

Application as Commissioning Tool of Various HVAC Simulation Programs and Visual Tools

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ABSTRACT

Various simulation programs and visual tools of HVAC system ever released, which were not originally developed to be used as commissioning tools, are considered to be potentially powerful tools for commissioning, as use of these programs facilitates the confirmation/comparison of function and performance of HVAC systems and detailed analysis of parameters influencing HVAC system performance.

In the present paper, application and convenience of several programs such as Micro HASP, Micro ACSS, FACES, LCEM, TRNSYS, DOE-2, EnergyPlus and DeST and their visual tools as tools to support commissioning were assessed by investigating their functions and performances.

KEYWORD

Simulation program, visual tool, commissioning tool

INTRODUCTION

The commissioning (hereafter abbreviated as Cx) in each phase of building/HVAC system is hoped to meet the function and performance demanded by purchaser to the full. When function/performance of the HVAC system is verified, it seems that Cx can be executed adequately and effectively by using the suitable simulation tools.

Many energy simulation programs of building/HVAC system and visual tools (visual user I/O support interface) have been developed. The principal simulation programs are classified in Table 1, according to simulation object, function, and performance. None of these programs, which are mostly used to calculate heat load of building or energy consumption of HVAC system, was developed for Cx. However, because these programs can be used for comparison/confirmation of function and performance of HVAC system and for analysis of fact checking system by using calculation results of indoor environment and energy consumption, it is hoped that they will become powerful tools for supporting Cx in the future.

In this paper, application and convenience of several programs and their visual tools were considered and 4 kinds of Cx support tools which are suitable for program, planning, preliminary design, and operation phase respectively were proposed.

REVIEW OF MAIN PAST RESEARCH

In IEA ECBCS Annex21 (Environmental Performance of Buildings, 1988 ~ 1993), it was pointed out that the maintenance consolidation of manuals and the introduction of high performance interfaces were necessary to verify the reliability and applicability of 17 extant simulation tools, and to expand the use of simulation in design phase in accordance with a standard verification process.

In IEA ECBCS Annex30 (Bringing Simulation to Application, 1995 ~ 1998 (Peter, 1998)), a detailed examination was performed about types of simulation tool, management and succession of simulation information, and benefits and convenience of different user interfaces and so on in order to be able to use simulation tools for all phases of the building/HVAC system. However, these pieces of research did not compare simulation tools as a means to support Cx, though they did examine the usability of simulation tools at all stages of an HVAC system.

Thus, the Cx Tool Development Subcommittee Of The Commissioning Committee Of SHASE in Japan (SHASE, 2004), of which the authors are members, examined applicability of simulation tools as tools for Cx by comparing the main functions/performance of five programs using simulation results such as HASP/ACLD/ACSS (SHASE, 1985), DOE-2 (James, 2001), EnergyPlus (Anonymity), DeST (Jiang, 2004), HVACSIM⁺(J) (SHASE, 2003a). However, since the original study, the applicability and convenience of some programs (for instance, ASSIST (Systech Environment Lab, 2005) and DesignBuilder (Anonymity A)) have improved greatly due to the development of visual tools. In this study, applicability and convenience of simulation tools as Cx support tools were examined by reviewing manuals of several programs and their visual tools.

Table 1 Classification of various simulation tools

Purpose of use	Application phase	Typical simulation programs
Calculation of LCC, LCA	Program, Plan	Database for LC evaluation, LCA calculation program
Heat load calculation	Design	MicroHASP, MicroPEAK
Energy simulation	Design~Operation	HASP/ACSS, TSNSYS, EnergyPlus, DeST, ESP-r
Dynamic analysis of HVAC system	Design~Operation	HVACSIM ⁺ , TSNSYS
Macro analysis of thermal environment in large enclosure	Design	DAIKUKAN
Analysis of air current and thermal environment	Design	Stream, Esim, Windy, FLUENT, CFD2000
Ventilation calculation	Design	COMIS, Ventsim, DeST, NETS(Okuyama, 1998)
Water/ice thermal storage system design	Program, Design	TESEP_W, TES_ECO, ice club(HPTCJ.)
Soil thermal storage system analysis	Design~Operation	Analysis tool of Soil thermal storage system(Miyada)
Cogeneration system evaluation	Program, Design	CASCADEIII(SHASE, 2003b)
Analysis of BEMS or measurement/ control system	Construction, Operation	Logic tracer

THE ROLE OF SIMULATION IN Cx

From program to operation stages of building/HVAC system, various tools are needed to support Cx in confirming and evaluating the function/performance of various equipment units, subsystems, and the entire building/HVAC system. The difference between general simulation use and Cx support simulation use in each phase and the role of simulation for Cx are shown in Table 2.

In planning and design phase of a building, the designer will calculate the building's PAL (Perimeter Annual Load Factor) or BEE (Building Environment Efficiency) value using BECS (IBEC, 1994) and CASBEE (Ikaga, 2005), then use this information to write an energy saving report and an environmental load assessment result report. Use of Cx to produce a yearly simulation of natural room temperature allows optimization of location, skin structure, size and position of apertures in the building.

In the programming/planning phase of an HVAC system, planners present a comparison of environment and energy consumption among various alternative solutions to the owner by using simplified calculation tools such as yearly energy consumption estimate tool, LCC(Life cycle cost) (BELCA,1999) and LCA (Life cycle environmental load) (AIJ,2000). Cx is used to validate the calculation result of the optimal solution presented by planner, and the owner is informed of the rationality of his request according to the result calculated using a standard simulation tool that has national or industry approval.

At the preliminary design phase, the designer calculates hourly and daily peak load by using MicroPeak (JBMEEA, 2000), selects HVAC and outdoor air introduction method, and decides the capacity of air conditioner and heat source equipment. It is necessary to confirm the indoor airflow and the temperature distribution by CFD in large enclosures. Cx is used to present the information on the HVAC system which suits the demand of the owner and the optimal capacity of equipment by using the energy simulation tool to calculate the hourly heat load and energy consumption performance.

At the working design phase, the designer examines various design and control parameters by using an analysis tool for the dynamic properties of the system and equipment such as TRNSYS (SELUW, 1996) and HVACSIM⁺ (Daniel, 1985). Moreover, the pressure balance calculation of duct and pipe system, noise analysis, indoor air current and the thermal environment is evaluated. CA only need to confirm the design calculate document and does not need to perform a new simulation.

At the construction, acceptance, and post-acceptance phase, the constructor performs measurement and confirms the function performance of various equipment, system, and BEMS. Moreover, the behavior of the BEMS and the measurement/control system for a closed-loop is occasionally confirmed using a logic tracer (Shioya, 2007) or other method. At this point, it is necessary for Cx to confirm the yearly behavior of system/equipment including low load state, the energy consumption,

Table 2 Comparison of simulation for normal work and for Cx in each phase

	Application phase		Main examination items for supporting work to Cx	Main contents of simulation
Building	Plan/Design	Normal	Design of building location, skin structure, aperture size etc., Calculation of PAL and BEE	Calculation of PAL and BEE with BECS,CASBEE
		Cx	Optimization of building location, skin structure, aperture size, and aperture position etc.	Yearly simulation of heat load and natural room temperature
HVAC System	Program/Planning	Normal	Decision of zoning, comparison of environment and energy performance of various alternative methods	Simple calculation of yearly energy consumption, LCC, and LCA
		Cx	Verification of validity of design objective and rationale of optimal design method	Calculation of yearly energy consumption, LCC, and LCA by using standard simulation program for Program/planning phase
	Preliminary design	Normal	Decision of HVAC and heat source, estimation of equipment capacity,confirmation of indoor airflow, thermal environment	Peak heat load calculation by using MicroPeak, Confirm airflow, thermal environment by CFD
		Cx	Optimization of HVAC, heat source, equipment capacity, number division of equipment	Detailed calculation of hourly heat load through the year
	Working design	Normal	Optimization of various design parameters, decision of equipment capacity and number, size decision, pressure balance analysis, and noise analysis of duct and pipe, Indoor comfort evaluation	Optimization of design parameters by using system dynamics characteristic analysis tool, Pressure balance analysis and noise analysis of duct and pipe, Calculation of PMV
		Cx	Confirmation of design and various optimal design parameters	
	Construction/Acceptance	Normal	Size decision, pressure balance analysis and noise analysis of duct and pipe, indoor comfort evaluation, confirmation of control logic, optimization of control parameter	Pressure balance analysis and noise analysis of duct and pipe, use of BEMS and control logic simulation
		Cx	Verification of function and performance of various equipment, system, and BEMS (FPT)	Dynamic analysis of total/part system, Simulation of BEMS/Control logic
	Post acceptance (one year)	Normal	Performance verification of continuous system, equipment, and BEMS, verification of yearly indoor environment and energy consumption	Statistical analysis of energy consumption by using measurement data of BEMS
		Cx	Performance verification of continuous system/equipment, and BEMS, Verification of environment and energy consumption in actual heat load and operation state, optimization of control parameters	Analysis and evaluation of environment, energy consumption and system dynamic characteristic in actual heat load state by using BEMS
Operation	Normal	Optimization of environment, energy consumption, and operation control	Statistical analysis for optimal operation and control by using measurement data of BEMS	
	Cx	Optimization of environment and energy consumption, fault detection and diagnosis, diagnosis of equipment deterioration, effect verification of energy conservation method and control technique	Analysis of environment and energy consumption using based on meteorological condition and indoor heat gain, Simulation of various operation and control pattern, Fault simulation	

and the indoor thermal environment by inputting system control parameters and actual equipment characteristics to the object system simulation model made at the design stage.

At the operation phase, the operator confirms the function and performance of system, equipment, and BEMS according to the measured data of BEMS, and performs statistical analysis of energy consumption to aim at the optimal operation control. At this point, simulations in some meteorological conditions and heat load states are performed as Cx work to verify if the function and performance of the system required by the owner are satisfactory. When faults occur in equipment operation or indoor environment, the fault reason and appropriate treatment are analyzed using a faulty detection and diagnosis tool or an energy simulation tool. Moreover, the effect of introducing the energy saving technique can be confirmed by comparing the simulation results with the measured data of BEMS.

CHARACTERISTICS OF TOOLS REQUIRED TO SUPPORT Cx

In IEA ECBCS Annex30, the succession of simulation information was emphasized to simplify the input work necessary for the simulation, and to maintain the consistency of simulation information when shifting from one phase to the next phase. However, the authors think it is not necessary to totally maintain the consistency of all simulation information, as the object and the purpose of Cx change at each phase. The reason for this is that information regarding the HVAC system and equipment changes gradually from unknown into known from the plan phase to the operation phase of a building/HVAC system. It is necessary to give appropriate default value because there is a lot of information unknown in program and planning phase. Default values need not be used when shifting to the design phase. Moreover, a lot of extant HVAC simulation programs are limited in their use as the input process to construct the model of building and system is troublesome and complex, and in particularly, there is no detailed data regarding the HVAC system at the program and planning phase.

If a simulation tool interface which can correspond to Cx in each phase can be developed, the problem mentioned above will be solved. However, when the necessary information for the simulation in one phase is different from that used in the former phase, (for instance, the equipment performance feature used in the design phase might be different from that delivered in the construction phase), a simulation tool which can easily change the information would be ideal. The following four kinds of Cx support tools and visual tools of extant HVAC simulation programs are preferable for performing Cx at each phase.

Tool for Cx in program phase

Tool, in which default value of input data of standard building/HVAC system for each usage is prepared beforehand, is necessary for the program phase. If total floor area, building usage, and standard skin specification are specified by the user, it is possible to simulate the thermal performance of building skin and the energy consumption even when a lot of input data isn't known. This is the kind of tool chiefly used in the program phase when energy consumption, LCC and LCA are being evaluated.

Tool for Cx in planning phase

Tool, which can be used to change the construction of building skin and opening parts and to make alternative solutions of some HVAC and heat source systems easily by using object building/HVAC system model constructed, is necessary for the planning phase. By graphing the simulation result of each case of these alternative solutions, user can compare these graphs and analyze the energy performance of object building, HVAC and heat source system easily.

Tool for Cx in preliminary design phase

Tool, which can be used to input details of simulation model of object HVAC system after default value of input data for simulation model construction is prepared, is necessary for the design phase. By the use of it, the user can optimize equipment capacity and various control parameters.

Tool for Cx in acceptance and operation phase

Tool, which can be used to construct simulation model of equipment units and subsystem and to perform simulation using measure data of existing building, furthermore, can be used to change performance characteristic of various equipment easily, is necessary for the acceptance and operation phase. Using it, the user can calculate the performance and confirm the performance degradation of equipment units or subsystem, and can perform real time simulation for fault detection and diagnosis.

APPLICABILITY OF SIMULATION TOOLS IN Cx

In IEA ECBCS Annex30, the influence that simulation structure, computational algorithm of each component, user interface, etc. exerted on simulation applicability was examined in detail. In this paper, when using extant simulation programs and visual tools for supporting Cx, program structure, default value and convenience of user interface were assessed to determine which Cx phase the programs and tools corresponded to. A comparison of the performances of typical HVAC system simulation programs or their visual tools developed is shown in Table 3. The application of these programs or visual tools for Cx in each phase is examined as follows.

Limitation of program structure

As the structure of many simulation programs is of a menu type, the module of new system and equipment cannot be added by users. Therefore, it is impossible to simulate the newly developed equipment and systems. The module types of program considered in this paper are HVACSIM⁺, TSNSYS, ACSES (Yoshida, 2006), and LCEM (Sugihara, 2006) only.

Presence of default value and corrective action

Many programs do not have a default value for constructing systems. Therefore, it is difficult to simulate at the program & planning phase as detailed data of HVAC system is not well known. In FACES (Yanagihara, 2004) or eQUEST (James, 2003) (a public simulation engine of DOE-2), almost all of the default value of input data for standard building and HVAC system model construction is prepared.

Therefore, even in the program and planning phase, if total floor area and building usage are specified, the simulation of the energy saving performance design is available. Typically, if Energy Efficiency Measure Wizard is used, nine alternative solutions can be easily generated using eQUEST. It is very convenient for comparison of alternative solutions and selection of the most suitable HVAC system at the planning phase.

In DeST, by use of "Idealization imitation type" instead of preparing default value of input data beforehand, building load, HVAC system, duct system, and the heat source system can be calculated individually. This means even if details of the HVAC system are unknown, simulation of building load becomes possible when building is assumed being controlled by the ideal HVAC system and control method. This "Idealization imitation type" has the following advantages.

1) Energy simulation in program & planning phase is available because the upstream simulation is possible even if the system specification in the downstream remains unknown.

2) Because the system in the downstream does not influence the simulation of the system in the upstream, optimal design is carried out in order of building, HVAC system, and heat source system.

Correspondence to equipment unit and subsystem

Simulation programs other than the one which has a module structure such as HVACSIM+, TSNSYS,

ACSES, and LCEM cannot be used for simulation of equipment unit and subsystem. However, it is possible to calculate building, HVAC system, duct system, and heat source system individually by using DeST. In addition, it is possible to simulate existing building/HVAC system too with measured data through the improvement of the program. Therefore, DeST could be used to verify performance and to simulate faults in subsystems at acceptance and operation phases.

Correspondence to system dynamics analysis

According to the Cx purpose in each phase, the simulation purpose can be divided into energy simulation and dynamic analysis for system behavior. Because programs considered in this paper except HVACSIM+ and TRNSYS are static programs, it is impossible to correspond to the system dynamic analysis using them.

CONVENIENCE OF USER INTERFACE

It is very important to use simulation as indicated in the technical report of IEA ECBCS Annex30. As Cx support tool, functions such as simplification of model construction, visualization of building/HVAC system, monitoring of on-line simulation with animation graphs, and making diagram of calculation result are preferable. The I/O screen of typical simulation programs or visual tools is shown in Table 4. The convenience of each program or visual tool is examined as follows.

Table 3 Performance comparison of HVAC system simulation programs and visual tools

Program name	MicroHASP	Micro/ACSS	FACES	LCEM
Developer	SHASE	JBMEEA	NIKKEN SEKKEI	PBA
Development(release) time	1982	1985	2005.3	2006
Program construction	Menu mode	Menu mode	Menu mode	Object mode
Module addition by user	Improprity	Improprity	Improprity	yes
Name of visual tool	MicroHASP/TES	ASSIST	GUI involving	involving in
Developer	HPTCJ, TOENEC	CEPCO		EXCEL using GUI
Develop(release) time	2005.3	2005.5		2007.3
Application phase of Cx	Elementary design	Design, Acceptance, Operation	Program, Planning, Design	Elementary Design, Operation
Building model creating method	Data input with GUI	Data input with GUI	Data input with GUI	Developing
Visualization of building	No	No	No	No
Selection/composition of system	No	menu selection	Menu selection	Equipment link
Visualization of system	No	Yes	No	No
Online animation graph	No	No	No	No
Program name	TRNSYS	DOE-2	EnergyPlus	DeST
Developer	Wisconsin Madison University	Lawrence Berkeley National Laboratory	Lawrence Berkeley National Laboratory	Tsinghua University
Development(release) time	1975.3	1980	2001.4	2000
Program construction	Module mode	Menu mode	Module mode	Menu mode
Module addition by user	Yes	Improprity	No	Improprity
Name of visual tool	IISSiBat, SimCAD	eQUEST	DesignBuilder	GUI involved
Developer	CSTB	Jeff Hirsch, Associates	Design Builder Software Ltd	
Develop(release) time		2001	2006.1	
Application phase of Cx	Design,Acceptance, Operation	Program~Operation	Design,Acceptance, Operation	Planning~Operation
Building model creating method	Drawing in SimCAD	Data input in GUI	3-D	CABD
Visualization of building	Yes	Yes	Yes	Yes
Selection/composition of system	Component icon	Menu selection	Menu selection	Menu selection
Visualization of system	Yes	Yes	No	No
Online animation graph	Yes	No	No	No

Note: The state of affairs in 2006.1 is that modules cannot be added by user with EnergyPlus, however the newest information about the latest version should be obtained from the homepage <http://www.eere.energy.gov>.

Convenience of construction of system model

In general, the user interfaces of the programs are divided into CLI (command line interface) and GUI (graphical user interface). In CLI, there are numeric input processors with a prescribed format such as DOE-2 or HASP/ACLD/ACSS and interactive mode numeric input processors like HVACGEN for generating simulation models for HVACSIM⁺. Input mistakes occur easily with the former as there is no error check function for inputted data. Although the latter has an error check function for input data, correction of input data is complex.

Therefore, GUIs for existing programs have been developed in recent years, and almost all of the newly developed programs have a GUI. However, even for the same GUI, the higher the usage ratio of graphic, the more convenient it is. According to the construction method of building/HVAC system model, GUI of various programs can be classified into three types as follows. a) GUI where data input and item selection are performed only by dialog box, b) GUI where visual screen of HVAC system and building skin specification and eaves configuration are added besides the dialog box for item selection and data input, and c) GUI where building model is constructed with 3-D drawing tool and HVAC system model is constructed through the connection of custom icons.

The HVAC system construction processors of BECS, FACES, DesignBuilder, and DeST belong to type a). Because there is no visualization screen of HVAC system, readability of the composed HVAC system is poor and it is difficult to correct the simulation model generated. The building model construction processors of Micro/HASP (SHASE, 1982), ASSIST, BECS, and FACES belong to type b). Readability of the model generated improves because the specification of building skin and eave are displayed on the visualization screen. Moreover, although eQUEST constructs the building model by an item selection with dialog box and numeric input, because 3-D display function of the building by AutoCAD is provided after the building model is generated; the building model can be confirmed by sight.

Advanced simulation programs with the function of illumination calculation, the shade calculation of adjacent building (i.e., DeST) and visual tool (i.e., DesignBuilder, the visual tool of EnergyPlus) belong to type c) because building model construction function with 3-D drawing tool is provided. Because the building model is constructed almost totally with the mouse in these programs, the construction work of the building model is very convenient. On the other hand, even for the programs that do not relate to building configuration, like the HASP (Inooka, 2005) series program or DOE-2 used to calculate load only, the function whereby the generated building model can be confirmed by sight is desirable for visualizing the building. Therefore, a 3-D display of the building function was added to simulation engine eQUEST of DOE-2.

As the HVAC system model construction function based on the relation of the components is provided in ASSIST, visual modeling tool of HVACSIM⁺ (J) (Yamatake-Honeywell, 1996), eQUEST, and IISSiBat, it is very convenient to construct and check the model.

Output format of calculation result

About the calculation output of each simulation program, it is very inconvenient for the arrangement of the calculation result of BECS and HVACSIM⁺ because output is text file only. In other programs, it is very convenient for arrangement/ comparison of calculation results because an output function in diagram of the calculation result is provided. In particular, as the account and diagram of HVAC system proposal etc. are automatically generated in FACES, the arrangement of calculation result is almost unnecessary.

Moreover, TSNSYS and ACSES have a function monitoring calculation result in real time using animation graph. The verifying time of simulation model is greatly shortened because the user may have the calculation discontinued ahead of time when calculation result becomes unfeasible or calculation become an infinite loop.

Limitation of language used

It is difficult to spread those programs developed in foreign countries in Japan because the I/O operations screen only displays in a foreign language. Therefore, the development of visual tool in Japanese is preferable. A Japanese version visual modeling tool of HVACSIM⁺ (J) has already been developed. Moreover, Japanese version visual tools of TRNSYS and EnergyPlus are being developed now (Anonymity B, Tetsushi, 2005). Furthermore, Chinese β version visual tool of EnergyPlus was developed by TianJing University (Liu, 2005).

CONCLUSION

In this paper, the investigation and comparison of program structure, default value treatment, and convenience of user interface of several HVAC simulation programs were performed, and it was proposed that four kinds of tools are necessary to support each phase of Cx. Various simulation programs and visual tools have the different good points about 1) construction of programs, 2) treatment of default value, 3) correspondence to equipment unit/subsystem, 4) correspondence to system dynamics analysis, 5) convenience of I/O operation of user interface and limitation of language used. So the application to each phase of Cx is also different.

Moreover, when these tools were used as support tool for Cx, the main applicable Cx phase was also considered. Realistically, large-scale energy simulation programs are used generally at Cx phases after preliminary design and simpler programs or powerful I/O interfaces are used more often in program and planning phases. Simulation engines like eQUEST, developed for the energy-saving system of building/HVAC system includes a Wizard with three levels (Schematic Design Wizard, Design Development Wizard, and Energy Efficiency Measure Wizard) and an interface for detailed data input (Detailed Interface). By the use of Schematic Design Wizard, Cx simulation is possible in the program phase as the default value of many input items is supplied. Moreover, simulation tools like DeST which is developed considering performance verification of each phase of design are hoped for. Using DeST, natural room temperature, heat load, energy consumption of HVAC system, duct system and heat source system could be calculated

individually and the calculation of equipment unit/subsystem using measured data of existing buildings and HVAC/heat source systems can also be performed.

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Table 4.1 Comparison of I/O performance of user interface of various simulation programs (Japan)

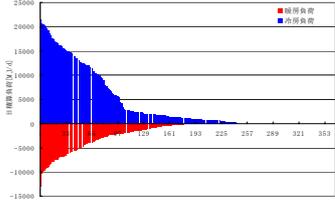
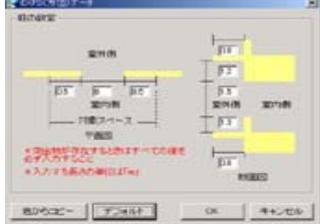
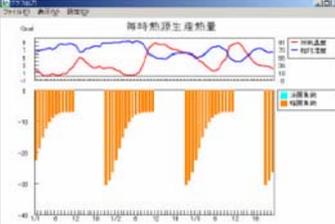
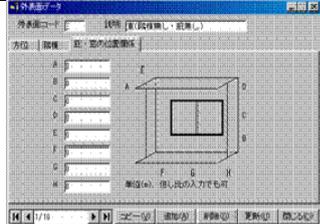
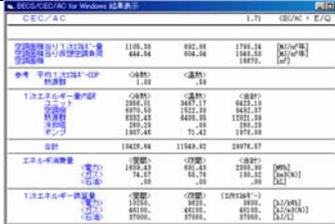
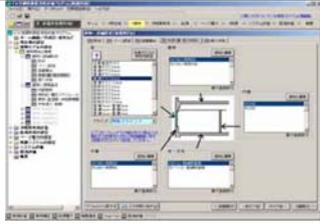
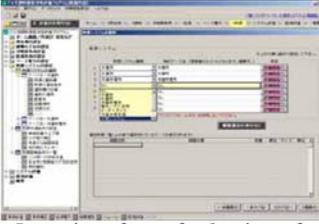
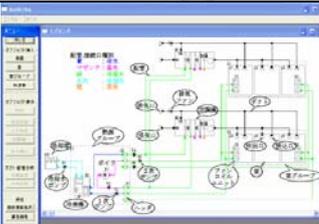
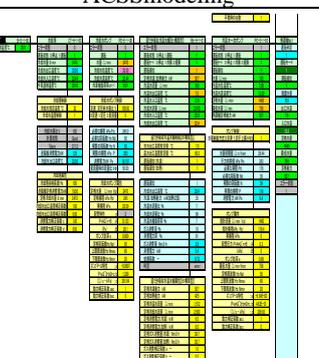
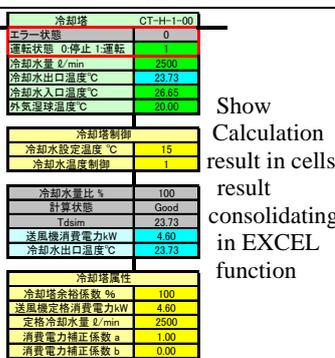
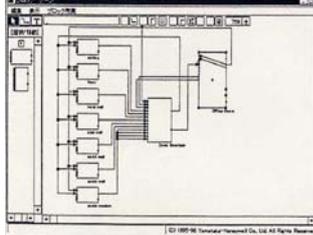
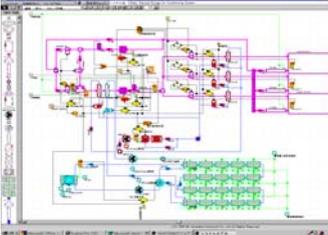
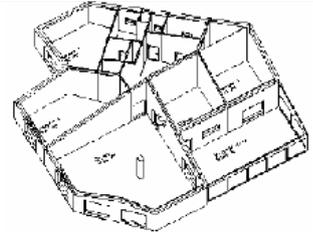
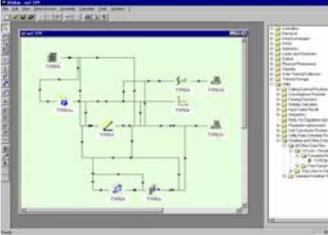
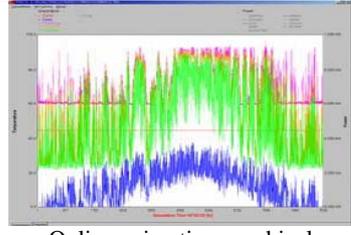
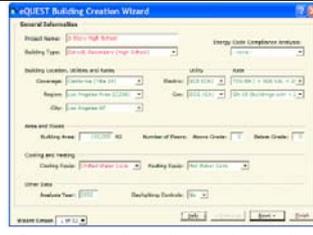
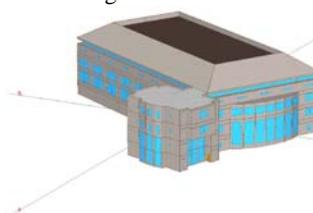
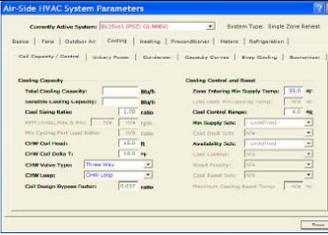
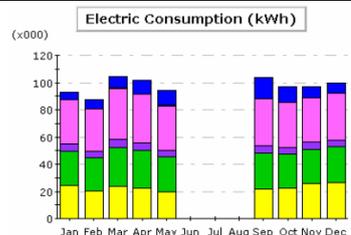
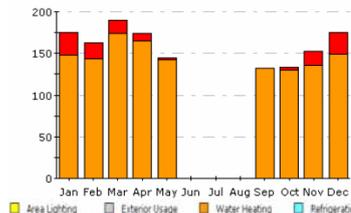
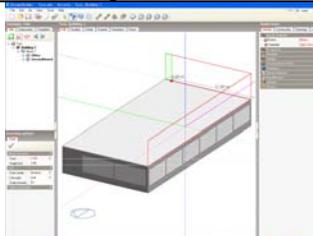
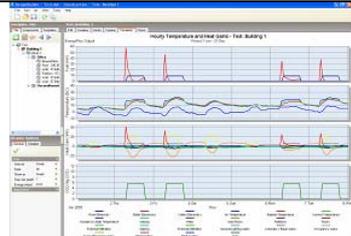
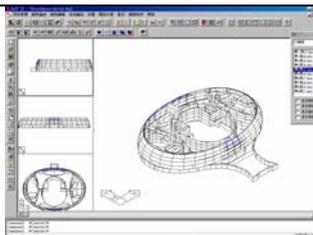
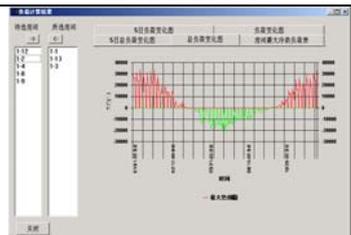
Name	Building model construction	Selection/construction of system	Output of calculation
MicroHASP (SHASE,1982) Micro HASP/TES (Toenec Corporation, 2005)	 <p>Input interface of eaves</p>	No	 <p>Output of descending order chart of daily total heat extraction rate</p>
Micro/ACSS (Kato, 2004) ASSIST (Systech Environment Lab,2005)	 <p>Input interface of eaves</p>	 <p>Input interface of HVAC system</p>	 <p>Output screen of heat source</p>
BECS (IBEC,1994)	 <p>Input interface of eaves</p>	 <p>Input interface of heat source</p>	 <p>Output screen of text data</p>
FACES (Yanagihara, 2004)	 <p>Input interface of building skin</p>	 <p>Input interface of selection of heat source equipment</p>	 <p>Output screen of proposal for HVAC system</p>
HASP/ACLD /ACSS (SHASE,1985) GUI (Hiroyuki, 2004)	 <p>Building input interface of ACLDedit</p>	 <p>System construction example in ACSS modeling</p>	 <p>Output screen of table calculation result</p>
LCEM (Sugihara, 2006)	<p>The building load is given as a boundary condition.</p>	 <p>Construction example of heat source system</p>	 <p>Calculation result output screen in EXCEL</p> <p>Show Calculation result in cells, result consolidating in EXCEL function</p>

Table 4.2 Comparison of I/O performance of user interface of various simulation programs (foreign country)

Name	Building model construction	Selection/construction of system	Output of calculation
<p>HVACSIM+(J) (SHASE,2003)</p> <p>Visual modeling tool (Yamatake-Ho neywell,1996)</p>	 <p>Input screen when constructing multi room building</p>	 <p>Input interface of HVAC system</p>	<p>It is possible to convert output text data to the CSV type with output convert subroutine</p>
<p>TRNSYS (SELUW, 1996)</p> <p>IISiBat SimCAD (Anonymity B)</p>	 <p>Drawing of building model with SimCAD</p>	 <p>Input interface of HVAC system with IISiBat</p>	 <p>Online animation graphical representation of calculation result</p>
<p>DOE-2 (James,2001)</p> <p>eQUEST (James,2003)</p> <p>Schematic Design Wizard</p> <p>Design Development Wizard</p> <p>Energy Efficiency Measure Wizard</p> <p>Detailed Interface</p>	 <p>Input interface for outline of building with DDWizard</p>  <p>Example of 3-D displaying of building with AutoCAD</p>	 <p>Input screen of HVAC system with DDWizard</p>  <p>Input screen of Detailed Interface</p>	 <p>Electric Consumption (kWh)</p>  <p>Gas Consumption (Btu)</p> <p>Output example of EEM Wizard</p>
<p>EnergyPlus (Anonymity)</p> <p>DesignBuilder (Anonymity A)</p>	 <p>Three-dimension drawing of building model</p>	 <p>Input screen of VAV HVAC system VAV</p>	 <p>Graphical output screen of calculation result</p>
<p>DeSt (Jiang,2004)</p>	 <p>Construction example of building with CABD</p>	 <p>Input screen of VAV HVAC system</p>	 <p>Graphical output screen of calculation result</p>