A MODEL FOR ENERGY PREDICTIONS OF A HOTEL ROOM

Adriana Acosta Corzo[(a)], Ana Isabel González Santos[(b)], Jesús M. Zamarreño Cosme[(c)], Víctor Álvarez Castelló[(d)]

[(a)] Automatic Control and Computation Department, Electrical Faculty, ISPJAE C/ 114 47011 Marianao C. Habana,Cuba
[(b)] System Engineering and Automatic Department, Faculty of Science,
[(c)]University of Valladolid c/Prado de la Magdalena, s/n 47011 Valladolid, Spain
[(d)] Hotel Energy Staff Havana City

[(a)] luism.rodriguez@etecsa.cu, [(b)] anita@electrica.cujae.edu.cu, [(c)]jesusm@autom.uva.es

ABSTRACT
In this paper a model for energy predictions in three different rooms in a Havana hotel is obtained. The method is based in the determination of the cooling load of the hotel rooms using method Radiant Time Series, RTS. The model was verified with real values of energy consumption in hotel and the results are promissory.

Keywords*:* Energy saving, Modelling, Predictions

1. INTRODUCTION

It is well known that hotel facilities are characterized by being buildings with a permanent use along the year and where their main objective is to ensure comfort and quality for guests in all services during their stay at the facility. (González 1996).

Because of the characteristics of hotel buildings, on hotel rooms and bedrooms, as well as on buildings in general, the cooling load can be predicted without difficulty during the process of designing the air conditioning system. (ASHRAE, 2007). The great diversity in the design, purpose, and use of hotels and motels makes analysis and load studies very important. Load diversification is due to guest rooms' transient occupancy and the diversity associated with support facility operation.

Hence, a climate control system is required, with great flexibility, to meet the conditions of comfort for the occupants during 24 hours. Wide load swings and diversity within and between rooms require a flexible system design for 24-hour comfort. Besides the opening of windows, the only way to provide flexible temperature control is to have individual room components under individual room control that can cool, heat, and ventilate independently of equipment in other rooms.

As stated in the literature, we have identified that the biggest consumers of electricity in a building are air conditioning systems, water pumping and lighting. (Gómez)

Energy use in commercial buildings represents a direct cost to business, while the thermal comfort, visual comfort and indoor air quality of the indoor environment have a substantial bearing on occupants' productivity. It is more than obvious that improved energy efficiency and reduction of energy cost can have beneficial impacts on the competitiveness, the environment, the health and the well being of citizens. (Nikolaou, Kolokotsa and, Stavrakakis).

The demand for energy and fuel consumption of heating, ventilating and air conditioning has a direct impact on the cost of operating a building and an indirect impact on the environment. (ASHRAE, Chapter 32, 2005) .

According to some previous works, the direct impact of the operation of heating, ventilation and air conditioning energy consumption of a building reaches up to 60% of the total energy consumption, thus the importance of paying special attention to this subject. (FIDE 2004; Mohanty 2004; Nikolaou, Kolokotsa and, Stavrakakis; Trott and Welch 2000).

In the analyzed data of consumers of electricity at the hotel, subject of this study, it is considered that the requirements of the hotel air conditioning system are among 61 and 63% of the total electrical energy that is consumed.

Of great interest to researchers and specialists in automatic control has been the application of many control strategies for better management of the air conditioning system, so that a considerable amount of electricity consumption can be saved, without compromising the required comfort.(González and Zamarreño 2005; Ismail 2003).

In the diversity of strategies applied one can identify predictive control, which uses a mathematical model of the process to predict the future evolution of the controlled variable on the prediction horizon. (De Prada 1996).

Obtaining a model for assessing the energy consumption of centralized air conditioning system that cools the hotel rooms is the main objective of this work, as well as the verification of the correct predictions adapted to the conditions of application.

The strategy used in the estimation of energy consumption of the centralized climate system consists of three basic elements: the calculation of the cooling load of the space under consideration, load and energy consumption of secondary equipment, and finally the energy consumption of primary equipment which refers to the large units with their respective chillers.

As a first step in this strategy, we will focus on determining the cooling load or thermal power of the hotel rooms. Various procedures to calculate this magnitude have been reported. Some of the simplest assume that this value depends only on the temperature outside the area as such (González and Zamarreño 2005). Other methods, more detailed, believe that it is a function of other concepts such as: the effects of solar radiation, internal heat gains, stored heat inside the walls, the effect of the wind, the atmosphere of the building and infiltration.

The calculation procedure that is used in this study to determine the cooling load on the hotel rooms, as a basis for analysis of energy consumption in the centralized air conditioning system of the entire installation, is the method of Radiant Time Series, RTS. (ASHRAE, Chapter 30, 2005)

In this work, there have been several studies with different rooms at different times of the year, which have allowed us to verify the feasibility of the application of the method in the estimation of energy consumption. The location of the surveyed rooms corresponds to different geographic areas of the building, so the behaviour of the cooling load in different areas, where the incidence of solar radiation is different in magnitude and time of the day, can be analyzed.

In a previous work, we proposed a model for predicting the cooling load of a room, to be used in the design of a predictive controller that minimizes the energy consumption of a hotel in Havana, as part of a comprehensive strategy for monitoring and control that takes into account the influence of the efficient use of energy carriers in hotel facilities. (Acosta and González 2007).

In this paper, we propose the evaluation of the results of the model previously obtained in the specific conditions of the mentioned hotel, using as a basis of the survey, data of energy consumption and also room occupancy, during 2007.

Results of the model were compared with actual values of daily energy consumption, which are available in a database.

2. MATERIALS AND METHODS

The radiant time series (RTS) method is a simplified method for performing design cooling load calculations that is derived from the heat balance (HB) method. (McQuiston and Spitler 1992). This method was developed to offer a method that is rigorous, yet does not require iterative calculations, and that quantifies each component's contribution to the total cooling load. In addition, it is desirable for the user to be able to inspect and compare the coefficients for different construction and zone types in a way that illustrates their relative effect on the result. These characteristics of the RTS method make it easier to apply engineering judgment during the cooling load calculation process.

The heat transfer can be accomplished through three processes: conduction, convection and radiation. The presence of such processes or a combination of them depends on the characteristics of the surfaces of the elements involved in the transfer of heat. Conduction and radiation processes have inherent delays.

In any particular room, heat sources are disparate and to determine the total heat load it is necessary to take them all into consideration.

The RTSM calculation procedure is illustrated in figure 1. The RTS method is based on the calculation of the gain for each source of heat, and then considers the delays of the conduction and radiation processes .

For this purpose, it uses the so-called radiant and conduction time factors, which are simply ratios of a series of time that distribute heat gains effectively over time. As heat gains are calculated each hour, which is sufficient to track the behaviour of the load, the time series consists of 24 factors and by definition, every radiant or conduction time series must totalize 100%.

The general procedure for calculating cooling load for each load component (lights, people, walls, roofs, windows, appliances, etc.) with RTS is as follows:

1. Calculate 24 h profile of heat gains components for the selected day (for conduction, first account for conduction time delay by applying conduction time series).
2. Split heat gains into radiant and convective parts for radiant and convective fractions.
3. Apply appropriate radiant time series to radiant part of heat gains to account for time delay in conversion to cooling load.
4. Sum convective part of heat gain and delayed radiant part of heat gain to determine cooling load for each hour for each cooling load component.

After calculating cooling loads for each component for each hour, sum those to determine the total cooling load for each hour and select the hour with the peak load for designing of the air-conditioning system. Repeat this process for multiple months to determine the month where the load peak occurs, especially with windows on southern exposures (northern exposure in southern latitudes), which can result in higher peak room cooling loads in winter months than in summer.

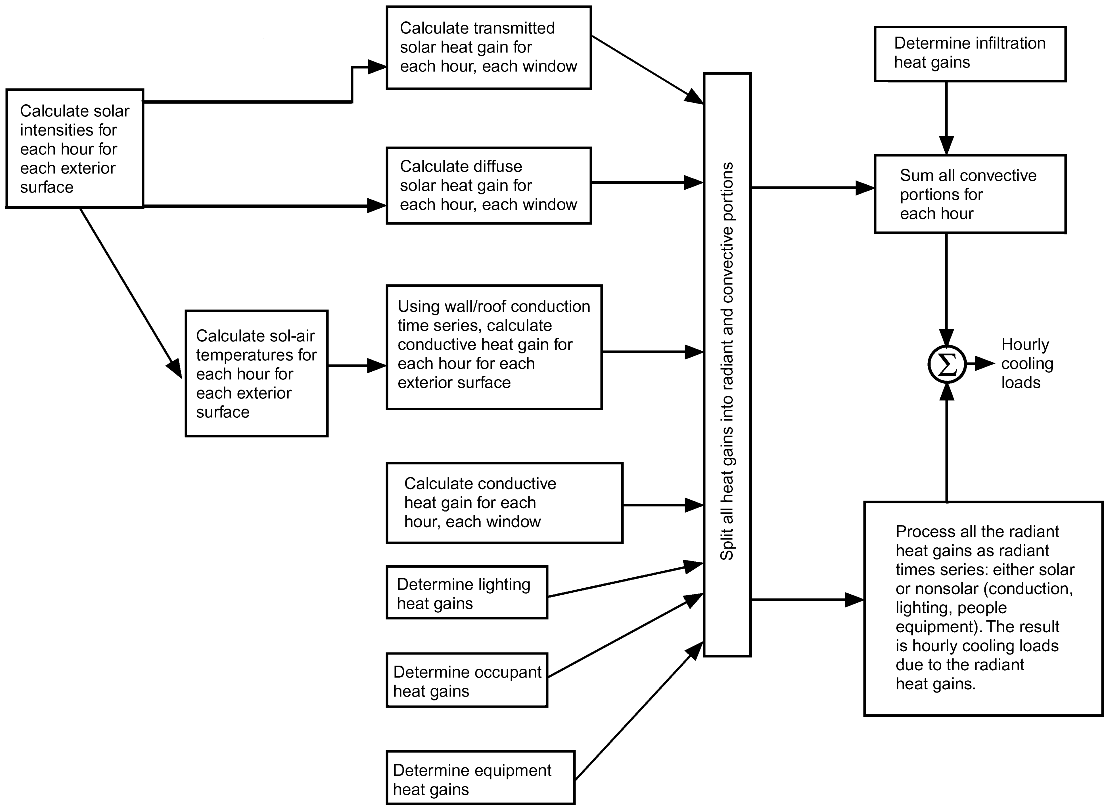

Figure 1: Overview of Radiant Time Series Method

In the RTS method, conduction through exterior walls and roofs is calculated using conduction time series (CTS). Wall and roof conductive heat input at the exterior is defined by the familiar conduction equation as:

$$q_{i,\vartheta-n} = UA\,(t_{e,\vartheta-n} - t_{rc}) \qquad (1)$$

where
$q_{i,\theta-n}$ = conductive heat input for the surface n hours ago, W
U = overall heat transfer coefficient for the surface, W/(m$_2$·K)
A = surface area, m^2
$t_{e,\theta-n}$ = sol-air temperature n hours ago, °C
t_{rc} = presumed constant room air temperature, °C

Conductive heat gain through walls or roofs can be calculated using conductive heat inputs for the current hours and past 23 h and conduction time series:

$$q_{\theta} = c_0 q_{i,\theta} + c_1 q_{i,\theta-1} + c_2 q_{i,\theta-2} + c_3 q_{i,\theta-3} + ... + c_{23} q_{i,\theta-23} \qquad (2)$$

where
q_θ = hourly conductive heat gain for the surface, W
$q_{i,\theta}$ = heat input for the current hour, W
$q_{i,\theta-n}$ = heat input n hours ago, W

The radiant time series method converts the radiant portion of hourly heat gains to hourly cooling loads using radiant time factors, the coefficients of the radiant time series.

$$Q_{r,\vartheta} = r_0 q_{r,\vartheta} + r_1 q_{r,\vartheta-1} + r_2 q_{r,\vartheta-2} + r_3 q_{r,\vartheta-3} + ... + r_{23} q_{r,\vartheta-23} \qquad (3)$$

where
$Q_{r,\theta}$ = radiant cooling load (Qr) for the current hour (θ), W
$q_{r,\theta}$ = radiant heat gain for the current hour, W
$q_{r,\theta-n}$ = radiant heat gain n hours ago, W
r_0, r_1, etc. = radiant time factors

The radiant cooling load for the current hour, which is calculated using RTS and Equation (3), is added to the convective portion to determine the total cooling load for that component for that hour.

3. EXPERIMENTS

The hotel selected for the application of the calculation method is located in the northwest part of the city of Havana, Cuba.

The building has 413 rooms, divided in two blocks. The A-block has 297 rooms in a 9-floor and B-block has 116 rooms in 4 floors. According to its structure and layout, there are three types of rooms: "A", "B" and "C". All measurements were performed in rooms of "A" type, which constitute the majority. For this reason, the building characteristics of the surveyed rooms were similar; the difference comes from their geographical location.

Table 1 shows total rooms by type and geographical location.

Table 1: Total rooms and geographical location

Location	Total rooms	Room Type
N	98 (44 single and 54 double)	A
NW	26	B and C
W	118	A
WS	8	B and C
S	41	A
SE	14	B and C
E	90	A
NE	18	B and C

Inside the room, there is the following equipment: a hair dryer in the bathroom, a coffee machine, a television set, moderate lighting and a small refrigerator. The furniture is abundant. It is believed that the greatest heat gain is the glass door separating the room from the balcony.

Temperature measurements were performed inside the room and on the balcony. We used a four-channel thermometer from "Hanna Instruments". The measurements were performed on February, August and October 2007.

The coefficients of the time series were generated with the help of a program developed by Iu, Pisen (Calvin) of the Faculty of Mechanical and Aerospace Engineering of the State University of Oklahoma, known as “PRF / RTF Generator”.

The program needs as input the constructive detail of the thermal area selecting the types of materials from a database published in the ASHRAE manual (Sowell 1988) .

Table 2 and Figure 2 show the result of the conduction time series generated by the program, for an "A" type room.

The results of the experiments are described in the work (Acosta and González 2007), those compares the behaviour of the load for rooms 7138 and 9109 in A-Block.

In this paper, unlike (Acosta and González 2007), results for three rooms are used: the two mentioned above and a third, 4206, belongs to B-block.

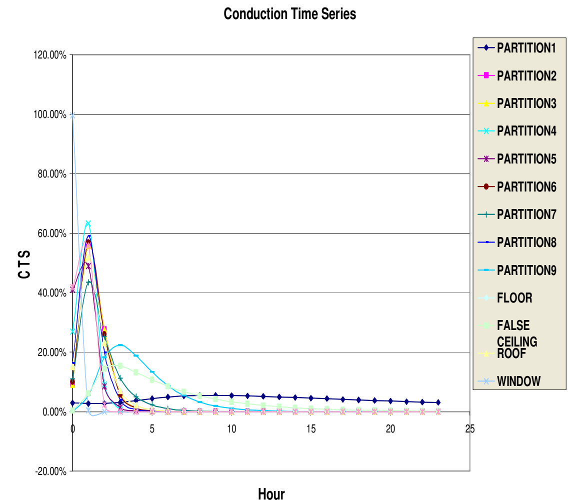

Figure 2: Coefficients of the time series by conduction, CTS, for the walls and divisions of room "Type A".

Table 2: Partition’s Conduction Time Series (CTS)

Surface Name	**PART. 1**	**PART. 2**	**PART. 3**	**PART. 4**
Hour	**CTS**	**CTS**	**CTS**	**CTS**
0	2.90%	9.00%	9.00%	26.92%
1	2.76%	55.76%	55.76%	63.31%
2	2.72%	27.68%	27.68%	9.12%
3	3.05%	6.03%	6.03%	0.62%
4	3.71%	1.22%	1.22%	0.04%
5	4.40%	0.25%	0.25%	0.00%
6	4.93%	0.05%	0.05%	0.00%
7	5.27%	0.01%	0.01%	0.00%
8	5.43%	0.00%	0.00%	0.00%
9	5.46%	0.00%	0.00%	0.00%
10	5.40%	0.00%	0.00%	0.00%
11	5.28%	0.00%	0.00%	0.00%
12	5.12%	0.00%	0.00%	0.00%
13	4.94%	0.00%	0.00%	0.00%
14	4.74%	0.00%	0.00%	0.00%
15	4.53%	0.00%	0.00%	0.00%
16	4.33%	0.00%	0.00%	0.00%
17	4.13%	0.00%	0.00%	0.00%
18	3.93%	0.00%	0.00%	0.00%
19	3.74%	0.00%	0.00%	0.00%
20	3.56%	0.00%	0.00%	0.00%
21	3.38%	0.00%	0.00%	0.00%
22	3.22%	0.00%	0.00%	0.00%
23	3.06%	0.00%	0.00%	0.00%
Sum	100.00%	100.00%	100.00%	100.00%

4. RESULTS AND DISCUSSION

For the implementation of the method in the current application all calculations of the cooling load were programmed on MATLAB language. (MATLAB 2006).

Every day, temperatures outside and inside different rooms were measured. The results are shown in Table 3. It includes the values of the maximum difference between outside and inside temperature of the room, the time of occurrence of such difference and the values of the outside average temperature of the room for each measurement date.

Figure 3 represents the results of measuring the temperature outside for each room. Despite being represented at different seasons, the differences between the average temperatures are not so remarkable.

Table 3: Measured outside temperature

Outside temperature				
Date	Room	ΔTmax [°C]	Hour ΔTmax	Tmean [°C]
23/2/2007	7138	11.4	17:00	24.695
13/8/2007	7138	7.5	12:00	25.937
14/8/2007	7138	9.8	14:00	27.145
18/8/2007	7138	11.1	13:00	28.458
26/2/2007	9109	9.0	15:00	26.004
3/10/2007	4206	7.7	12:00	26.050
4/10/2007	4206	7.1	16:00	26.316
5/10/2007	4206	7.0	14:00	26.341

Nomenclature:
ΔTmax: Maximum difference between outside and inside temperature
Hour ΔTmax: Time of occurrence of the maximum difference
Tmean: Average values of the outside temperature

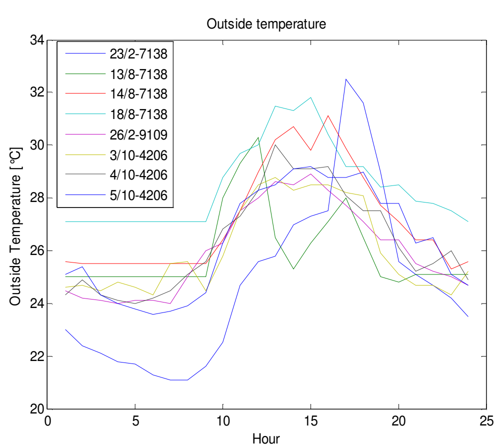

Figure 3: Outside temperature of rooms

Table 4 shows observed values of the cooling load as determined by the implementation of the RTS method, considering the temperature measurements from Figure 3.

Table 4: Cooling load determinate by method RTS

Cooling load by RTS						
Date	Room	qmax [kW]	Hour qmax	qmin [kW]	Hour qmin	qmean [kW]
23/2	7138	2.980	17:00	0.503	6:00	1.140
13/8	7138	3.151	17:00	0.588	6:00	1.259
14/8	7138	3.221	17:00	0.633	6:00	1.332
18/8	7138	3.268	17:00	0.696	6:00	1.394
26/2	9109	3.076	9:00	0.456	6:00	1.139
3/10	4206	1.363	14:00	0.453	6:00	0.791
4/10	4206	1.359	20:00	0.440	6:00	0.747
5/10	4206	1.389	20:00	0.451	6:00	0.781

Nomenclature:
qmax: Maximum cooling load
Hour qmax: Time of occurrence of the maximum cooling load
qmin: Minimum cooling load
Hour qmin: Time of occurrence of the minimum cooling load
qmean: Average load of the room.

The behaviour of the values of the load at each room depends on its geographical location, taking into account that the influence of solar radiation is different. One room is located in the west wing, where the sun shines in the afternoon. Another room in the northern wing, where the incidence of the sun is much lower, and one in the east wing where the sun shines in the morning. Figure 4 shows the values calculated for the total cooling load of the room for each hour during each date of study.

As in the total value of the load all sources of heat gain are important (generated by the occupants, equipment in use, etc..), in Room 4206, where the values of fenestration are small compared to other sources, it is not possible to observe the trend of the behaviour of the load as a function of the incidence of solar radiation, it can be related from Figure 5, where fenestration determined for each measurement date can be seen.

Fenestration is an architectural term that refers to the arrangement, proportion, and design of window, skylight, and door systems within a building. For our purposes, fenestration and fenestration systems will refer to the basic assemblies and components of exterior window, skylight, and door systems within the building.

To verify the results obtained through the RTS method, we used electrical consumption records from the hotel, as well as the number of occupied rooms for the dates on which the measurements were taken. Considering the equipment installed in the building, electricity consumption for cooling corresponds to 63% of the total value; so all the calculations have been performed in the 60 to 66% range of electricity consumption which corresponds to the point of view expressed in the literature, (FIDE 2004; Mohanty 2004; Nikolaou, Kolokotsa and, Stavrakakis; Trott and Welch 2000), and in turn allows us to get a range of variation.

Table 5: Energy and occupancy

Energy and Occupancy				
Date	Energy [kWh]	Occupancy	61 % Energy [kWh]	63 % Energy [kWh]
23/2/2007	17060	335	10406,6	10747,8
26/2/2007	20071	343	12243,3	12644,7
13/8/2007	22432	261	13683,5	14132,2
14/8/2007	23837	300	14540,6	15017,3
18/8/2007	27612	334	16843,3	17395,6
3/10/2007	25437	227	15516,6	16025,3
4/10/2007	25757	305	15711,8	16226,9
5/10/2007	26502	208	16166,2	16696,3

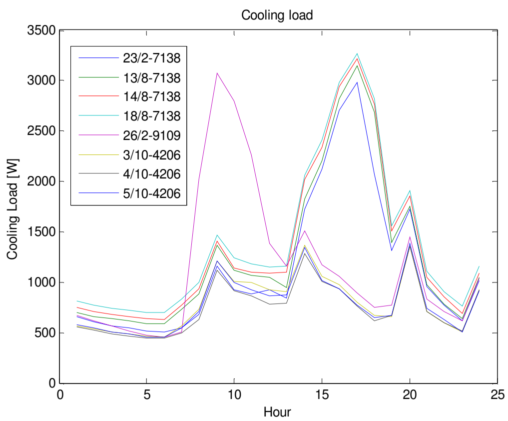

Figure 4: Values of the cooling load calculated for each room.

Table 5 shows the values of total electricity consumption of the hotel, total of occupied rooms and the values corresponding to 61 and 63 % respectively of the total electricity consumption.

During the assessment, it is necessary to consider the nominal electric consumption of the equipment inherent in the climate control system in local offices, restaurants, lounges and other local events in the building, as well as water pumps, fans and cooling units of the fan coils units rooms, so the consumption of only the compressors can be determined. For this purpose, we took into account that the load factor of the engines was 0.75. The nominal power of fan coil units of the rooms was calculated depending on the number of rooms occupied.

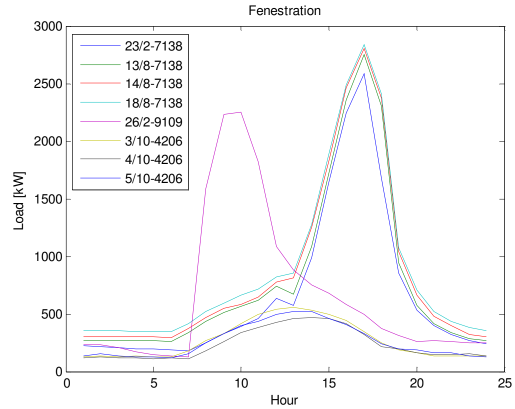

Figure 5: Fenestration values calculated for each room.

The values for the energy consumption of all electric motors, which are involved in the climate control system, taking into account the working hours for each one, was inferred from the total value of electricity consumption hotel (see Table 6) , obtaining electrical energy consumption for the compressors alone. Energy consumption in local offices and restaurants was obtained too by analyzing hotel energy database.

To describe the operation of the compressors, is frequently used, the coefficient of performance known as COP (Coefficient of Performance). This ratio represents the relationship between refrigerating capacity of the compressor and its electricity consumption. (ASHRAE, Chapter 32, 2005). The COP was considered characteristic of the cooling units installed at the hotel, with a value of 2.2.

Table 6: Consumption of compressors

Date	Compressors in "on"	Energy consumption by compressors in "on" [kWh]	Energy consumption by local offices and restaurants [kWh]	Energy consumption by rooms only [kWh]
23/2	11	9675.6	5617.9	4057.7
26/2	11	9675.6	5617.9	4057.7
13/8	12	10555.2	6128.6	4426.6
14/8	12	10555.2	6128.6	4426.6
18/8	8	7036.8	4085.7	2951.1
3/10	13	11434.8	6639.3	4795.5
4/10	13	11434.8	6639.3	4795.5
5/10	13	11434.8	6639.3	4795.5

If we multiply the value of the electricity consumption of a compressor by the corresponding COP, we get the value of the refrigerating capacity. Dividing for 24, we get out the value of the cooling load, which can be removed by the action of the compressors.

Table 7: Cooling load of occupied room calculated taking into account electrical consumption of compressors.

Date	Refrigerating capacity compressors by rooms only [kWh]	Cooling load in total occupied room [kW]	Occup.	Cooling load in each occupied room [kW]
23/2	8926.94	371.95	335	1.110
26/2	8926.94	371.95	343	1.084
13/8	9738.52	405.77	261	1.554
14/8	9738.52	405.77	300	1.352
18/8	6492.42	270.51	334	0.809
3/10	10550.1	439.58	227	1.936
4/10	10550.1	439.58	305	1.441
5/10	10550.1	439.58	208	2.113

Table 7 shows cooling load in each room. These values were obtained by the difference between total energy consumption by compressors in "on" and energy consumption by local offices and restaurants. We get an average value of the cooling load of the hotel rooms dividing the value of the obtained cooling load in total occupied room by occupancy.

Table 8: Comparison of range of cooling load by RTS method and cooling load by real data of compressors consumption

Date	[qmin-qmax] range cooling load by RTS method [kW]	Cooling load by room [kW]
23/2/2007	[0.503 - 2.980]	1.110
26/2/2007	[0.588 - 3.151]	1.084
13/8/2007	[0.633 - 3.221]	1.555
14/8/2007	[0.696 - 3.268]	1.353
18/8/2007	[0.456 - 3.076]	0.809
3/10/2007	[0.453 - 1.363]	1.936
4/10/2007	[0.440 - 1.359]	1.441
5/10/2007	[0.451- 1.389]	2.113

Table 8 presents the intervals of the cooling load obtained by RTS method, and the values of the cooling load, determined taking into account the consumption of the running compressors.

5. CONCLUSIONS

The temperature measurements show the presence of external disturbances affecting their behaviour. Disturbances can be rain, wind speed, clouds and others.

The study confirms what can be found in the literature with regard to the fact that the consumption of air conditioning systems corresponds to a 60 to 66% range of total consumption. For this hotel we found to be between 61 and 63%.

From the results, we conclude that, with the exception of the results corresponding to Room 4206 of Block A, the values obtained for the cooling load for the 7138 and 9109 hotel rooms are in range, comparing them with real data.

Moreover, the values obtained by the application of the method RTS in the 4206 room are lower than those obtained from the actual consumption, which asserts the existence of a reservoir of energy savings, this should be investigated further and will contribute to the success of the implementation of a comprehensive strategy for monitoring and control.

6. FURTHER WORK

It is necessary to perform more measurements, in order to obtain a larger sample of the behaviour of the temperature in different seasons and in different rooms.

It is also necessary to undertake more studies to obtain the power consumption of each individual cooling device.

ACKNOWLEDGMENT

The authors thank the cooperation of the hotel staff, who allowed the realization of the measurements basis of this work and Ms Mercedes Garcia for the English language revision.

The third author thanks the support of the "Ministerio de Educación y Ciencia" through the project "Técnicas avanzadas de supervisión y control para la operación óptima de EDARS".

REFERENCES

Acosta, C.A., González, S.A.I., 2007. Primera aproximación a un modelo de predicciones energéticas de habitación hotelera. *XIII Convención de Ingeniería Eléctrica,* UCLV, Cuba.

ASHRAE, 2005. Chapter 30, Nonresidential cooling and heating load calculation procedures, *ASHRAE Handbook of fundamentals*. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

ASHRAE, 2005. Chapter 32, Energy Estimating and modeling methods, *ASHRAE Handbook of fundamentals*. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

ASHRAE, 2007. Chapter 5, Hotels, Motels, and Dormitories, *ASHRAE Handbook of fundamentals*. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

De Prada, C. 1996. *Fundamentos de control Predictivo de Procesos*, Instrumentación y Control de Procesos: Los manuales de Ingeniería Química.

FIDE, 2004. *Administración de la demanda y experiencias de ahorro de energía eléctrica, Fideicomiso para el ahorro de energía eléctrica*. San Salvador.

González, P.A., Zamarreño, J.M., 2005. Prediction of hourly energy consumption in buildings based on a feedback artificial neural network. *Energy & Buildings* 37/6, pp. 595-601.

González, Santos A. I., 1996. *Sistema de regulación automático para controlar el índice de confort en ambientes climatizados*. Tesis de Maestría. ISPJAE. Cuba.

Gómez, S., *Cuba apunta hacia edificios inteligentes*. XI Convención de Informática, Tribuna de la Habana, edición digital.

IP Seng IU, 2002. *Experimental Validation of the radiant time series method for cooling load calculations*, Oklahoma State University.

Ismail M. Budaiwi, 2003. Air conditioning system operation strategies for intermittent occupancy building in a hot – sumid climate, King Fahd university of petroleum and minerals architectural Engineering Department, *Building simulation.*

MATLAB, 2006. The Language of technical computing. Version 7.2.0.232 (R2006a), The MathWorks, Inc.

McQuiston, F.C. and J.D. Spitler, 1992. *Cooling and heating load calculation manual*, 2nd ed. ASHRAE.

Mohanty B., 2004. Energy efficient air conditioning system, Asia Pro Eco Training Workshop in the Maldives ED72.03 Rational Use of Energy in Industry SMILES MALDIVES: *Building Energy Management*.

Nikolaou, T., Kolokotsa, D., Stavrakakis, D., *Introduction to Intelligent Buildings: INTELLIGENT BUILDINGS: THE GLOBAL FRAMEWORK.*

Sowell, E.F., 1988. Cross-check and modification of the DOE-2 program for calculation of zone weighting factors, *ASHRAE Transactions* 94(2):737-53.

Trott A. R. and Welch T., 2000. *Refrigeration and air-conditioning*, Third edition by Butterworth-Heinemann.