PROCEDURE FOR PERFORMANCE DIAGNOSTIC FOR SMALL AIR CONDITIONING SYSTEMS USING DYNAMIC SIMULATIONS

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ABSTRACT

Because of their low cost, small air conditioning, systems are often installed without any study on building envelope performance and without strictly complying with the rules of art. This article presents a pragmatic and global approach to diagnose performances of air-conditioned building relying on a numerical tool and dynamic simulations of buildings coupled with HVAC systems. Simulations calculate the required cooling power and evaluate the impact of the implementation and of maintenance. The result of this global analysis helps to qualify the entire system by assigning an energy label. The article presents the architecture of the numerical simulation tool and the energy criteria used to express the overall performance. A comparison with measurements and an analysis of case studies provide some elements of validation.

INTRODUCTION

Consumption of buildings accounts for over 40% of electricity consumption in France and in many developed countries in the world. In hot climates, air conditioning (AC) often represents the largest share of electrical consumption in a building. Small room air conditioning units are marketed freely and, in most cases, few regulations apply during their installation. When air conditioning is essential to ensure comfort conditions in hot climates, there are, however, ways to reduce energy consumption in buildings. Improve the design of buildings and systems, to reduce cooling loads is the subject of many research in southern hemisphere tropical climates. Much expertise has been developed on this topics especially in the case of French overseas departments warm climates (Garde, 2007), (Lucas, 2008).

Assessing energy performance, defining energy rating and labeling systems for buildings are major issues addressed since the early 1990s. Many initiatives were conducted to define global procedures to rate or label buildings and/or their components, especially in the European country (Directive, 1993), and in the US (EIA, 1995). In the US, the Environmental Protection Agency (EPA) introduced ENERGY STAR in 1992 as a voluntary government program to increased energy efficiency of product and homes. In 2000, Green Building Council (USGBC) introduced the Leadership in Energy and Environmental Design (LEED) (Turner et al., 2008). Every certification method faces critical issues (Pérez-Lombard et al., 2009) as (1) definition of the energy performance index, (2) development of an energy performance calculation tool, (3) setting a threshold value for the performance index, (4) definition of the comparison scenario, (5) definition of the scale for energy labeling, (6) identification of potential energy efficiency measures and (7) gathering energy information in the certification process. As mentioned by Conti (Conti, 1994): Three different approaches are commonly used for building certification or labeling:

- Computational approaches relying on input data collected by an energy auditor.
- Performance approaches based on energy bills.
- Measurement based approaches consisting of in situ measurement procedures.

Using the measurement approach, Richalet (Richalet, 2001) developed a methodology for single family houses, including the experimental equipment, the monitoring protocol and the calculation tool. Radu Zmeureanu (Zmeureanu et al., 1999) developed energy rating system for existing houses which can be qualified has combined as it uses information from utility bills with on-site measurements and computer simulation. This tool is dedicated to buildings under cold climate and has been applied in Montreal City. Lee Siaw Eang proposes a labeling program for the hot and humid climates of Singapore and especially design for office buildings using central air conditioning systems (Lee et al., 2008). This system is similar to the US Energy Star system as it is based on a national benchmark but it considers system's efficiency.

This paper presents a pragmatic, comprehensive and combined approach for the labeling of existing buildings. It was developed for tropical territories located in the southern hemisphere. The approach is original because it offers an energy audit based on hourly simulations for the studied building and over a period of one year. The simulations allow the study of buildings equipped with air conditioning but they can also be started assuming that the building has no air conditioning, to see if it is required. For the duration of the audit remains reasonable, description of the building is simplified. The approach is comprehensive because it also includes a dissemination strategy based on an awareness of building owners. The methodology will be exposed in a first part of this paper, including the description of the diagnostic procedure, the dissemination of this approach and the simulation tool. Then, details on the simulation inputs will be presented followed by the description of the outputs and reference figures. Finally, this article will provide a brief experimental comparison.

METHODOLOGY

The methodology used is based on energy audits of premises equipped with split system air conditioning. It has two main steps:

- A diagnostic procedure relying on a simple to use tool for dimensioning and performance analysis of air-conditioning installations. This procedure is also based on developing materials to support the analysis and the search for improvements for the studied building.
- Some dissemination actions to promote this approach to the public, the owners and the potential energy auditors, as well as the completion of training programs for the energy auditors.

For this exercise to be undertaken on a significant scale, it must remain simple in its implementation and with the use of computer tools. A number of limitations are set:

- The approach applies only to buildings located in climates where air conditioning is commonly used. In tropical climates, these are low-lying coastal areas. For altitudes above, 400m bioclimatic building design ensures satisfactory comfort conditions without the use of air conditioning.
- It applies only to rooms or buildings with a conditioned floor area less than 300m² and a maximum of 20 split systems installed. For premises larger than 300m², air conditioning using split systems is inadequate, central air conditioners should be the preferred solution.
- The study is limited to recommendations for actions to reduce the energy consumption of air conditioning. It does not propose to estimate the financial cost of the improvements highlighted by the diagnosis. The evaluation of this cost should be a special analysis in order to determine the investment payback time for each proposed change.

After the diagnosis, the client will have a "roadmap" indicating the way to improve his air conditioning installation with the assistance and incentives available. These improvements will include:

- reduce energy bills,
- improve the quality of its building and its intrinsic value,
- improve the management and maintenance of the facility,
- improve the health qualities of the building and its compliance to regulation,
- to maintain or improve comfort,

The diagnostic procedure

A person trained to the process, the energy auditor, operates the diagnostic in several stages. This assumes that during a preliminary contact with the building owner, the auditor makes a pre-diagnosis by gathering all written documents in order to judge the quality of the buildings and of the air conditioning installation (bill of the equipment and materials, invoices of maintenance contract, electricity utility bill, building plans, etc..). At the end of the pre-diagnosis, the site visit's main purpose is to collect technical and nontechnical data needed for the next step: the numerical simulation. Indeed, a number of elements such as, for instance, user behaviour can be evaluated only thanks to an onsite evaluation. It is also to check if the written documents are in accordance with the reality and to complete missing technical data on the building frame, room air conditioner (RAC), etc..

Dissemination of the approach

A public authority or public body responsible for energy control in the territories is usually at the origin of the labelling process. It coordinates the dissemination process and provides possibly financial support. It is clear that the ultimate aim being to reduce energy consumption in buildings, a wide dissemination of information seems desirable. However, dissemination of information on the process is substantially different depending on the target. Two targets can be defined: the owners and the energy auditors.

Targeted owners are those with a room or building they want, for various reasons, to improve energy efficiency and enhance this improvement by obtaining a label. It is obviously important to convince them of the benefits they can derive from an energy label for their homes. As noted by Zmeureanu (Zmeureanu et al., 1999), three approaches are possible: the awareness of energy performance approach, the financial approach and the quality approach. In this project, the three approaches were used. Awareness on energy issues and the quality approach has been addressed in a booklet distributed widely to the public, building stock owners. The financial aspect is dealt with in partnership with public bodies to promote the demand side management on the territory. Thus, the cost of diagnosis is fully supported. It is paid directly by the body to the auditor without any money transfer between him and the owner.

The second target is the people working in the building trade who may make the diagnosis on behalf of a contracting authority. This opens up a potential market of service to offer as part of assistance mission to the owner. The viability of the whole procedure is mainly based on the quality of diagnostic work. To preserve the quality of this analysis, the process has not been set free. The rights to use the computer tool are transferred to auditors selected based on their skills and trained in the process. The training provided is not limited to the manipulation of the tool. They recall the principles of the thermal design of buildings in tropical climates and educate the auditor to the energy impact of air conditioning. These courses also emphasize the design rules that can avoid the recourse to air conditioning in some premises. At the end of training, the auditor receives a personal empowerment. Furthermore, the implementation of the audit process is controlled and the auditor should report the results of its analysis to the contracting authority but also the public body that has funded. The auditor establishes, in his diagnosis, an inventory of building energy and suggests improvements in quantifying the gains in reducing consumption and electrical demand. It fills a summary based on a methodological guide. The client uses the results of the diagnosis to proceed with the improvement of its building or its property assets. The public body centralize all the information coming from diagnostics to build a database on the status of buildings and to assess the potential for reducing electricity consumption on the territory.

Simulation tool

The main objective of this tool is to establish a rapid diagnostic of an installed room air conditioners and of the building envelope. It also provides assistance to size the system by evaluating the optimum cooling power required considering the premise thermal loads. It is developed from the EnergyPlus simulation code (Drury et al., 2001), which provides the simulation core. A graphical interface is specifically designed to allow the rapid entry of input variables and the display of the generated output.

The tool being intended for audits of premises with a small air conditioning unit like split system type, the building concerned is therefore a single thermal zone. The software architecture is as follows:

- A user interface for entering parameters to define building characteristics (description of the envelope and internal loads) and system (installed cooling capacity, Energy Efficiency Ratio (EER), temperature setpoint, etc. ..)
- An interface for viewing the simulation results (energy labels, numerical values, temporal evolutions of internal conditions) .
- A core calculation for dynamic simulations. This core performs successively two runs of simulation coupling the building and the HCVAC system model (COIL: DX:CoolingBypassFactorEmpirical) provided by ENERGYPLUS. A first simulation called "design run", uses a specific weather file characteristic of a hot summer day and determines the required cooling capacity. The second simulation run is performed on an annual weather file and is intended to evaluate the overall performance of the plant with its electricity consumption, its EER, its Seasonal Energy Efficiency Ratio (SEER), etc.

The tool is designed to evaluate the behaviour of an air-conditioned room but it also allows the simulation of buildings operating without air conditioning. By checking the comfort conditions inside the room without air conditioning, the auditor can verify if it is necessary.

The interface is in the form of five "inputs” tabs and one "output" tab. The five "inputs" tabs allow defining all the parameters describing the thermal zone. The "output" tab is used to display results of calculations and gives access to temporal evolution files of some physical figures of the building (temperature, humidity, ...). In the lower part of the interface, status bar permanently provide partial results of simulations and allows to choose the method of calculation (with or without air conditioning).

SIMULATION INPUTS

The interface includes five tabs with a limited number of pre-defined inputs in order to reduce the building time description. The first tab specifies the weather data file used for the “design simulation” and for the simulation of the overall performance over one year. This choice is made by defining the location of the building under study. The description of the building is simplified to ensure a quick audit. Thus, the user specifies the dimensions of the area (length, width and height), the constitution of the roof and the list of walls in contact with the outside or with another air-conditioned area. In the latter case, the walls are considered adiabatic. For the walls to the outside, it is necessary to specify the percentage of glass area. To simplify the building description, the usual methods of construction are taken into account to define the most used types of walls forming the envelope. The auditor has the choice between walls with high inertia (concrete 16 or 18 cm), medium inertia (hollow blocks) or low inertia (One or two wood layers). The roof can be either a flat concrete roof with high inertia or a low inertia metal roofing. Insulation is defined by the type of insulation and hence its conductivity and its thickness. Only the outer walls can be coated with insulation. Adiabatic walls having by definition a thermal flux nil. The windows are predefined (single or double-glazing, built with wood, aluminium or PVC). Infiltrations, ventilation through openings and mechanical ventilation generate air exchanges between the zone and the outside. Infiltration by openings are taking into account by the window airtightness class (A0, A1, A2, A3, or "undefined") corresponding to an hourly airflow per square meter of window area. Ventilation of the zone due to the door openings at the entry and exit of persons in the premise is defined as a volume of indoor air changes per hour. The value of this rate of fresh air is set by default to 0.4 vol/h. The air intake into the building by the ventilation devices, with a known flow rate, is evaluated according the regulations, which consider usually for one person 18m3/h. The total flow is then calculated directly based on the number of occupants. The mechanical ventilation can be operated permanently or with an adjustable profile. The internal loads are of three types:

- People's influence is taken into account as a latent and sensible contribution.
- Lighting can be defined by total power in kilowatts or using a flux ratio in W / m².
- Other internal loads (electrical devices, computer, etc..) are purely sensible.

Each internal loads and mechanical ventilation may be assigned a profile to specify the time of operation. There are predefined profiles corresponding to office hours, business, school, home or specified profiles by 2 hour slots.

An essential component in tropical climates is the solar protection of walls. A specific tab allows defining the type (blinds or overhang) and size of these protections.

Maintenance or lack of maintenance, ultimately affects the performance of the RAC by degrading the instantaneous energy efficiency ratio (EER) and seasonal (SEER). The software takes into account the evaluation of system electricity consumption, the degradation of the SEER and assigns an energy label accordingly. It is also possible to qualify the implementation of the air conditioner by specifying the quality of the insulation on the refrigerant line, connecting the outdoor unit (EU) and the indoor unit (IU). The ventilation and the protection from the sun of the outdoor unit are also set in the implementation tab.

The system parameters are adjustable in the lower band of the interface. You can then specify:

- The installed cooling capacity of the split.
- The indoor set temperature. It is deliberately limited to values above 20°C and below 30°C.
- The energy efficiency of split using the EER referring to the Eurovent certification (Eurovent, 2006) of air conditioning systems. In case the RAC does not have this certification, it is agreed to assign the EER default value to 2.6.

OUTPUTS AND REFERENCE FIGURES

The software allows two calculation modes:

- The mode "without air conditioning" that helps evaluate the comfort in the building and the appropriateness of the use of air conditioning. The result tab displays the maximum values of dry air temperatures and operative temperature in the zone without air conditioning for the entire simulation period.
- The mode "with air conditioning" performs two separate simulation runs. The "design run" evaluates the optimal required cooling capacity for the zone. The second run evaluates the behaviour of the building with the actual split system. This double run allows a comparison between the existing situation and the optimal design of air conditioning.

The output values of the software are of three types:

- Energy labels for classifying from A to F the main features of the facility. The tool proposes a rating for each of the walls and windows. It also describes the level of infiltration. Finally, it establishes a global label to qualify the overall building envelope.
- Numerical output values. For example: maximum temperatures, optimum cooling capacities, EER calculated solar factor, average power consumption, etc.
- Time evolutions of comfort conditions inside the room, a CSV file.

Envelop labelling

The definition of target values for the qualification of envelop relies on the definition of the solar factor for windows and walls. This indicator is relevant in tropical climates because it takes into account the both the radiative and convective fluxes. Solar factor are given below :

$$Fs_{Window} = \frac{0{,}05\alpha}{R_{th} + 0{,}22}$$

$$Fs_{wall} = \frac{0{,}06\alpha \cdot c_m}{R_{th} + 0{,}17}$$

Where α is the absorptivity of the surface, R_{th} is the thermal resistance of the wall and C_m a coefficient taking into account the solar protection of the wall. The target values to assign a label and define the quality of the walls expressed by the solar factor depend on the orientation of the wall. All the targets are proposed in the Table 1.

Table 1: Solar factor for envelop components

ROof	**wall**	**Wall**	**window**			**Label**
	North, west, east	South	North	West, East	South	
Fs< 0,012	Fs< 0,045	Fs<0,06	Fs< 0,225	Fs< 0,15	Fs< 0,30	A
0,012 < Fs<0,015	0,045 < Fs< 0,06	0,06< Fs<0,08	0,225 < Fs< 0,3	0,15 <Fs< 0,2	0,30 < Fs< 0,4	B
0,015 < Fs< 0,02	0,06 < Fs< 0,075	0,08< Fs<0,1	0,3 < Fs< 0,375	0,2 <Fs< 0,25	0,4 <Fs< 0,5	C
0,02<Fs<0,03	0,075 < Fs< 0,09	0,1< Fs<0,12	0,375< Fs< 0,45	0,25<Fs< 0,3	0,5< Fs< 0,6	D
0,03 < Fs< 0,04	0,9 < Fs< 0,12	0,1< Fs<0,16	0,45<Fs< 0,6	0,3< Fs< 0,4	0,6< Fs< 0,8	E
0,04 < Fs	0,12< Fs	0,16< Fs	0,6< Fs	0,4 < Fs	0,8< Fs	F

The classification of the windows refers to the solar factor. Table 2 shows the values of $Fs_{windows}$ for the most common glazing in the area. The label is obtained by referring to Table 1.

Table 2: Values for solar factor for common window and glass types

WINDOW TYPE	**CLEAR GLASS**	**TINTED GLASS**	**REFLECTING GLASS**
Aluminium frame single glazing	0.62	0.35	0.19
Aluminium frame double glazing	0.56	0.32	0.17
Wood frame single glazing	0.59	0.33	0.18
Wood frame double glazing	0.53	0.30	0.16
PVC single glazing	0.56	0.32	0.17
PVC double glazing	0.5	0.28	0.15

Table 3 gives the classification of windows regarding air infiltration.

Table 3: classification for air infiltration and window types (Air flow rates in $m^3/h/m^2$ of opening)

AIR TIGHTNESS CLASSIFICATION	**AIR FLOW RATES**	**EXTERIOR JOINERY TYPES**	**LABEL**
A0	15	Gliding windows	D
A1	7	Casement windows	C
A2	3	Classified windows	B
A3	1,2	Classified windows	A
Not defined	25	Louvers	E

The tool allows assigning a label to each component of the building envelope. It also defines an overall mark for the whole envelope. This label is determined by comparing the building under study to a reference building. This building has the same geometry as the actual one but receiving a label A for all its walls and windows. The tool calculates the energy transmitted by the walls Q_{ref} for the reference building and the energy Q transferred through the walls of the actual building. The label is assigned by referring to table 4.

Table 4: evaluation of the global performance of the envelop

COMPARISON OF ENERGIES	**LABEL**
$Q < 1.3\ Q_{ref}$	A
$1.3\ Q_{ref} < Q < 1.7\ Q_{ref}$	B
$1.7\ Q_{ref} < Q < 2.3\ Q_{ref}$	C
$2.3\ Q_{ref} < Q < 3\ Q_{ref}$	D
$3\ Q_{ref} < Q < 4\ Q_{ref}$	E
$4\ Q_{ref} > Q$	F

Air conditioning split system labeling

To describe the system several labels are needed:

- "System label": qualifying the choice of the system among the models on the market.
- "Sizing label": determining if the installed cooling capacity is matched to zone requirements.
- "Maintenance label" for the quality and frequency of scheduled maintenance. Of course, maintenance affects the performance of the system but it has also a great impact on air quality. Therefore, the filter cleaning is a major concern for evaluating the maintenance contract.

These labels are intended to evaluate the performance of the RAC in the actual operating conditions and taking into account all the parameters that could degrade the performance. Usually, this evaluation operates in two steps.

The first is to determine the value of the EER that reflects the instantaneous system efficiency at full load. Generally, two values for EER are available: one established by the manufacturer and one evaluated according to standard Eurovent (Eurovent, 2006). To establish the label, the auditor must use the value established by Eurovent and not the value from the manufacturer.

the HVAC system full cooling capacity (Garde et al 2002). Moreover, the split operating on a full season guess it does not always work in nominal conditions. The Seasonal Energy Efficiency Ratio (SEER) was introduced to reflect the influence of changes in external conditions on the behaviour of different types of HVAC systems. For European weather conditions, Adnot (Adnot et al. 2003) established a specific factor: the European Seasonal Energy Efficiency Ratio (ESEER).

However, an air handling system operating in a real building sees its performance affected by other parameters. Over time, the heat exchanger clogged with dust, which affects the quality of heat transfers and thus reduces the EER. If the RAC maintenance is performed regularly and correctly, the influence of fouling is limited. Unfortunately, in reality, the maintenance operations are not regular and are not always carried out rigorously. This should therefore be taken into account to precisely evaluate the actual system performance. The quality of the installation including the length of refrigerant line between the outdoor unit and indoor unit also has a great influence. It should therefore provide an additional calculation to account for these new elements that degrade the performance of RAC. The diagnostic tool introduces a coefficient K_1 qualifying maintenance and influencing the seasonal performances. The value of the EER_{sys} used to define the “system label" is given on the table 5 below using the coefficient K_2 considering the implementation. Table 7 and 8 give the values for respectively K_1 and K_2.

$$EER_{sys} = K_2 \cdot EER_{Eurovent}$$

The EER_{sys} is reported in the following table for the classification.

Table 5: Evaluation of the “System label”

REFERENCES	« SYSTEM » LABEL
$3{,}4 < EER_{sys}$	A
$3{,}2 < EER_{sys} < 3{,}4$	B
$3{,}0 < EER_{sys} < 3{,}2$	C
$2{,}8 < EER_{sys} < 3{,}0$	D
$2{,}6 < EER_{sys} < 2{,}8$	E
$2{,}4 < EER_{sys} < 2{,}6$	F
$EER_{sys} < 2{,}4$	G

The model of air conditioning system implemented into the kernel calculation EnergyPlus, evaluates the performance degradation of the split system, depending on sizing and operating conditions (indoor and outdoor temperature). The diagnostic tool corrects this estimation by computing a particular value of the SEER designated by $SEER_{calculated}$, to account for the maintenance and implementation. It

The second step is to consider the partial-load operation by multiplying the EER by the Part Load Factor (PLF), (Mara et al. 2005). The PLF is deducted from the Part Load Ratio (PLR) defined as the ratio of the Building thermal load to

also determines the cooling capacity required for the thermal zone is maintained at the specified set point temperature, during the use of air conditioning. The software infers the required electrical power, corresponding to the required cooling capacity. Electrical power is obtained by dividing the required cooling capacity by $SEER_{calculated}$, and introducing the coefficients K1 and K2, ie:

$$\dot{Q}_{elec,req} = \frac{\dot{Q}_{cool,req}}{K_1 \cdot K_2 \cdot SEER_{calculated}}$$

The annual electrical energy is calculated from the annual cooling energy delivered in the thermal zone and from the $SEER_{calculated}$ value determined by EnergyPlus using:

$$Q_{elec,annual} = \frac{Q_{cool,annual}}{K_1 \cdot K_2 \cdot SEER_{calculated}}$$

The sizing of the system is evaluated by comparing the actual cooling capacity installed, with the required cooling capacity assessed by the software. A difference lower than 30% between the cooling capacity installed and the required cooling capacity provides access to the notation A. In addition, classification deteriorates as shown in table 6.

Table 6:Figures for K_1 and ”Sizing label”

REFERENCES	LABEL
$\dot{Q}_{cool,installed} < 1.3 \times \dot{Q}_{cool,req}$	A
$1.3 \times \dot{Q}_{cool,req} < \dot{Q}_{cool,installed} < 1.5 \times \dot{Q}_{cool,req}$	B
$1.5 \times \dot{Q}_{cool,req} < \dot{Q}_{cool,installed} < 1.7 \times \dot{Q}_{cool,req}$	C
$1.7 \times \dot{Q}_{cool,req} < \dot{Q}_{cool,installed} < 1.9 \times \dot{Q}_{cool,req}$	D
$\dot{Q}_{cool,installed} > 1.9 \times \dot{Q}_{cool,req}$	E

The quality of the maintenance contract directly affects the “maintenance label" and results in performance degradation for the RAC through the coefficient K_1 propose in Table 7.

Table 7:”Sizing label”

MAINTENANCE CONTRACT	K_1	“MAINTENANCE LABEL”
Specific Opticlim contract	1	A
Comprehensive annual maintenance and regular cleaning of filters	0,92	B
"Light" maintenance : annual recharge of refrigerant, no control, no filter cleaning	0,85	C
No maintenance	0,75	D

The coefficient K_2 takes into account the presence and condition of the insulation of the refrigerant line as well as the presence of an obstacle near the outdoor unit or its installation in a poorly ventilated place. If the length of the refrigerant line is greater than 5 m, the performance of the system is affected as stated in table 8.

Table 8: Figures for K_2

REFRIGERANT LINE INSULATION	**WITH** (and in good condition)		**WITHOUT** (or degraded)	
Good ventilation of outdoor unit	yes	no	yes	no
Refrigerant line lenght	Coefficient K_2			
< 5 m	1	0,97	0,93	0,91
5 to 10 m	0,97	0,96	0,86	0,83
10 to 15 m	0,96	0,95	0,79	0,74
15 to 20 m	0,95	0,93	0,73	0,65
20 to 25 m	0,93	0,91	0,61	0,54
25 to 30 m	0,92	0,9	0,49	0,43
> 30 m	0,80	0,7	0,45	0,40

ELEMENTS OF VALIDATION

The labelling process being based on numerical simulations and a simplified description of the building, it is necessary to evaluate its validity through an experimental comparison. The aim is not to present a comprehensive validation procedure, such as those envisaged for the numerical simulation codes. A future work will address this issue. The experimental comparison will allow verifying the approach, the simplifying assumptions and parameters used. Monitoring of zone internal conditions as well as on the AC system have been carried out in a building equipped with a RAC. The studied thermal zone includes two rooms separated by a door that remains always open (figure 1).

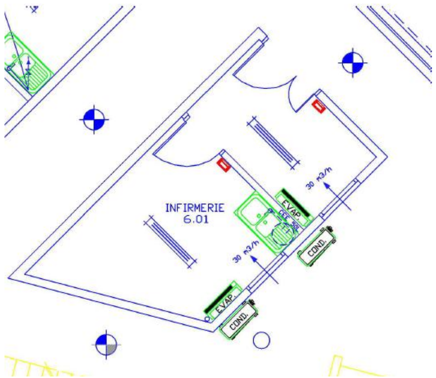

Figure 1: Thermal zone under study

The surface of the room is 21 m², it includes a window of 2.3 m² on the north wall with a large overhang solar protection 2.1 m long. The zone is occupied by one person from 8pm to 4am. All the walls are made of concrete with high inertia and without any insulation. The installed cooling capacity is 5.2 kW with an EER of 2.6.

Simulations show first that that the cooling system is greatly oversized, as the required cooling capacity is only 1.9 kW. Figure 2 presents the output window.

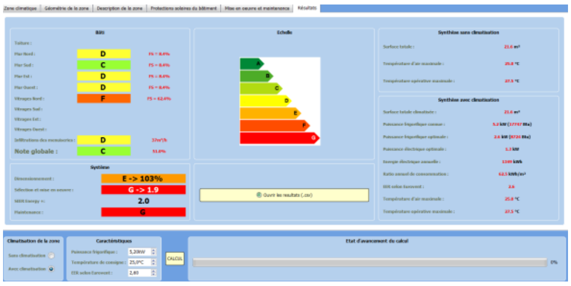

Figure 2: Outputs for the simulation of the case study.

The estimated required electrical power is 1.3 kW. Measurements, on a three-month period, show that the annual electrical energy is 325.3 kWh. The prediction of the numerical simulation gives a value of 317.8 kWh. The relative error being about 2.5%, this prediction is accurate taking into account the assumptions made for the description of the building. This diagnostic of a single thermal zone can be realized very fast, (about 15') as soon as all the written documents (plans, occupancy schedule…) are available.

CONCLUSION

The process of diagnosing small air conditioning installations presented is exemplary on many levels:

- It can offer solutions for rehabilitation of buildings, which constitute the main deposit of energy conservation.
- It is global. It proposes to involve private builders and public control offices, trade unions professional air conditioning and public bodies.
- It is efficient and scientific because it relies on proven dynamic simulation tools.
- The software tool has a simple interface that allows a fast energy audit by people not experienced in the field of numerical simulation of buildings. However, a training program is proposed to help energy auditors to propose accurate investigations.
- The rating process (energy label) of the envelope and the system can effectively target the sources of energy savings achievable with existing technological processes on the market.

A future work will present a comprehensive validation of the numerical tool and a case study carried out on a large building stock.

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