Building Energy Simulation Software: An End User's Viewpoint

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This paper describes the recent, current and projected uses of building energy simulation szftware. Limitations of the currently available software are discussed Suggestions as to the format of future program are offered.

Introduction

During the latter half of the 1980s, as the power of microcomputers increased, the use of these machines by consulting engineering practices increased enormously. Prior to this time calculations had been carried out manually, or where the scale of the project justified the cost, by logging in as a terminal to a remote mainframe computer.

Coincidentally, the latter half of the 1980s saw an unprecedented boom in building activity in the Australian market. The ready availability of funds and the limited supply of proprietary software combined to prompt a number of consulting firms to develop their own software. Many of these firms suffered enormous development cost over-runs abandoned projects and poor software documentation standards. For these reasons and the fact that the building industry is unlikely to reach the boom levels of the 1980s in this decade the consulting industry in the future can be expected to look increasingly to third parties to meet their software requirements.

Although Lincolne Scott Australia uses modelling software for virtually all disciplines, the greatest user by far is the mechanical discipline.

The mechanical discipline currently uses modelling techniques for the following purposes:-

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(a) Calculation of peak heating and cooling load, for use in sizing of air conditioning plant.

(b) Estimation of energy use of planned buildings and analysis of energy use in existing buildings.

(c) Facade analysis at the design development stage of projects. This analysis typically involves a life cycle costing of various facade types, to ascertain whether more (thermally) efficient facades are justified in energy use terms.

(d) Comparison of various system types at the design development stage.

Lincolne Scott Australia employs either in-house software (Thermaglas) or the ACADS program CAMEL for item (a).

The APEC/ACADS program ESPll is used for energy use calculations as detailed in (b). This should not be confused with the ESP program developed by the University of Strathclyde.

One may expect this program to also be employed for items (c) and (d), however, this is not generally the case. No separate fee is generally offered by the client for these services, therefore it is not economical to use the ESPll program, as it is far too time consuming. Lincolne Scott uses it's own programme, Energy + for this purpose. This programme has limitations as to the types of projects it is applicable to, however it is simple to use and gives sufficient information for valid comparisons.

Past Present and Future Markets and Applications

In July 1987, Murray Mason of ACADS (a member of the organising committee of this conference), produced a paper entitled *Energy Consumption Analysis by Computer Simulation* (Mason, July 1987). It is interesting to compare his view of the modelling situation then to the current state of affairs.

In 1987, Mason estimated that "little more than twenty" building had been analysed using energy simulation programs. Though he offered a number of theories for this state of affairs, perhaps the most significant were:-

(a) The tax deductibility of energy use mitigated against spending capital to achieve energy savings in existing buildings.

(b) The tariff structure of energy suppliers favoured high energy consumption - the higher the energy use the lower the tariff.

(c) The consulting engineering industry considered the available programs difficult and uneconomic to use.

(d) Consulting firms had great difficulty in obtaining a separate fee for these simulations.

While there has been little change in the past six years to items (a), (b) and (d), the receptiveness of the consulting industry to simulation software has increased markedly and can be expected to continue to increase. The limits to this increase in demand now lay not with the consulting engineering profession, but with their clients.

In 1987, the users of computer systems in many consulting practices were young inexperienced engineers under the direction of more senior colleagues. This was a reflection of the backgrounds of the people involved, but led to difficulties with handling the complex energy simulation packages, which require both sound engineering knowledge and a good measure of computing ability. It is now common for a PC to be found on almost every engineers desk and a majority of engineers are familiar with at least the simpler load calculation software. The computer literate graduates of the 1980s are now sufficiently experienced in engineering, as well as the use of a wide range of software to exploit these simulation packages more effectively. It can be said that the infrastructure for wide use of modelling is now present.

The fact remains that an energy simulation for a building of significant size (eg a 20000m^2 office building) will take an experienced user at least 60 hours, including time to prepare reports. thus the consulting firm must convince the building owner that the sizeable resultant fee is justified. There remains considerable resistance from owners of buildings to this expenditure. It can be seen therefore that the market for energy simulation of existing buildings is limited by the enthusiasm for building owners to save energy. The tax and tariff structure, together with the trend for tenant leases to be structured towards a "user pays" arrangement, will tend to limit this enthusiasm.

Other marketing opportunities exist, however, as follows:

Facade Upgrades

The current oversupply of new office space has led to some building owners electing to undertake major refurbishment to stay competitive. This has, in a number of cases, led to complete facade upgrades.

Facade upgrades have also been undertaken on a number of aging government building recently. Recent discussions with government architects concerned with one such upgrade revealed that energy efficiency had not been considered when defining the scope of the work and the materials used. An energy simulation, coupled with a life-cycle costing would enable the building owners to make a reasoned assessment of the merits of a variety of facade types.

Energy Studies at Design Stage

It has been common practice for consulting engineers to provide advice on the relative merits of various glazing and facade types at the design development stage of a project. This has often, however, been carried out within the negotiated fee for the project as a whole. As such empirical calculations, based on the peak cooling and heating loads, are used as the basis for this advice. The complexity of the existing energy simulation software does not allow the more rigorous simulations to be carried out within the normal scale fee.

In any case, the lack of detail in the mechanical design at this stage, which could be expected not to have advanced past the concept stage, implies that the level of accuracy of a computer energy simulation is so low as to not justify the effort.

This is a case where a simple, easy to use energy simulation package can be of considerable use. The inaccuracies inherent in making such packages quick and simple to use are acceptable at this stage of a project, due to the magnitude of the "unknowns". Lincolne Scott's programme Energy + has been useful to our organisation in this role, however there are some limitations to it's validity.

Frequently, it is at this very early stage of the evolution of the mechanical design that critical decisions are made as to the configuration and concept of the system. Will the system be chilled water or not? Will the chillers be air or water cooled? Will primary/secondary pumping be used? Fan assisted variable air volume terminals or not? Variable speed fans or inlet guide vanes?

These decisions are often made after specific detailed study, naturally, but a good measure are made based on either

(a) previous studies on similar sized projects,

(b) the policy of the practice or

(c) the experience of the engineer

The use of a simplified energy package helps to add a measure of "science" to this process, without excessive expenditure of time. We are not aware of any software package, apart from our own limited version, which adequately services the area between the crude "rule of thumb" manual calculations and the sophisticated full simulation packages.

The Use of ESPII to evaluate an Existing Building

Since acquiring from ACADS the ESPll program in 1989, Lincolne Scott Australia's Adelaide office has carried out simulations of several buildings, including offices, industrial facilities, an airport terminal building and a hospital.

The ESPll system comprises a series of executable files, being WEATHER, RESPONSE, LOADS, SYSTEMS and ESPEDIT. The programs accept inputs from fixed format input files, which are in "card" format. ACADS has developed an input program which eases the creation of these input files, which have been extremely laborious to produce in the past.

The WEATHER program produces a machine code file of weather data for use by the program. The RESPONSE program calculates the thermal behaviour of the building materials. LOADS is an ASHRAE method loads estimating routine which calculates the heating and cooling loads for each space in the building for every hour of every day of a year.

The SYSTEMS program accepts inputs from the user defining the nature and capacity of the mechanical systems serving each space and the building as a whole. Using this information and output from the LOADS program determines:-

(a) the energy use of the various components of the system at all times of the year

(b) the peak energy use

(c) situations where loads are not met due to insufficient capacity.

The package allows the user a good deal of flexibility in defining the nature of the mechanical systems. The systems are divided into primary (essentially central thermal plant) and secondary (the plant which operates directly on the building spaces - generally air handling).

While considerable flexibility is provided for, the single greatest limitation of the program is that the secondary (ie air distribution) systems must be chosen from a set menu of 20 different types. While the list is quite comprehensive, it does not allow for a number of systems which are popular in the Australian market place, for example:

(a) Fan assisted VAV terminals

(b) Skin systems, which employ separate air handling to handle the fabric loads and the internal loads.

(c) Ice storage systems

(d) Primary/secondary pumping

Lincolne Scott has recently patented a new air distribution system which is called the "twin duct" system. This system employs purpose made terminal boxes serving individual spaces which mix appropriate amounts of cold air and "neutral" air. On one of the projects where this system is being installed part of our scope is to carry out an energy simulation. Unfortunately the system has little similarity to any of the 20 types offered by ESPll.

Given these difficulties, ESPll is a powerful program and the simulations carried out in Adelaide have been largely successful.

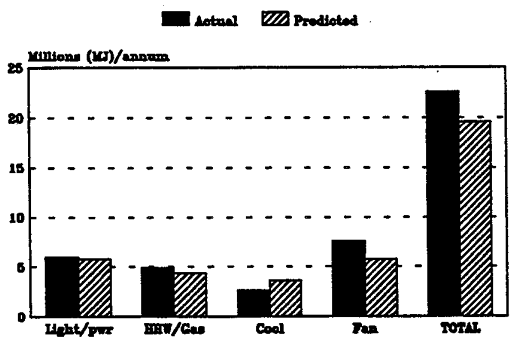
The Grenfell Centre, in the heart of Adelaide was modelled in October 1992 for the Australian Mutual Provident Society, the building owners.

The building is served by a series of centralised air handling plants, serving constant volume terminals on the floors. These are being replaced with fan assisted VAV terminals or modified to operate as conventional VAV terminals. As mentioned earlier, fan assisted VAV terminals are not explicitly supported by the ESPII program.

The central thermal plant uses a conventional arrangement of chillers and boilers and was therefore relatively straightforward to model.

The final result can be seen in fig. 1. The agreement between the predicted results and the actual results is within normal bounds. It is unusual for a simulation to be more accurate than ±15 % in our experience.

Fig. 1
Predicted to Actual Energy Comparison



A strength of the ESPII programme lies in the extent that the areas of energy use are broken down. Thus the user can more readily identify where the significant energy savings can be made.

Future Software Requirements

In the text of this paper there are several references to a crude, quick and simple energy program, to enable consultants to carry out broad-brush comparisons economically. This type of program would be used where the percentage difference of several options is more important than the final magnitude.

There remains, however a need for the detailed analysis software which will enable users to accurately define every element of the building.

Thus it can be seen that two complimentary programs could co-exist in a given practice.

The form of these programs could be debated at length, but it is suggested that the following features could be incorporated.

(a) Object oriented (graphical) input of systems - Refer fig 2.

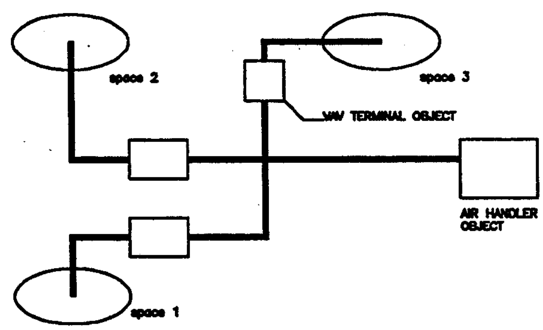
(b) Graphical input of architectural (ie building element data, refer fig 3, perhaps based on CAD files.

(c) Facility to add new system types to the database defining the mode of operation.

The graphical input approach will minimise errors in input as the user will find it easier to visualise what he or she is doing.

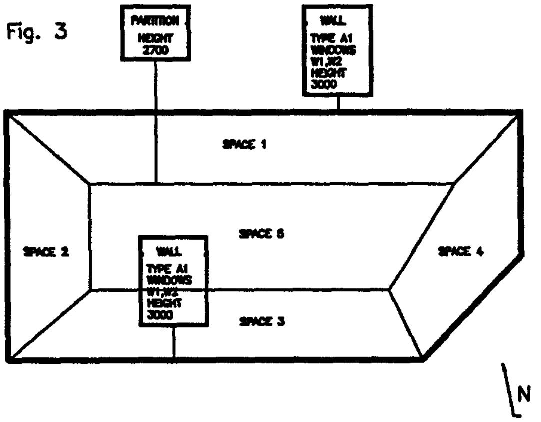
In the example below, pre-defined VAV terminal objects and an air-handling unit object are configured to service three spaces within a building. The spaces are defined by the user from architectural information

Fig. 2



This object oriented systems input approach is not dissimilar to the approach employed by several building management systems, such as Barber Colman's Autoblock, an AutoCAD based programming tool, Honeywell's CARE engineering software, or the Staefa programming system. Thus it can be seen that a significant precedent exists for this approach.

Fig. 3



Likewise, the input of the building fabric could reasonably be adapted to a CAD format. With the programs which are currently available, the input of the building fabric is the most time consuming element of the simulation. Importing a CAD file into the simulation program could reduce this time significantly.

In order to facilitate additions to the database of mechanical systems supported, object oriented methods could also be employed using standard blocks. The standard blocks would include such basic elements as heating and cooling coils, dampers, fans and so on. Figure 4 shows how a fan assisted VAV terminal could be defined with three such blocks.

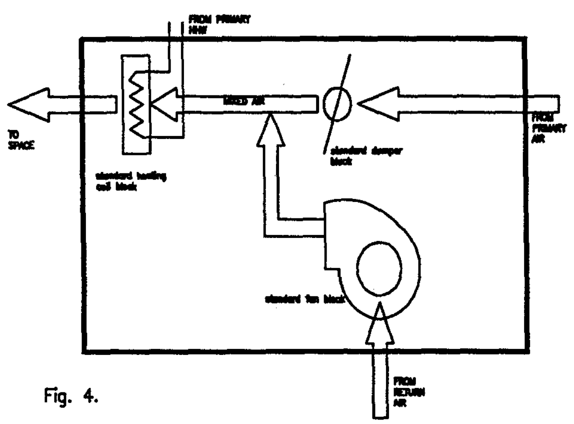


Fig. 4.

An extension of this graphics based approach is real or accelerated time modelling of the performance of a building under changing ambient conditions and solar loads. This form of modelling may become possible given a significant increase in computing power. Such a facility would allow the engineer to identify any problem areas as they occurred, and identify the causes far more easily than is the case with the retrospective "Loads not met " tables available with the ESPII programme.

It remains to be seen where the funding for such a large project would come from. We believe it could only arise from a large joint venture, with numerous organisations contributing funds.

However, with the computing power currently available and with the expectation of further increases in power, we believe that graphics based systems should form the basis for future development.

References

Mason, Murray *Energy Consumption Analysis By Computer Simulation*, (AIRAH Journal July 1987)

Mason, Murray, *Mechanical Engineering Design Aids Nº DA12: User Guide for the APEC Energy Simulation Computer Program ESPII*, (Department of Housing and Construction, in Association with AIRAH)

Appendix A :

Secondary Systems Supported by ESPII

1. Constant volume single zone with space reheat.
2. Constant volume single zone with heating and cooling.
3. Constant volume dual duct.
4. Constant volume face and bypass, heating and cooling.
5. Constant volume face and bypass cooling, space heating.
6. Constant volume triple deck.
7. VAV with perimeter radiation.
8. VAV with space reheat.
9. VAV dual duct.
10. VAV dual conduit.
11. Two pipe fan coil unit with outside air.
12. Four pipe fan coil unit with outside air.
13. Two pipe fan coil unit with primary air.
14. Four pipe fan coil unit with primary air.
15. Two pipe fan coil unit with outside air.and economy cycle
16. Four pipe fan coil unit with outside air.and economy cycle
17. Two pipe induction unit with primary air.
18. Four pipe induction unit with primary air.
19. Water loop heat pump system.
20. Reverse cycle heat pump system.