BRINGING SIMULATION TO APPLICATION; SOME GUIDELINES AND PRACTICAL RECOMMENDATIONS ISSUED FROM IEA-BCS ANNEX 30.

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ABSTRACT

Simulation tools are not yet used as much and as well as they should all along building life cycle (BLC). Most important decisions are still taken almost without using these tools. The work done in the frame of IEA-BCS Annex 30 consisted in identifying and eliminating as much as possible the main bottle necks encountered in the use of simulation tools.

INTRODUCTION

Simulation should be applied at all stages of the building design process, so that a quick feedback on design implications can be given. Simulation tools should make it possible to compare many possible options.

The aim of Annex 30 was to promote the best use of energy simulation at all stages of Building Life Cycle (BLC). The work done consisted in identifying and (as much as possible) in eliminating the bottle necks encountered when using simulation tools.

A synthesis report, published at spring 99 [1], intended to answer four questions:

1. which help can be expected from simulation at each stage of BLC ?
2. how could we make the simulation models more reliable ?
3. which data do we need to perform the simulation at each stage of BLC ?
4. how could we make more efficient the data transfers among the different softwares all along the BLC ?

These four questions are addressed in the four following chapters respectively.

DESIGN PROCESS ANALYSIS

A whole BLC can be subdivided into the following seven stages. The definition of each stage is, of course, conventional and all building "stories" will not fit with this schematic and sequential subdivision.

First step: Conceptual design

This is the most challenging stage : most important decisions are usually taken very early in the project story and they are very often irreversible !

Everybody agrees on the fact that calculation tools should be much better used at the stage, but we must recognise that most of existing tools are not well adapted to this business.

Thermal simulation can help in comparing different architectural concepts (building shape, orientation, zoning, energy saving options, …).

Computer fluid dynamic (CFD) tools can also be used here in order to get a first idea of ventilation and internal air flow patterns. But the safety and cost effectiveness of CFD are not yet guaranteed today …

Second step: Preliminary design

System simulation programs are already currently used in this second stage of BLC. With the help of existing tools, HVAC engineers can give some feedback to the architect in terms of preliminary equipment, volumes, heating and cooling powers to be installed and corresponding energy costs.

It is here that the most important comparisons among various HVAC alternatives should be made.

Architect's preliminary drawings, structural types, occupancy schedules loads and requirements are the main simulation inputs at this stage.

Most challenging problems are still the definition of a lot of default informations and also a friendly visualisation of simulation results in order to improve the dialog between HVAC engineers, architects and the contracting authority.

Third step: Detailed design

It is supposed here that all important options are already fixed. Simulation tools are there used in order to verify all the possible consequences of previous choices and to size HVAC equipment.

Detailed architect's drawings and detailed technical information are supposed to be used as simulation inputs. How far to go with characteristics of real equipment (provided by manufacturers) is still an open question.

Fourth step: Tender evaluation

This phase leads to the selection of the real equipment.

The success of the work performed is depending very much on the quality of the work done at previous stage : attention should be paid to the documentation and to the clarity of detailed design simulation results. This will very much help the tenders to preparing their offers. And this will also help in the tenders evaluations.

A non-technical difficulty encountered at this stage is the (more or less well defined) responsibility sharing among the different contractors.

If these responsibilities were better defined and if simulation was better used at this stage, not only investment costs but also running costs would be better integrated in tenders offers …

Fifth step: Construction and commissioning

The introduction of system simulation tools in balancing and commissioning work is another important challenge.

All product information and all on-site measurements should be used as simulation input data (simulation models must be tuned in order to fit with real performances).

Simulation should be better used in order to interpret (interpolate, extrapolate and transpose) commissioning results. If well done, this work can provide a useful feedback to all contracting parties. It can also provide a strong reference for the next stage of the BLC …

Sixth step: Operations and maintenance

Simulation should be used more and more in order to fix energy targets and references.

It is by comparison with such targets and references, that the building manager could run the HVAC equipment in optimal conditions, detect possible faults and decide maintenance actions.

Simulation should help a lot in applying (previously defined) optimal control strategies and adapting them to all changes occurring in the building (occupancy, zoning, schedules, etc, …).

This work should also benefit from the outputs of all previous stages : actual building and HVAC data have to be used here …

Seventh step: Renovations

Renovations bring us back to the begin of BLC, but with an important difference in the input data : very detailed information about the existing building is now supposed to be available.

Simulation is currently used at this stage in order to assess retrofit proposals. One of the challenges is still to make the best use of all information available in order to get most realistic retrofit analyses.

MODEL QUALIFICATION

Practitioners are offered today a lot of models, embedded in ready-to-run packages, but very often almost without information about their domain of use and their actual accuracy. Objective information about the quality of the model is very often lacking as if the implementation of a given model in a program offered a sufficient guarantee concerning the ability of the model to adequately translate the behaviour of the real world.

Qualification procedure

Consequently, a "qualification" procedure is strongly needed in order to provide the users with some guarantee about the reliability of the simulation results.

The model qualification procedure can be seen as a quality assurance “proof” further defined as *a standardised quality assessment procedure to be passed by a certain model before its implementation in a given simulation program*. The output of the Annex proposes that the procedure contains the following items.

Qualification documentation

The documentation should present a general description of the model, the main modelling assumptions, the terminology, the mathematical equations and all input/output files. Samples of results are also required. This can be done by writing “forms” related to a model [2]. An other modern option is to use simulation environments which provide embedded within each other the source code of the model, the explanations about the different selected hypothesises as well as the calculation engine. A more and more popular example of this approach is provided by the “EES” software [3]. For instance, fig. 1 show a set of lines extracted from an EES implementation of a chiller model.

Parameter identification

This key item has been too often neglected by scientists : many "beautiful" models staid unusable because the users were not provided with a satisfactory parameter identification procedure. Technical data used by practitioners do not correspond directly to the model parameters. The paradox is that so-called "simplified" simulation models usually required more complex parameters identification methods : the simpler the model, the more different the parameters from the technical data (geometrical data, fluid properties, etc, …). Static models (mainly for HVAC components) are usually identified by a reverse use of the model equations (straightforward in EES) while dynamic models require more complex methods.

Examples of use

Real case applications of a model are required but it is clear that the usefulness of these examples depends very much on how well they are documented.

Validation

This is the key issue today. But a lot of work has still to be done in order to make validation safe and meaningful. One of the biggest problems associated with validation is to agree on the definition of the reference "entity": should it be a reference "model" or a set of reference "data"? For instance, fig. 2 shows the results of the comparison of a building simplified model to a more detailed for the simulation of one case study of the Annex.

Implementation

Although not directly considered as part of the modelling process, the implementation of a model appears to be a key issue as it is able to significantly enhance the different steps of the qualification procedure. Therefore, "modern" simulation environments like EES or Matlab-Simulink [4] offer very interesting properties. For instance, fig. 3 shows how a cooling model was implemented within the Simulink graphical environment. This allowed to intelligently restructure the model.

Relation between model validation, commissioning and fault detection

These three tasks are very similar and common methodologies should be developed. In each case, the problem is to compare simulation with a reference. In each case, all theoretical and experimental uncertainties have to be very well analysed. This is probably one among the most important questions to be addressed in future research programs.

Dissemination

As one of the conclusions of the Annex, the need for an international organisation that would centralise, standardise and dispatch the correct information on simulation models is emerging. Among other tasks, it would take in charge the future development and the real application of the procedure in an international context.

Standardisation is a dynamic process which should go in two directions, as already mentioned by the conclusions of the PASSYS project :

1) develop simulation-based energy standards;
2) develop a simulation accreditation procedure.

INFORMATION MANAGEMENT

This is obviously one of the most important bottlenecks in the simulation process. Many beautiful simulation models are still poorly used because of the difficulty to manipulate all input and output data.

In order to help simulation users, it is proposed to provide them with :

1) checklists for recording the basic input data;
2) interfaces for data input, project administration and visualisation;
3) output data treatment procedures.

Checklists

Relevant input data can be classified according :

1) "categories" (project identification, system information, etc.);
2) precision;
3) requirements all along BLC.

Three precision levels are proposed :

- "exact"
- "standard"
- "not necessary".

A great attention has to be paid to the availability of "default values".

This is particularly true for all the "physical" information and for "internal" and "external" loads. Information about internal loads have to be continuously updated. Standards and good default values are also very necessary.

It is a key issue in office building where the loads may vary from 15 to 75 W m^{-2} !

Future evolution of internal loads is very uncertain (explosive increase of computer use, but dramatic increase of computer efficiency …).

The definition of occupancy schedules (and corresponding temperature requirements) stays as a tricky task. "Diversity" factors have to be carefully defined.

The problem of weather data selection is not yet completely solved : reference years are available, as well as Winter and Summer design days. But little is said about the definition of hot and cold waves and about the correlations among different climate variables (as dry bulb and wet bulb temperatures).

But one among the most important tasks to be realised in the future is the standardisation of equipment data.

User interfaces

Better and better user interfaces are offered by program developers. These interfaces are organised to :

1) simplify input and output manipulations;
2) allow identical inputs to be processed only once;
3) allow simulation results to be re-used as inputs in further calculations.

Output data

The outputs must be treated in such a way the user can follow the simulation one line. Very different treatments are required, according to the use considered : research or design.

Visualisation of the results must include inputs as well as output data.

DATA EXCHANGE

Data exchange occurs all along the process of simulation use, either between the user and the program or between different programs sharing some common data. Consequently, it has to be organised at each stage of the computational process: data input, calculation, data output.

Data input

At this stage, five different methods of data exchange can be distinguished :

1) "Paper to program" : information transferred from drawings and reference books to the computer (this can be considered as the "less friendly" process);
2) digital paper (spreadsheet) with help of digitiser "reading" of scale drawings (in two-dimensions only);
3) "closed" data base (only open to software belonging to a same "family");
4) "open specific" data file (only viable with international standardisation);
5) "open generic format" (the dream towards which EU "COMBINE" and "IAI" projects are oriented).

Calculation

One typical data exchange problem is encountered by building and HVAC designers when passing from *plant sizing* to energy *simulations* : these two tasks usually involve different software.

Output

Display methods can be distinguished in the same way as for data input process : from "hand" methods to the use "generic format". At this stage, the evolution is very much conditioned by software producers (they like to have calculation sources acknowledged) as well as by the designers (they like "house style").

Current and future states of the art

Although a number of methods are today available to carry out data exchange, fully operational data exchange systems are not so common. Two important difficulties can be identified for what is generally considered as one of the main bottlenecks of simulation use, namely the input of the geometrical data of the building:

1) Drawing systems product lines rather than surfaces required by analytical tools;
2) architect' drawings are too complex; they need to be simplified and the simplifications have to fit with the analysis considered …

Different solutions were tested, for instance during the COMBINE project. The modern trend involves the use of standard data formats (previously STEP and now IFC). This will allow world-wide information sharing throughout he project life-cycle and across disciplines and technical applications.

A number of data exchange processes were demonstrated during the Annex, specially concerning the simultaneous use of programs in a given simulation (TRNSYS [5] and COMIS [6]; TRNSYS and Matlab). They illustrate the benefit of the approach. For instance, fig. 4 shows a comparison of a TRNSYS simulation of the first case study of the Annex when connected or not to the air flow calculation program “COMIS”.

As conclusion, a safe and efficient organisation of data exchange might be the key towards "bringing simulation to application" …

REFERENCES

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[5] KLEIN, S. et al. TRNSYS 14.2 reference manual. University of Madison-Wisconsin, USA, 1997.

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Hypotheses:
1)all electromechanical losses injected in the fluid before compression;
2)adiabatic machine.

Supply heating-up:

$$\dot{W} - \dot{W}_{s2} + \dot{Q} = \dot{M} \cdot (h_{su1} - h_{su})$$

with $\dot{Q}$ = heat transfered from the surroundings to the compressor.

$$\dot{Q} = 0 \qquad \text{(second hypothesis)}$$

$$p_{su1} = p_{su}$$

Supply mixing:

$$\dot{M} \cdot h_{su1} + \dot{M}_l \cdot h_{exd} = \dot{M}_{in} \cdot h_{su2}$$

$$p_{su2} = p_{su1}$$

Isentropic compression:

$$h_{ex} = h_{exs2}$$

Isentropic nozzle:

Real gas:

$$h_{sun} - h_{thr} = \frac{C_{thr}^{\ 2}}{2000}$$

$$C_{thr} = \dot{M}_l \cdot \frac{v_{thr}}{A_{thr}}$$

Fig. 1: extract of the EES implementation of a chiller model

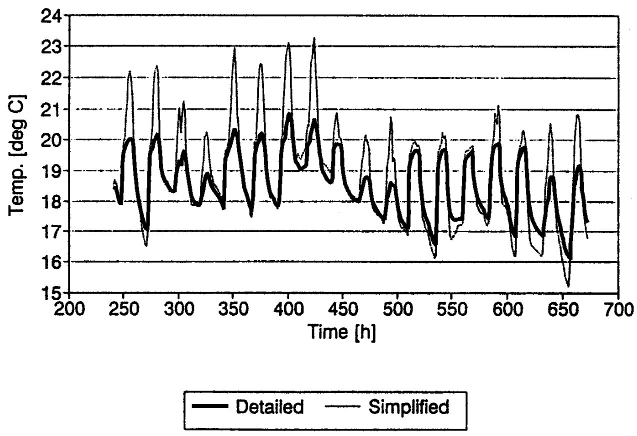

Fig. 2: comparison of a simplified and "detailed" building model for the simulation of the Annex 30 Case Study n° 1

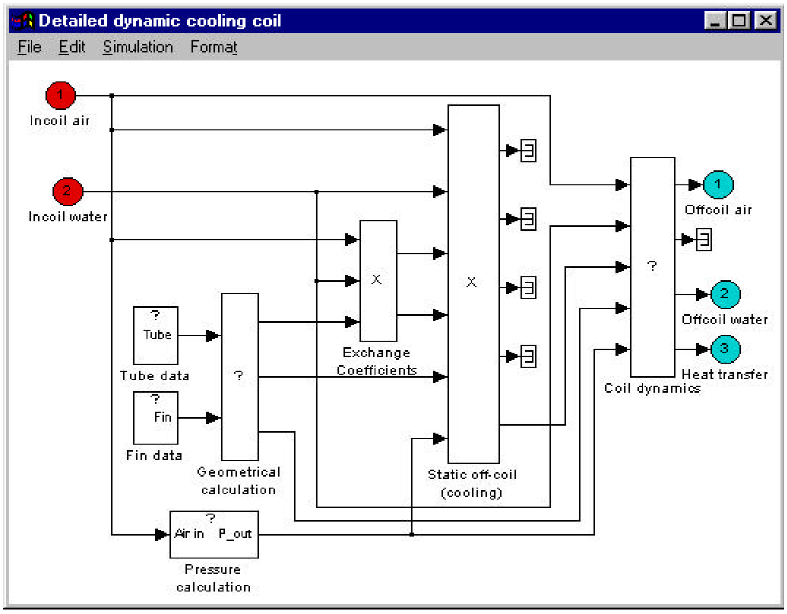

Fig.3: cooling coil model implementation in Simulink

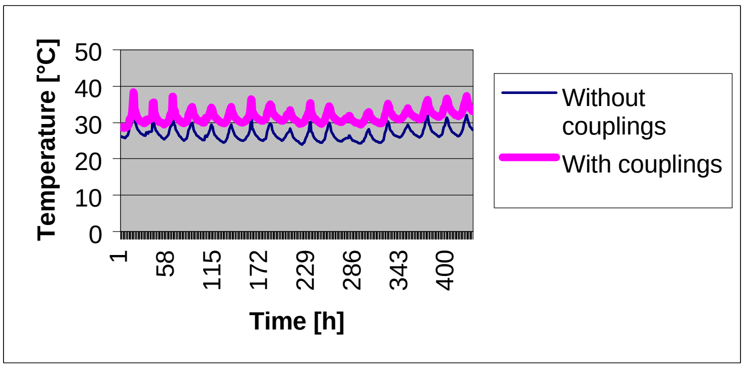

Fig. 4: Case Study n°1 simulation: TRNSYS vs coupling TRNYS/COMIS