

CODYBA – V. 6.0 : new version of software for building dynamical behaviour simulation

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Abstract

In the new version of **CODYBA** software, a building model is based on its decomposition in elementary objects (air volumes, walls, windows, control systems, etc.). The global building model is obtained by the connection of these different “objects/models”, associated to excitations like the exterior climate and/or the internal loads. These excitations are also manipulated as “objects/models”. To summarize, the **CODYBA** graphical user interface (GUI) introduces concepts that are identical to those manipulated in everyday practice by building professionals (walls, windows, construction materials, regulators, etc.) and that are reproduced on screen by a classic “icono-graphical” representation in the “Windows” environment.

INTRODUCTION

CODYBA software has existed at CETHIL since 1985 [1], [3]. It has shown the validity of scientific concepts that it utilises, as well as their efficiency in the development of industrial software. Taking into account the evolution of computer tools and methods of these last years, a complete change has been made on the practical and theoretical plans.

This change was implemented to extend the building modelling. A preliminary bibliographical study showed that the functioning of the “thermal system” represented by a building in its climatic environment, is the object of numerous developments for the energy conception design tools.

One of our conclusions is that a major difficulty encountered even before the development phase of these tools, is the building decomposition in elementary objects permitting a sophisticated programming and giving to the professionals the possibility to find familiar entities in the graphical user interface. We present our new modelling which, we hope, provides a solution.

Once the modelling was adopted, it had to be programmed taking into account available tools on the market. As we have adopted an “object” type modelling, an “object” type programming language has been imposed. So, **CODYBA** was developed in the C++ programming language : we will present here formally the classes issued from our modelling.

METHODOLOGY

CODYBA aims to offer to the greatest number of users a prevision tool for the thermal behaviour of a building permitting to establish an energy balance or to analyse the

influence of certain parameters (like, for example, the control, the windows, the solar protections, the building inertia or orientation, etc.). This simulation tool should be simple, accessible, reliable, robust, evolutionary.

It must also give an accurate analysing tool to the scientist. For that reason, the calculation module must authorise the most advanced calculations which cover or could cover in the future all domains of the building physics applications.

This double objective brought us, among other reasons, to introduce two levels of modelling : one for the structuring of the building data and another one for the implementation of the calculation algorithms. This utilisation of two distinct levels is not a novelty in itself (see LARET [2]).

MODELLING OF THE BUILDING ENTITIES

Schematization

The integration of the Fourier equation gives (when limited only to “mass” volumes with uniform properties) :

$$\rho.C.Volume.\frac{dT}{dt} = \sum Surfaces Flux + \sum Voluminal Flux$$

The modelling that we have adopted consists in representing the volumes by the nodes of a graph and the fluxes by its arcs (see Figure 1). In reality, the voluminal fluxes are linked to only one volume. To generalise, we consider that the energy that they involve comes from a specific volume that we call “exterior” (see Figure 2). In this way, we always dispose of two nodes for each arc.

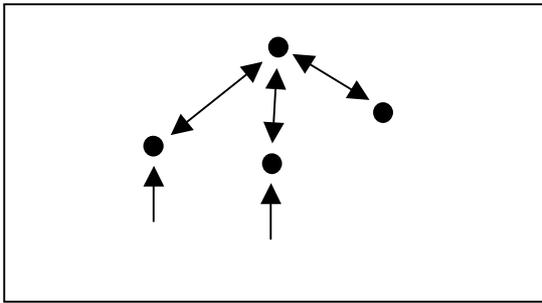


Figure 1 : Nodes and arcs modelling

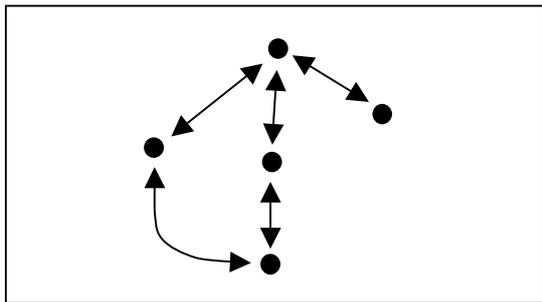


Figure 2 : "Exterior" modelling

The adopted modelling consists in reducing it to a "valued" graph. This modelling is not new, it has already been used under the form of "capacity-conductance" in the domain of building physics. Our originality is that we simply "push" the logic to its limits, generalising this modelling to the whole of the building and to its climatic environment.

Basic modelling : the network element

The building entities representation is based upon two basic conceptual classes : the nodes and the arcs. In fact, because of the duality arc-node, we use only one entity which will be of a "node" or of an "arc" type according to the cases. This entity is called "Element of Network" (ENET). An ENET is

a node if it is of a "mass" type and an arc if it is of "energy" type. An ENET of "energy" type (arc) has always an "upstream" and a "downstream" ENET.

Auxiliary modelling : the material and the function

Our modelling is completed by the addition of two complementary entities : the "material" and the "table". The "material" is a constituent that has a unique list of thermo-physical properties. The "table" is an entity that permits to define the variation law of a variable. This law can be a piecewise constant or linear function for which the values are coded internally or stored in a file. For our modelling, each data of the building is potentially a variable. But practically, only certain ones are.

A material is uniquely associated to an ENET of a "mass" type, while a "table" can be a priori associated to any variable of our modelling.

Manipulation : the typical-object

This basic "brick" that is the ENET is difficult to access for the user. So, we have joined a work entity to the modelling : the "Typical-Object". This entity brings together a certain number of ENETs, though permitting their manipulation by blocks. Moreover, it contains a certain amount of information relative to all the ENETs that constitute it. We give as examples, a wall and an internal load (see Figure 3).

The final ENETs of a "Typical-Object" are called "fictive" and serve uniquely to link the "Typical-Objects" together.

Remark : actually, the ENETs of a "Typical-Object" are predefined. A possible future evolution will allow the user to create and to access the ENETs of a "Typical-Object" in order to make his own models based upon the polymorph entity which is the ENET. This one will be accessible only to **CODYBA's** developers which will be in charge of verifying that the introduction of any combination of these "atomic" models in the global network would not noticeably modify the calculation algorithms performances.

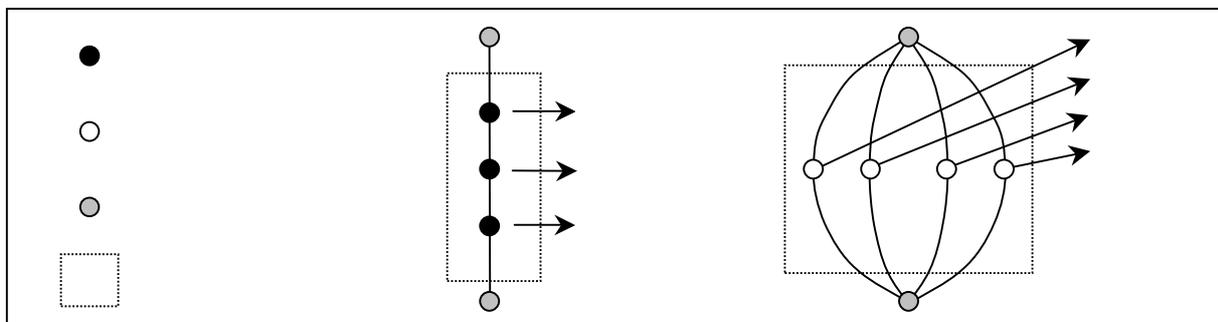


Figure 3 : Examples of "Typical-Objects"

The modelling classes

MODELLING OF THE CALCULATION ENTITIES

In practice, the four predefined entities exist under the form of classes and they inherit from the same class, the “Graphical-Object” which must assure their visibility (see Figure 4).

The calculation classes

The previous “valued” graph can not be exploited directly : so, we have used a new graph based on it which allows us to take into account equations as well as a form where a simple algorithm could be applied. For that, it was necessary to define the next class hierarchy (see Figure 6).

Overview

In figure 5, we present an overview of our modelling and its implementation.

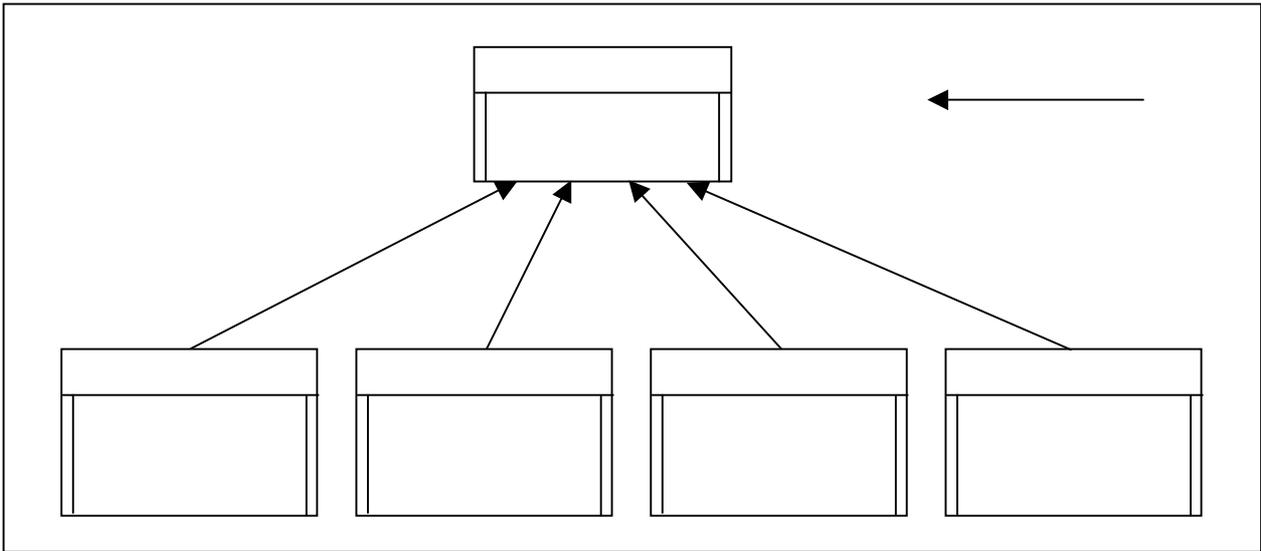


Figure 4 : Modelling classes

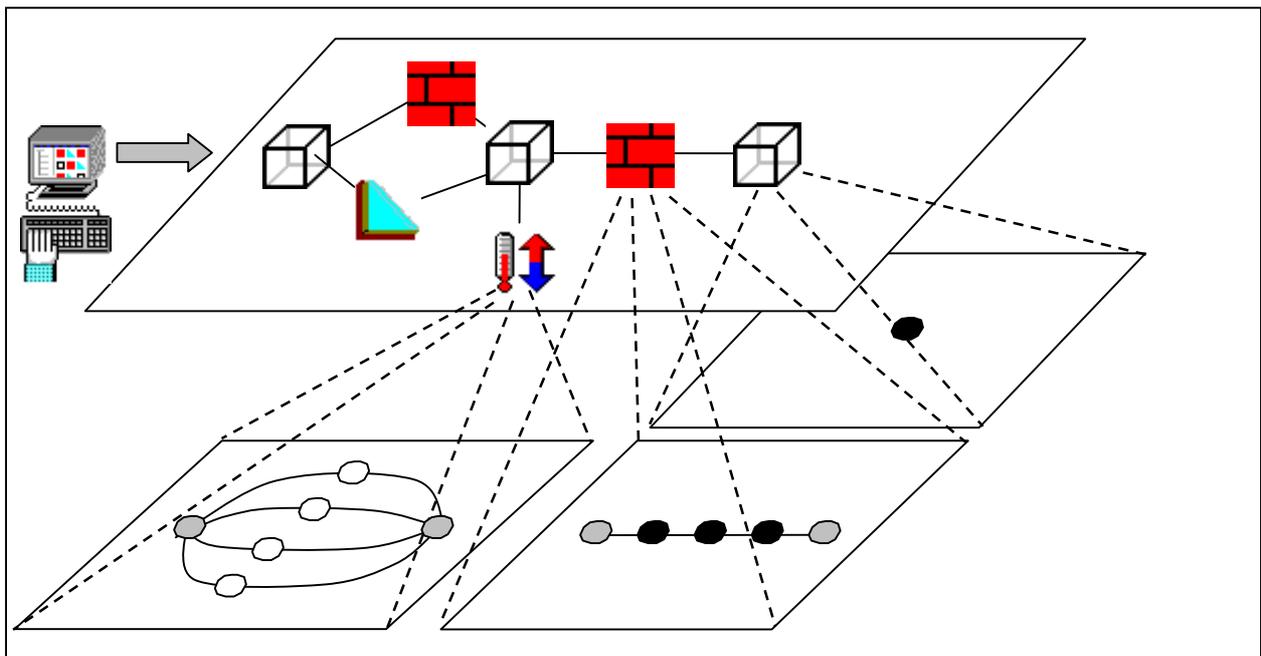


Figure 5 : Overview of building modelling and its implementation

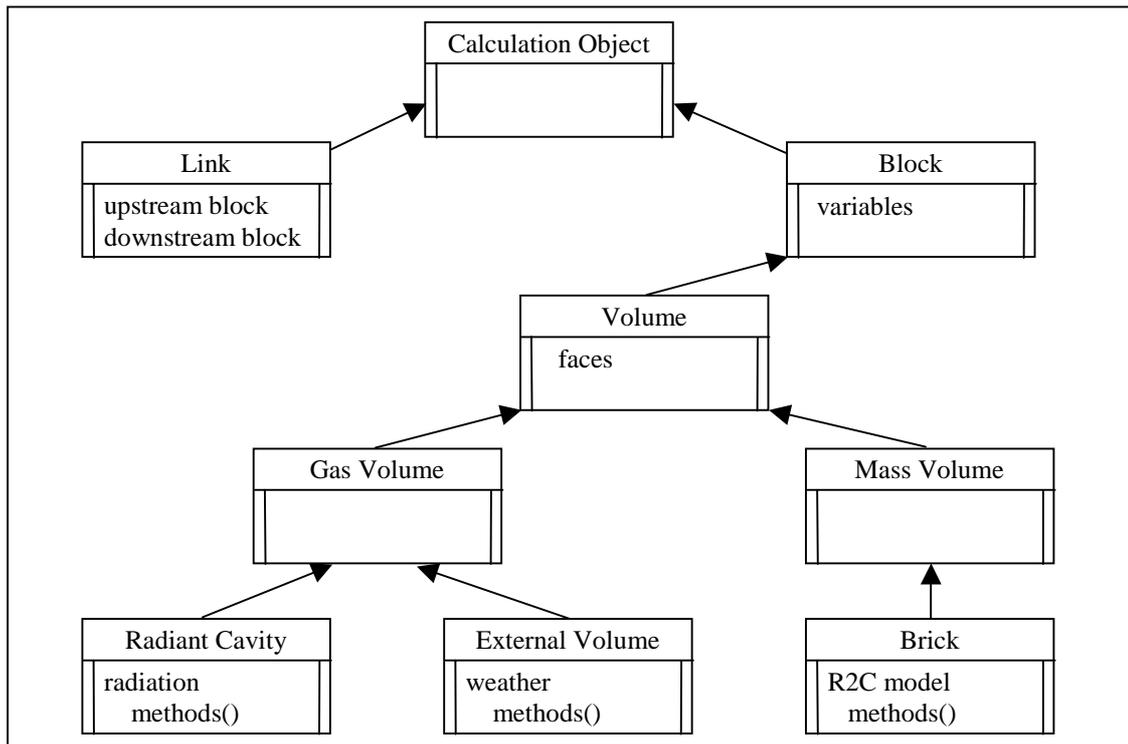


Figure 6 : Hierarchy of calculation classes

The derived classes contain the physical models, which are hidden to other classes (“data-hiding”). In the future, several other models could be introduced without changing the software (simplified models of LARET [2], reduced models [3], finite elements, etc). The models’ common point is their linear aspect, which allows their integration in the utilised iterative solver.

EXAMPLE

To study the impact of CODYBA’s evolutions, we have compared our results with those given by Roldan’s software

[4]. We must determine the daily evolution for the energy consumption which is necessary to assure a given temperature in a two housing ensemble (see Figure 7). The heating is permanent and its set-point is fixed at 19°C. The air change is also permanent. All test cases we present next have been made for the same climatic sequence, entirely fictive. This sequence has been defined by S. Rousseau [5] in order to prepare tests for building energy requirements calculation methods. These tests have already been applied to a dozen French software. The results which interest us concern the 14th day of this climatic sequence.

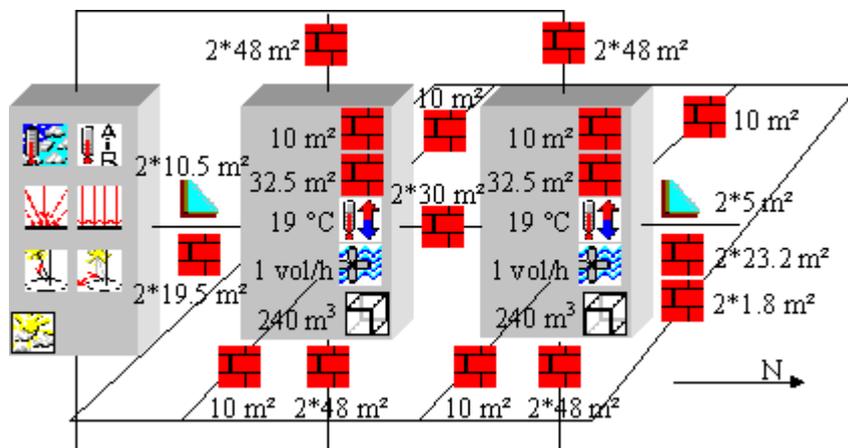


Figure 7 : Example of application (described in [4])

The input screen as well as an example of computed results are shown next :

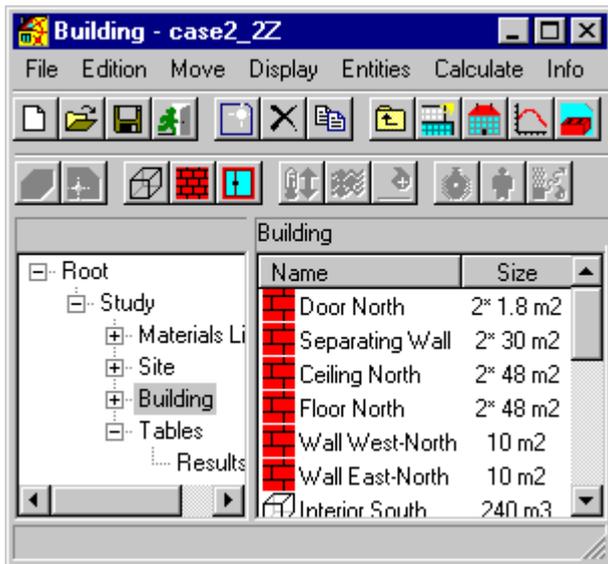


Figure 8 : “Icono-graphical” description of the project

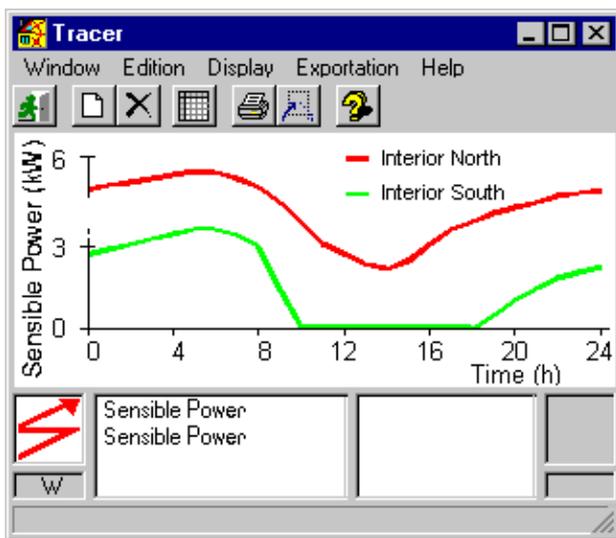


Figure 9 : Evolution of the energy requirements to maintain 19°C in the house

We notice in Figure 8, the building’s presentation under a hierarchical form according to usual ergonomics in modern exploring software.

Each entity is accessible by its icon for the edition operations. The drag-and-drop technique facilitates the introduction of a component from the libraries.

The “activity” and “set-point” variables can have scenarios : in our test case, the tables are associated to the heating device (according to the tables definition).

Figure 10 represents the data input screen for a heating device.

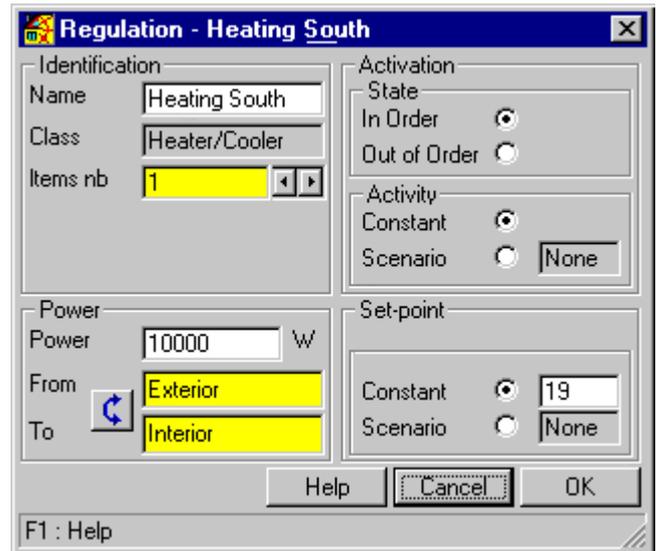


Figure 10 : Typical screen for a heating device

In our test cases, “Ref.” curves correspond to Roldan’s results , while “Cod” curves correspond to results obtained with CODYBA software. We compare the sensible powers, as well as the consumed energies. We finally compare the results for two different descriptions of the same housing ensemble : firstly, a single zone description, “1Z” curves, (see Figure 11) and secondly, a two zones description, “2Z” curves, (see Figure 12).

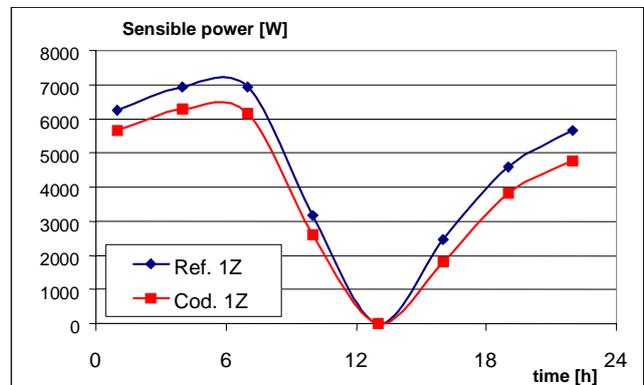


Figure 11 : Sensible power for a single zone description

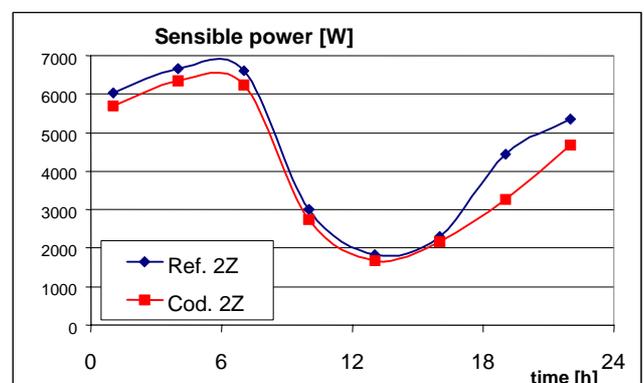


Figure 12 : Sensible power for a two zones description

The differences remarked for the sensible powers and the energy requirements for the single zone description are presented in Table 1.

Table 1 : Results for the single zone description

	CODYBA	Reference
Maximum sensible power [W]	6466	7200
Energy requirements [kWh]	92.6	98

We notice 10.2% of difference for the maximum sensible power and 5.5% of difference, respectively, for the energy requirement. For the two zones description, we obtained 6% of difference for the maximum sensible power and 4% for the energy requirements. So, both test cases give good results compared to the reference.

In Figure 13, we stress the importance that can have the degree of complexity in the buildings description.

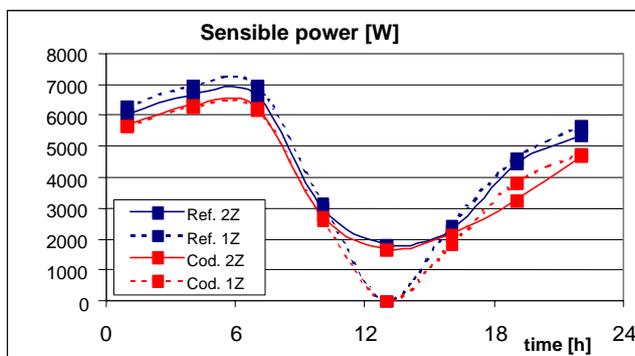


Figure 13 : Influence of the building description

The thermal behaviours are obviously different for the single, "1Z", and for the two zones, "2Z", descriptions. The two zones are oriented to the North and to the South. The instantaneous differences can reach values of 1800 W when we have solar radiation, fact that can be explained by their different way of recuperation. For the single zone case, the thermal load becomes equal to zero, while for the two zones case, the zone oriented to the North is never overheated as the zone oriented to the South and, globally, the building thermal load is never null.

CONCLUSION

In the present version, CODYBA is essentially a calculation tool for which the interface is well adapted to the treatment of buildings represented by a few zones. Actually, CODYBA V6 software is addressed to design offices and to teaching and research organisms. This software determines the energetic fluxes of a building zone. The basic data are the zones geometry and constitution (walls, windows, volumes, etc.). The main parameters are the climatic conditions, the internal loads and the heating and air conditioning powers, as well as their regulation mode. We can easily vary data like the building's orientation, the ground's reflectance, the width and material of the walls' layers, the windows glazing and masks or the control systems, in order to study their influence on the outputs. As outputs, we can find the temporary evolutions of air temperatures, consumed energies, as well as the values of latent and sensible powers.

Concerning the treatment of more complex buildings (more than a dozen zones), our development is oriented in two directions. Firstly, a command language permitting to constitute rapidly a CODYBA file based upon macro-instructions (for example, the automatic generation of 6 walls for a volume). Secondly, a 3D representation for the created geometry based upon this command language. These two orientations demand a restructuring of the software to achieve the best utilisation of the commercial products.

REFERENCES

1. CODYBA – *Cahier des algorithmes*. ADEME Editions, Paris, February 1992, 59 p.
2. L. LARET – *Building and HVAC simulation : the need of well-suited models*. Building Simulation '89, Vancouver, 23-24 June 1989, pp. 199-204.
3. J.-J. ROUX – *Proposition de modèles simplifiés pour l'étude du comportement thermique des bâtiments*. PhD thesis, INSA Lyon, April 1984, 202 p.
4. A. ROLDAN – *Etude thermique et aéraulique des enveloppes de bâtiment : influence des couplages intérieurs et du multi-zonage*. PhD thesis, INSA Lyon, December 1985, 312 p.
5. S. ROUSSEAU, J. BRAU – *Comparaison des méthodes agréées pour le calcul du coefficient B. Analyse des résultats de la première série des tests*. Contrat INSA – Ministère de l'Urbanisme et du logement. Report, November 1982.