CA-SIS: AN ENGINEERING TOOL FOR THERMAL STUDIES WITH A GRADUAL ACCESS

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Abstract

CA-SIS[1] software has been developed on PC as a tool for engineering offices in their Heating, Ventilating and Air Conditioning studies. Based on TRNSYS solver, its major revolutionary characteristics consists of a gradual approach driven by a user friendly graphic interface:

- **a first step called « Esquisse » (sketch) is based on a database of past studies. It enables a simple comparison of different HVAC solutions on the basis of simple criteria like the building area, its geographical location, etc... in a few minutes. Results are given in terms of energy and costs (minimum, maximum and average values).**
- **a second step called « Projet Sommaire » (basic project) uses libraries of buildings and HVAC systems. The engineer connects a building (he can either find it in the standard library or eventually draw it through a 2 dimension interface) and the HVAC system he wants to simulate. He can use standard data describing building occupation, lighting,... or adapt these data to his case.**
- **in a third step called « Projet détaillé » (detailed project), the user can build his own HVAC solution assembling simple elements as coil, fan, etc... or replacing the elements constituting the standard system proposed in library.**

A classical study will begin by an « esquisse » where the user will select interesting solutions (in terms of energy consumption and cost). He will eventually have a look at similar previous projects found in the database.
Then the user will simulate the behaviour of the building and its HVAC system taking those elements in standard libraries. Simulations are performed for up to one year on an hourly basis considering real meteorological data.
Generally the study will stop at that point. For some particular cases, the user may go on detailing and modifying the HVAC system (replacing for example a fuel boiler by an electric one).

Finally the user will obtain graphic results of consumption, required power, room temperatures,... He will also dispose of a study synthesis giving the general hypothesis made, principal results, etc.... that he might introduce in a technical report presenting his work.

[1] Conditionnement d'Air - Simulation des Systèmes (Air Conditioning - System SImulation)

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1. Introduction

In the beginning of the 90s Electricité de France (EDF) started the development of a software dedicated to the comparison of HVAC systems named CA-SIS (for « Conditionnement d'Air - SImulation des Systèmes » which means « Air Conditioning - System SImulation »). It was based on the TRNSYS solver from MADISON University. A specific model library has been developed to simulate HVAC systems and allow easy comparisons between them.

CA-SIS first used IISIBât interface (1) developed by CSTB with partial support from EDF. But it appeared that it did not fit with the engineering office users' requirements. Therefore the product was rethought to be adapted to those constraints: CA-SIS PC was born.

1997 is the experimental year for this new product which will be tested in a β version by 12 different companies. Their remarks will be collected and taken into account in a new release of the software.

This paper presents the software, its particularities and the results it provides. The computing architecture of CA-SIS and a part of the validation work are also presented before concluding.

2. A new gradual approach to answer users' complaints

An inquiry carried out in design offices revealed out that their ideal tool would be the one where a project can be constructed over time as knowledge of the architect's final goal increases. Starting from little data (location, surface, insulation,...), the tool would capitalise the data as the project description improves (building description, HVAC system,...).

CA-SIS offers therefore a three step approach corresponding to the different levels of knowledge in a project: sketch, basic and advanced project. Every level inherits from the data already known at the preceding stage (building type,...).

The sketch is based on a database of past studies. Projects consist of icon charts. Each icon is a model (building, system,...). These models are linked with each other. The links correspond to data transfer from one model to another: for example the available heating power is connected from the system to the building while the latter sends inside air temperature information back to the system.

2.1 Sketch

This level is characterised by the very limited knowledge of the future building. It corresponds roughly to a concourse level and takes just a few minutes. It uses a database containing past validated studies and provides annual consumption and cost ratios for heating and cooling (kWh/m^2 and Francs/m^2). The sketch window is shown on figure 1.

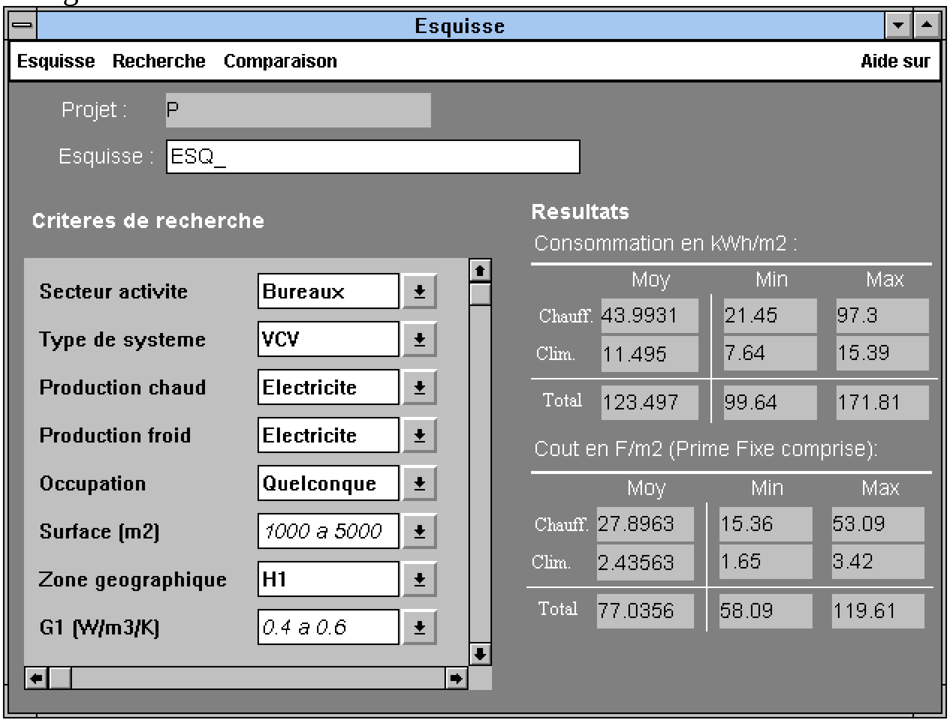

Figure 1: Sketch window. It enables an easy and rapid comparison between different solutions.

2.2 Basic project

An example of a project chart is shown on figure 2. This level uses standard data in a first approximation. A classic study can therefore be shortened to a few hours depending on the amount of non standard data introduced in the project description in place of the default elements.

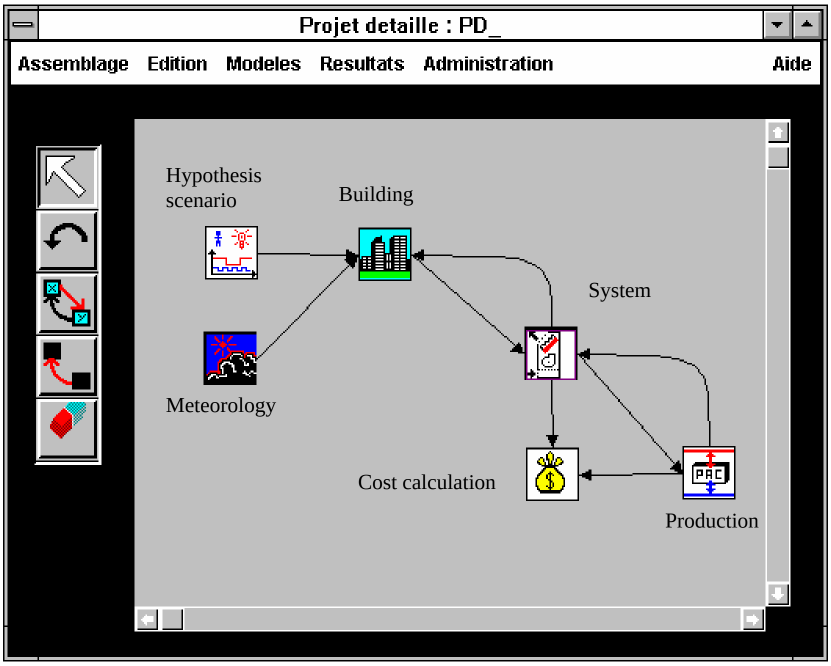

Figure 2: Example of project chart. Meteorological and hypothesis scenario data are connected to the

building which exchanges information with the system. The emitter and the production source are connected to the cost calculation model.

One should note that default elements include

- representative buildings in different sectors (offices, schools,...),
- heating and cooling systems (such as convectors, heat pumps on a water loop,...),
- scenario hypotheses for occupation, lighting,...
- system leading strategies as a function of energy costs, outside temperature,...

The building description is fastened by the use of a 2 D graphical interface shown on figure 3. It is based on type floors that are described once and can be repeated several times in the building. For example, in the case of a 10 storey office building, the user may describe the first, the top and the intermediate floor. The latter is then declared as repeated 8 times between the 2 first floors and the description is completed.

NB 1: In basic projects, model descriptions are lightened by hiding some secondary order parameters from the user. Their values are taken at standard mean values.

NB 2: Moreover when the user tries to connect models with each other, a coherence control is performed on the unit and also on the nature of pieces of data connected (Unit is effectively inefficient to avoid connecting an air temperature to a water temperature). To perform these controls, the inputs and outputs of every model have been characterised by their physical attributes.

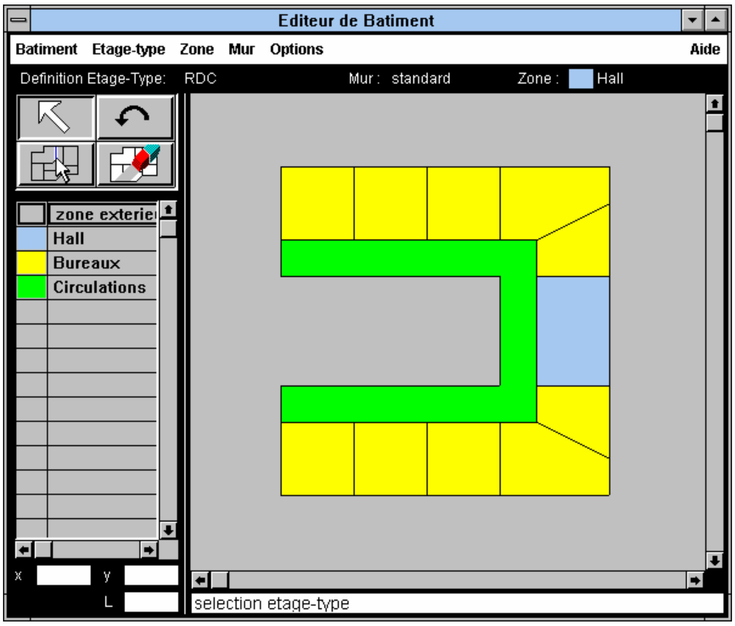

Figure 3: Building description window. Three different zones have been distinguished on this case.

2.3 Detailed project

This level is characterised by the precision of the model descriptions. In basic projects some parameters are hidden from the user simply so as not to overwhelm him with details. In advanced studies every parameter is visible.

Furthermore at this stage, physical compatibility (air temperature, water temperature,...) in connections is no longer absolutely required. It is possible to connect data from different sources: a warning is issued to the user who can bypass it.

3. Facilities

- The building interface uses 2 libraries: standard and personal. Each user can thus declare his own materials, types of wall, of window,... that he can use again in another project. Standard data corresponds to the elements used to describe the library standard buildings. They are generally sufficient to carry out classical studies.
- Each major system component is represented by a unique model: for example production,... This helps to have a clear view of the important points of the project.
- When complex systems are simulated using several models linked with each other, they are represented in a project by a single icon called « macro-model ». If desired, the user may expand the macro-model into his project chart so as to clearly see every element involved.
- Standard libraries also propose « blank projects » where all items needed for a study are present and connected with one another. A user only has to specify the study parameters like boiler power, number of fans,... and to describe the building if he does not use a standard one.

4. Abilities

CA-SIS software allows the study of different types of HVAC systems:
- convectors,
- rooftops,
- variable or constant air systems,
- water loop heat pump systems,
- fan coil systems,
- Variable Refrigerant Volume,
- Heating/cooling floor and ceiling,

with different kinds of production source:
- electricity (boiler, heat pump,...),
- gas (boiler, absorption),
- heating or cooling network,
- cooling towers,...

Hourly simulations can be performed for up to one year.

The hourly meteorological data used in the software is of 2 types:
- standard average data for 9 French cities,
- real data for a cold, a cool and a medium year (within an observation period of 10 years) for 15 French cities. This data is especially useful to see if a heating (or cooling) system will be sufficient for a cold (or cool) year.

The software also enables the study of the different gas and/or electricity cost contracts and eventually their impact on the way the system is driven (for example, one can tolerate a lower temperature during a short period if energy cost is especially high at that time).

In practice, simulations can be performed either instantaneously (as soon as the project is described), or postponed (for example, all the simulations can be grouped to be executed at night).

5. Results provided

One can distinguish 5 types of results provided by CA-SIS:
- monthly reports of consumption, costs, maximum power required for the different installations,
- hourly values of any model output (consumption, temperatures,...),
- hourly psychometric data chart (temperature, humidity) as shown on figure 4,
- project description (scenario, system hypotheses, building,...),
- simulation report (time elapsed, error or warning encountered).

Data can be transferred to the specific CA-SIS post processing or to a standard spreadsheet programme.

6. CA-SIS Constitution

As already mentioned, CA-SIS is based on TRNSYS solver. Its computing architecture is presented on the figure 5. One can distinguish 2 major levels: interface and calculation.
The software can be executed either on a Unix platform or on a PC.

Interface	Project manager Sketch window Assembly chart Building description ...	Model data	Post processing
Transfer files	Simulation description		Result files
Calculation	Solver	FORTRAN models	

Figure 5: CA-SIS consists of an interface and a calculation level which dialogue through data files

The model library is easily updated. Each model is fully characterised by 2 files: its interface description and its FORTRAN code.

7. Validation

Different kinds of validation tasks are performed on CA-SIS:

- Academic exercises where all data is clearly identified. They generally consist of blind tests on cells undergoing a variable heating or cooling load. Calculated and measured temperatures are then compared.

- Real size experiments. The purpose is to simulate the behaviour of a real building where measurements have been made. Generally the comparison deals with calculated and real consumption and costs.
- Software comparisons. These comparisons consist of one exercise simulated on different softwares.
- User influence tests. The aim is to compare the way one study will be carried out by different users. Normally several users should obtain the same results but simulation tools often refer to unspoken assumptions. These exercises help to indicate the areas where potential errors lie and therefore help the users be better informed and guided.

Some academic and life size exercises are briefly presented hereafter.

7.1 Academic exercises

Two major academic exercises have been performed; one on the Building Research Establishment (BRE) cells. The second on the ETNA cells of EDF. Both tests consisted of clearly identified cells undergoing pseudo-random heating sequences. Results were on the whole satisfying (see for example table 1). Moreover an error analysis was performed on both cases to determine the principal discrepancy sources (see [2]): rapid convective heat exchange, solar gains and external wind effect (see figure 6).

	Mean error (°C)	Standard deviation (°C)
Purely convective heating	0.58	0.63
Partly radiative heating (15%)	0.29	0.63

Table 1: Mean errors and standard deviations for the simulation of a pseudo random heating sequence on ETNA test cells (the first cell being equipped with a partly radiative (15 %) heating system, the second one with a purely convective one).

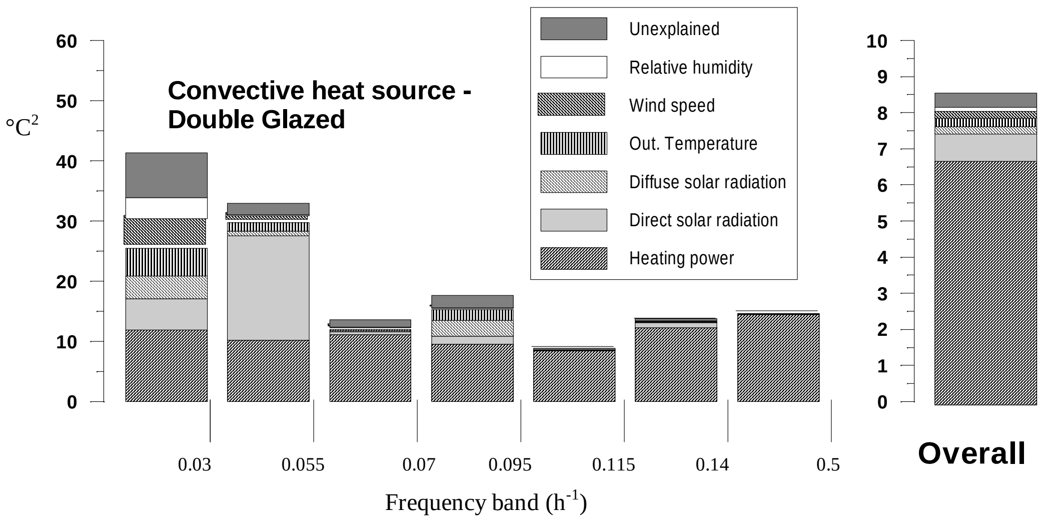

Figure 6: Simulation of a pseudo random heating sequence on one of the BRE test cells and disaggregation of the error variance of the simulated air temperature (°C^2) versus the selected dynamic ranges.
The room under consideration is equipped with purely convective heating and double glazing. One can see the decreasing influence of heating power, solar direct radiation, solar diffuse radiation, external temperature, wind speed, relative humidity. The unexplained part remains very low.

7.2 Real size experiments

CA-SIS software has been used by EDF for internal studies in the tertiary activity sector since the beginning of the 90s.

Different kinds of buildings and systems have been analysed. Some buildings have been studied with different versions of the software in order to test the evolutions; for example the EDF-GDF office building of Bordeaux Mérignac (8800 s m) equipped with heat pumps on a water loop. The comparison of different consumption levels shows a relatively good agreement between calculations and measurements (see figure 7).

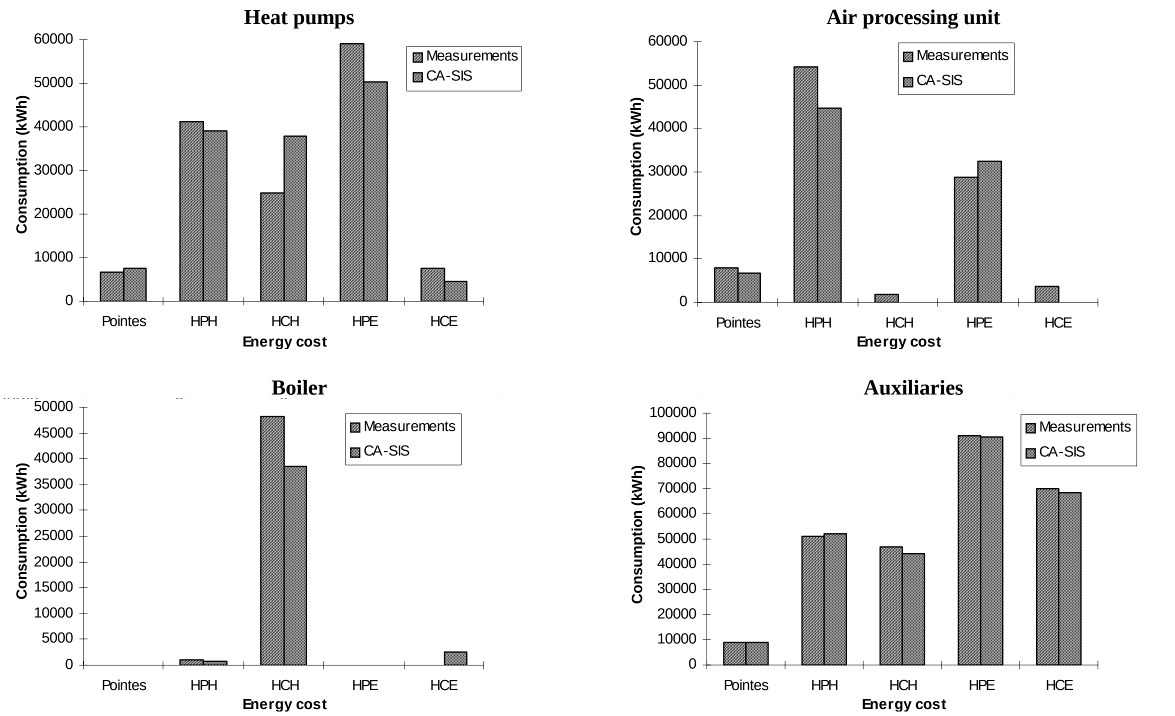

Figure 7: Comparison of annual energy split between the different electricity rates for in situ measurements and CA-SIS simulation in the case of a 8800 s m office building. The diagrams concern different pieces of equipment: the heat pumps, the air processing unit, the boiler and the auxiliaries.

A study carried out on a supermarket in Avignon (10000 s m of sale surface) shows good agreement on heating/cooling consumption (see figure 8) despite the case complexity. However one has to be cautious when considering intermediary seasons and specific energy uses like alimentary refrigeration which is far from being an easy phenomenon to simulate.

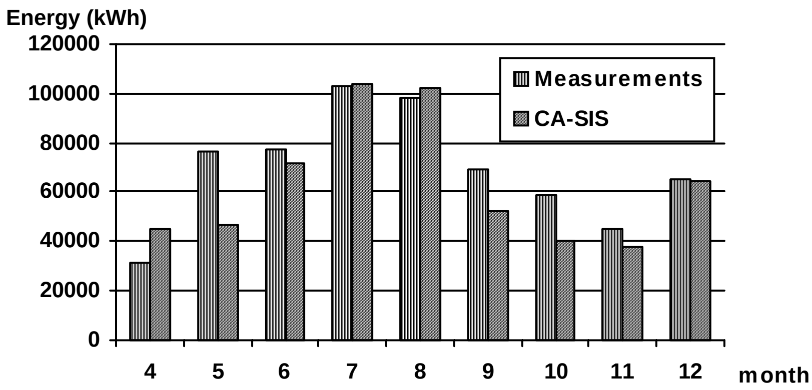

Figure 8: Comparison of simulation and measurements for heating / cooling monthly energy consumption in the case of a 10000 m^2 supermarket

8. Ergonomic approach

Because CA-SIS should be distributed to design offices, it has to be user friendly. To ensure a clear dialogue between software and users, some professionals have been involved in the software elaboration. Furthermore a β-version will be provided to a dozen design offices during 1997. They will test the product and their remarks will be taken into account for the next release which will be available in 1998.

9. Conclusion

Enabling comparisons between heating/cooling solutions using different energy sources will demonstrate that in some cases well managed electric solutions are the most adapted ones. CA-SIS software has been developed to facilitate these calculations in engineering office studies.

It has been validated through academic exercises and life size experiments. Its interface will be upgraded following the remarks of the β version users and the final product will be available in 1998.

REFERENCES

1. Transferring simulation techniques to end-users - Application to TRNSYS. Pelletret R., Soubrah S., Keilholz W.
Proceedings of the 4th International Building Performance Simulation Association (IBPSA) conference, Madison, Wisc., USA 14-16 August 1995.

2. An error analysis method applied to a building simulation software: An example of application and its results. Tabary L., Ramdani N.
Proceedings of the 4th International Building Performance Simulation Association (IBPSA) conference, Madison, Wisc., USA 14-16 August 1995.