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

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1. 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 consist 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.
- a second step called « Projet Sommaire » (basic project) uses library of buildings and HVAC systems.
- in a third step called « Projet détaillé » (detailed project), the user can build his own HVAC solution.

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 into a technical report presenting his work.

2. INTRODUCTION

In the beginning of the 90's 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 the University of Wisconsin-Madison (USA). A specific model library has been developed to simulate HVAC systems and allow easy comparisons between them.

It appeared that design offices were interested in such a product. However the first versions of the software were not adapted to their constraints. CA-SIS was re-conceived to fit with their requirements : CA-SIS PC was born.

This paper presents the software, its arcitecture, its characteristics and also its abilities. A part of the validation work is also presented before concluding.

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

3. OBJECTIVE OF THE SOFTWARE

3.1 Enabling accurate energy calculations

First of all design offices need accurate tools for analysis and previsions of energy consumption in buildings. They generally have a short time and very little money to put into such calculations Therefore they often satisfy themselves with approximations or incomplete softwares. It appeared that CA-SIS could be an answer to their problems enabling accurate thermal calculations within a relatively short timescale.

3.2 A new gradual approach to answer users' complaints

An inquiry carried out in design offices revealed that their ideal tool would be the one in which 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.

3.3 Enabling comparisons of HVAC systems

Designers are often interested in comparing different technical solutions in terms of investment and utilisation costs. Most common softwares enable the study of a very limited number of solutions (for example : only air based solutions,...). The idea was therefore to define the building, the scenarios,...once only and then test a wide range of HVAC systems. This is possible and facilitated through the CA-SIS approach where a user can easily replace one system by another just by replacing one icon by another.

4. TECHNICAL BASIS

As already mentioned, CA-SIS is based on TRNSYS solver. One can distinguish 2 major levels : interface and calculation.

First, paragraph 4.1 describes the calculation level. Then paragraph 4.2 presents the way a project is managed taking advantage of the evolutive interface. Paragraph 4.3 briefly describes the facilities available when using the software.

4.1 Calculation level

CA-SIS computing architecture is presented in Figure 1. Within the calculation level, one can distinguish the solver and the model library.
The TRNSYS solver has already been fully described (see [1,2]).
The model library contains 2 major kinds of models:
- « black box » where one output is calculated by interpolating between reference points (constructor performance data for example),
- physical models constructed from physical laws. In that case preliminary work has been done so that the model parameters can be given from standard constructor data (for example, in the case of a coil, the user is not asked to give the number of rows of tubes, etc... but rather the significant power).

Some complex systems are modeled using several models linked together. In this case, they can be identified and stored in a specific library (see the paragraph « Facilities »).

4.2 Leading a project with CA-SIS

4.2.1 Sketch

This level is characterized 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 completed with 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 in Figure 2.

4.2.2 Basic project

An example of a project chart is shown in Figure 3. This level uses standard data in a first approximation. A classical 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.
One should note that default elements include
■ representative buildings of different activities (offices, schools,...),
■ heating and cooling systems (such as convectors, heat pumps on a water loop,...),
■ scenario hypotheses for occupation, lightning,...

■ system leading strategies in function of energy costs, outside temperature,...

The building description is fastened by the use of a 2 D graphical interface shown in Figure 4. It is based on 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 former 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 establishes a link between 2 models, a coherence control is performed on the nature of pieces of data he connects with each other.

4.2.3 Detailed project

This level is characterized by the precision of the model descriptions. In basic projects some parameters are hidden from the user so as not to overwhelm him with details. In advanced studies every parameter is visible.
Furthermore at this stage, phisical compatibility in connections is no longer absolutely required (for example, an output « air temperature » can be connected to an input « water temperature »,...). It is possible to connect data from different sources: a warning is issued to the user who can bypass it. This corresponds to the need of flexibility expressed by experienced users.

4.3 Facilities

The building interface uses two 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, they can be 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, the number of fans,... and to describe the building if he does not use a standard one.

5. SOFTWARE CHARACTERISTICS

5.1 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).

5.2 Results provided

One can distinguish 5 types of results provided by CA-SIS :
- monthly reports of consumption, costs, maximum power required for the different parts of the installation,
- hourly values of any model output (consumption, temperatures,...),
- hourly psychometric data chart (temperature, humidity),
- 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.

5.3 Computer characteristics

The software can be executed either on a Unix platform or on a PC.

PC minimal characteristics are :
- RAM : at least 8 Mo,
- 20 Mo available on hard disk to install the software,
- color monitor : 800 x 600 points/256 colors,
- MS-DOS 6.21 and WINDOWS 3.11 (better WINDOWS 95).

Unix version are presently on HP9000-700 with
- 32 Mo RAM,
- 20 Mo available to install the software,
- color monitor : 800 x 600 points/256 colors,
- system: HP-UX A.09.05,
- library X11, Xt, Xm.

The Unix version is not intended for distribution.

6. 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.
- ■ Life size experiments. The purpose is to simulate the behavior 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 with 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. Thus the software interface can be improved to better inform and guide the users. These tests will be performed with the β version of CA-SIS, once the software has been distributed to the dozen test users (which is not performed at the time of writing).

Some academic and life size exercises are briefly presented hereafter.

6.1 Academic exercises

Two major academic exercises have been performed; One on the Building Research Establishment (BRE) cells (see [4]); 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 : rapid convective heat exchange, solar gains and external wind effect (see Figure 5).

6.2 Life 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 analyzed.

Some buildings have been studied with different releases of the software in order to test the evolutions; for example the EDF-GDF office building of Bordeaux Mérignac (8800 m²) equipped with heat pumps on a water loop. The comparison of the different consumptions shows a relatively good agreement between calculations and measurements (see Figure 6).

A study carried out on a supermarket in Avignon (10000 m² of sale surface) shows good agreement on heating/cooling consumption (see Figure 7) 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.

6.3 User influence tests

These exercises help to make the interface more user friendly. They will be carried out once the β version of CA-SIS PC is distributed, which is not the case at time of writing. However previous similar experiments performed with Clim2000 software (a research energy computing programme developped by EDF) showed a large variability in the results between several users; up to 40% on the heating consumption for a 100 m² house (see [5]). Thermal bridge simulation was for example an important source of discrepancy: some users forgot them in their building modelling while others overestimated their influences. It shows how much it is important to guide users and to offer them data control in order to avoid errors or at least decrease their magnitudes.

7. 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 at the beginning of 1998.

8. REFERENCES

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

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TABLE AND FIGURES

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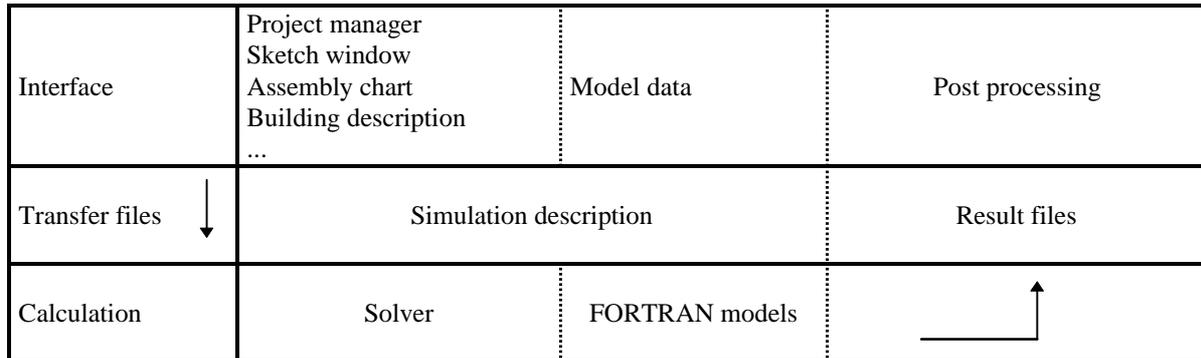
Interface	Project manager Sketch window Assembly chart Building description ...	Model data	Post processing
Transfer files ↓	Simulation description		Result files
Calculation	Solver	FORTRAN models	↑

Figure 1: CA-SIS consists of an interface and a calculation level which dialogue through data files
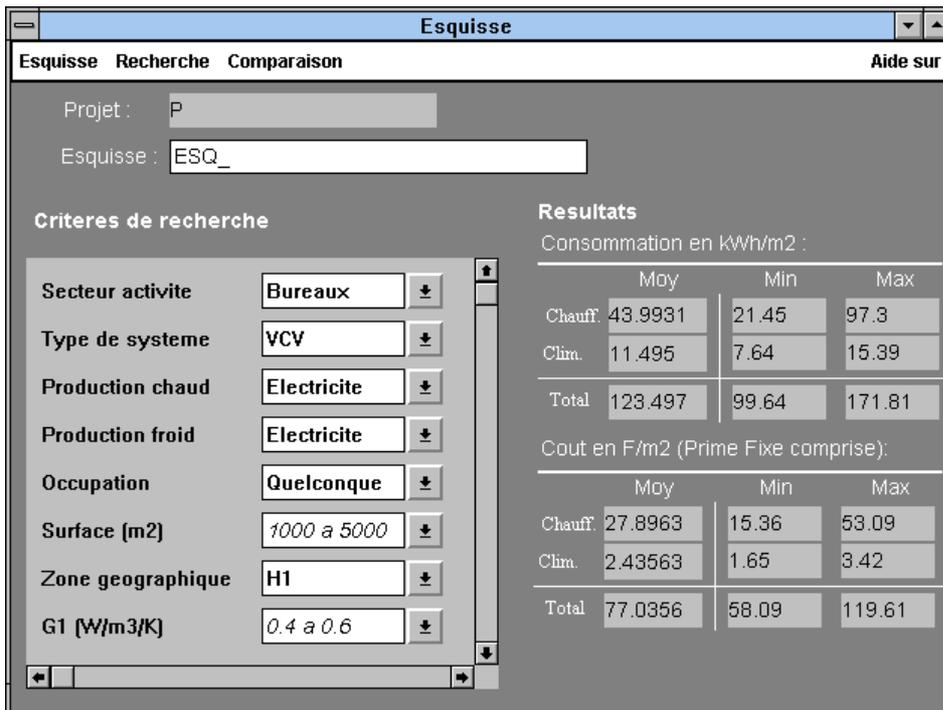
Figure 2: Sketch window. It enables an easy and rapid comparison between different solutions.
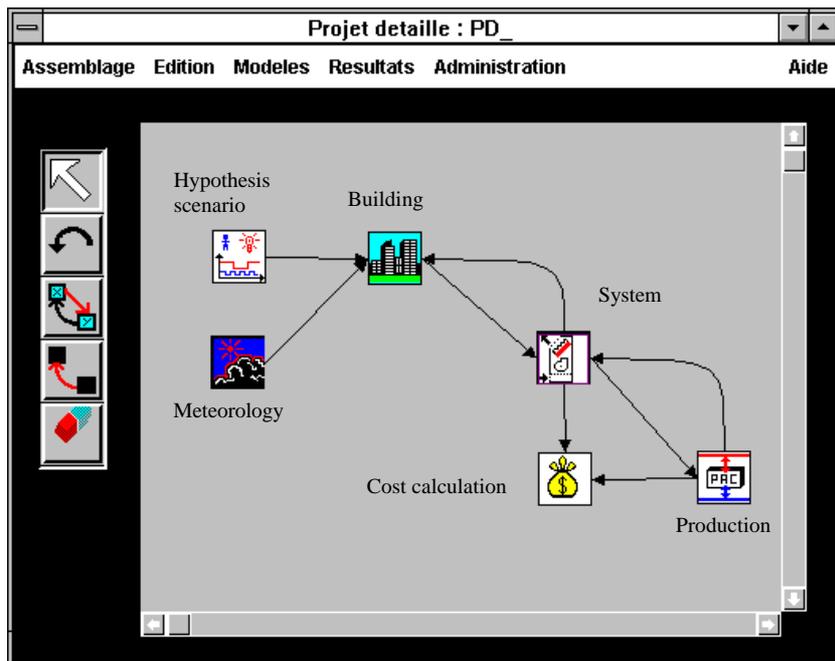
Figure 3: Example of project chart. Meteorological and hypothesis scenario data are connected to the building which exchanges information with the system. The emitter and the production source are connected to the cost calculation model.
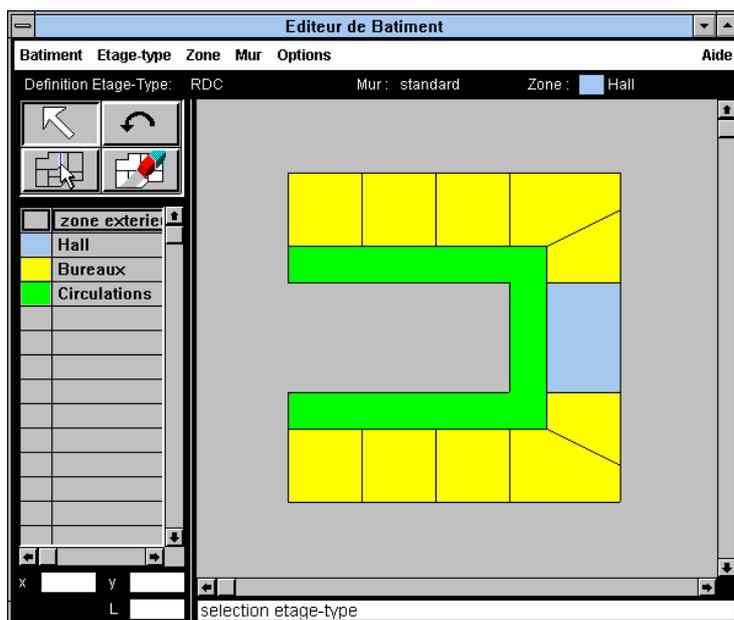

Figure 4: Building description window. Three different zones have been distinguished on this case.
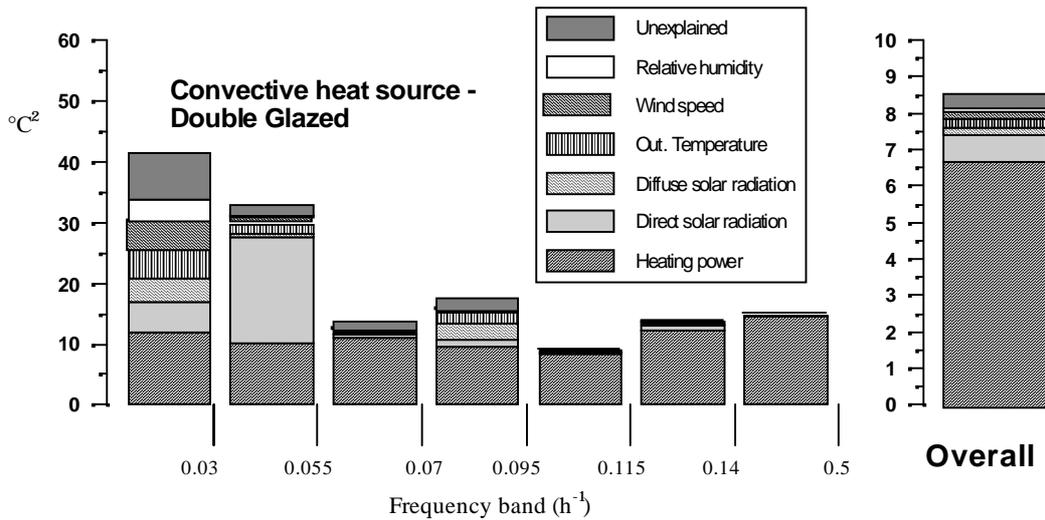
Figure 5: Simulation of a pseudo random heating sequence on one of the BRE test cells and disaggregation of the error variance of the simulated air temperature (°C^2) versus the selected dynamic ranges.

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 error part remains low.
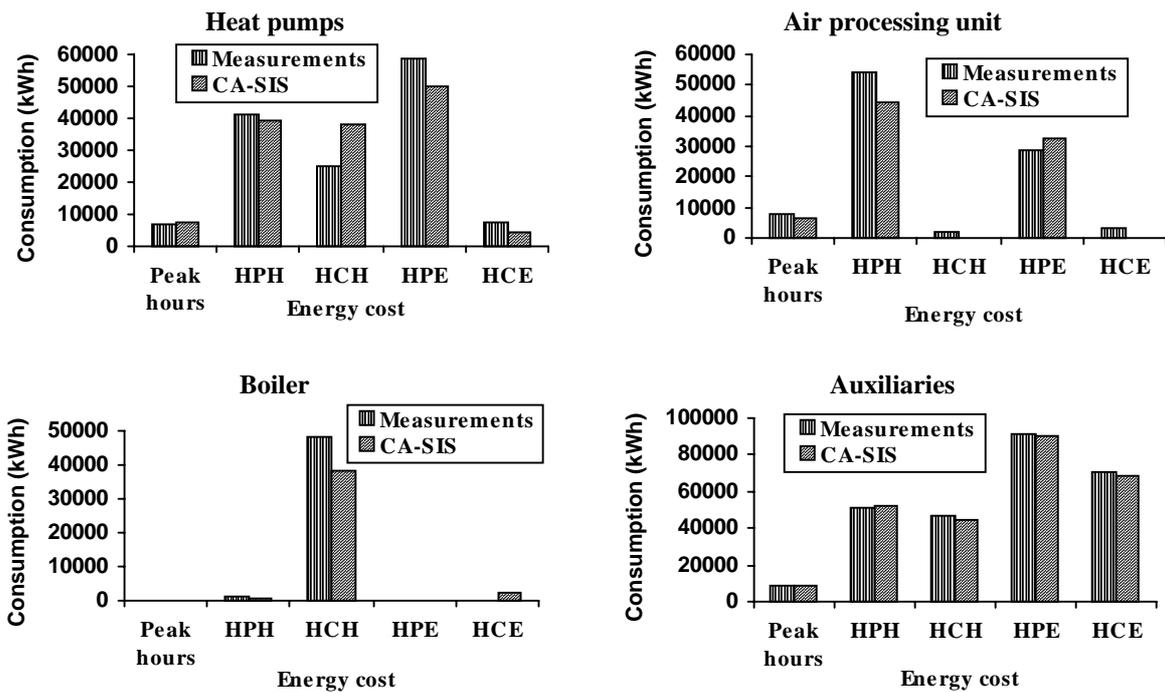

Figure 6: Comparison of annual energy distribution between the different electricity cost rates for in situ measurements and CA-SIS simulation in the case of a 8800 m² office building. The diagrams concern different pieces of equipment: the heat pumps, the air processing unit, the boiler and the auxiliaries.
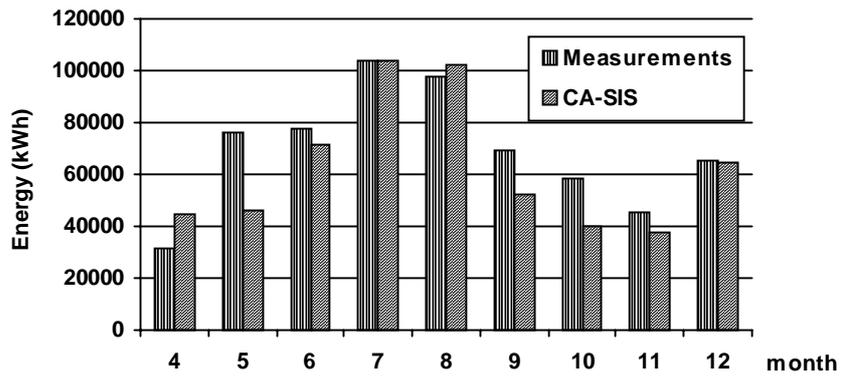
Figure 7: Comparison of simulation and measurements for heating/cooling monthly energy consumption in the case of a 10000 m^2 supermarket