room OBC of a hotel or a similar building. An analysis of how much energy can be saved, and an equation to properly calculate it was developed. A similar analysis and equation can be applied to a similar building by using their specific FCU electric parameters.

The selected by the guest FCU speed is in relation with his level of room comfort satisfaction. A simple relation between guest comfort and FCU speed was proposed and qualified. However, further studies that would take into account not only the FCU speed, but also the variation of the room temperature set point (24 ± 2 ºC) made by the guest should be done.

As monitoring the selected FCU speed brings immediate information about the guest comfort satisfaction, it is a useful tool while doing research or managing the installation.

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