

SOFTWARE TOOLS FROM BUILDINGS ENERGY SIMULATION

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Abstract: *Energy simulation software tools are an important support to reduce the cost of energy in buildings. The energy simulation software allow to determinate with accuracy some variables that can support designers to take decisions about the best measures to apply for any building to built or already existent. There are several energy simulation software tools in the market. The present study aims to identify some of the most important due to their capacity of calculating a significant number of variables and to compare them in order to establish their differences.*

Key words: *Energy Consumption, Building Energy, Simulation.*

1. Introduction

In the EC, about 40% of energy is consumed in buildings. Therefore, the energy simulation software tools can be important for reducing the cost of energy in buildings.

Today, designers need tools that answer to very specific questions even during the initial design phase, respectively, to predict the thermal behavior of buildings prior to their construction. Or to simulate the costs of energy in existent buildings, establishing the best thermal retrofitting measures to adopt in these buildings. Simulation software tools can also be used calculate to the following variables [5]:

- Indoor temperatures;
- Needs for heating and cooling;
- Natural lighting needs of the occupants;
- Levels of ventilation;
- Consumption needs of HVAC systems.

Thermal simulation software tools for buildings allow to:

- Determine the size of HVAC systems;

- Analyze the energy consumption.

The calculation of energy consumptions allow a more accurate determination of design charges and help to decide with highest accuracy the possible devices to be used in a room or dwelling.

2. Energy Simulation Software Tools

2.1. Energy Plus

EnergyPlus is a whole building energy simulation program, developed beganing 1996 and sponsored by the U.S. Department of Energy. The EnergyPlus is organize in modules that can easily work together or separately. It is important to know that in EnergyPlus does not exist a visual interface that allow users to see and concept the building. In this case third-party software tools, i.e., Design Builder need to be used.

Energy Plus is a thermal simulation software tool that allows the analysis of energy throughout the building and the thermal load and it is used by engineers,

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architects and researchers to model the energy use and water use in buildings. The software tool simulates models for heating, cooling, lighting, ventilation, other flows of energy and water use. The simulation of a building is divided into two stages [1, 2]:

- Construction of the building;
- Introduction of data, such as environmental aspects, effects of shading, cooling system, internal gains, etc.

2.2 ESP-r

The ESP-r software tool (Energy Simulation Software) is a mathematical software for a project manager that coordinates the data, simulation, CAD applications, different tools for evaluating performance, display and report generators, etc.. The ESP-r uses several complex equations to deal with all aspects at the same time (geometry, construction, operation, distribution, heat dissipation, etc.). The geometry of the building can be set in CAD software tools or other similar tools to allow the specification of the geometry of buildings. The models created in this software can be exported to Energy Plus [4].

The operating conditions are determined through database support. Shading, insulation, HVAC systems, areas of computational fluid dynamics (CFD), electricity, renewable energy embedded systems, lighting, natural ventilation, combined heat and power generation, facades photovoltaic systems for control of indoor air quality can also be included in the models pre-determined.

The time simulation of the building with ESP-r simulation tool can vary in a range from one minute to one hour. The outputs of the simulations can be viewed by the interactions between the domains of assessment or exported to other graphics software. The ESP-r is extremely useful and is a powerful tool to simulate many

innovative technologies. However, the program requires a great knowledge and expertise from its users, and requires a long learning process.

2.3. IDA ICE

The thermal simulation software tool IDA ICE (Indoor Climate Energy) is based on a general system simulation platform with a modular system. The multi-domain physical systems are described in the IDA ICE using symbolic equations starting with a simulation language Neutral Model Format (NMF - Neutral Model Format). The user defines the tolerances which control the accuracy of the solution, thus allowing the isolation of numerical modeling approaches. End-user has the following advantages [5]:

- Extensions can be added to the initial model;
- The mathematical model can be inspected to investigate the variables, parameters and equations;
- The research models are easily performed.

2.4. IES VE

The simulation software tool IES VE (Integrated Environmental Solutions-Virtual Environment) provides the design professionals with a variety of variables in simulation analysis of buildings. The model works on the geometric representation that represents the building. The software tool allows interaction with other energy simulation software tools. The simulation software tool incorporates a tool for dynamic thermal simulation of heat transfer processes of buildings, which is the ApacheSim. The simulation software tool was tested using the IES ASHRAE 140 and is qualified as a dynamic model in CIBSE system of classification. The software tool provides an environment for

the detailing of the building systems, allowing their optimization taking into account criteria such as comfort and energy. The dynamic tool ApacheSim can be dynamically linked to the Macro FLO dynamic tool for natural ventilation and HVAC Apache dynamic tool to perform analysis of air leaks and for analysis of natural lighting and shading. The results should be automatically exported [5]

2.4. IES VE

TRNSYS (Transient System Simulation) is a simulation software tool with a modular structure that has been specially designed to develop complex systems related to energy, outlining the problem in a number of smaller components [6]. The components ("Types") may range from simple heat pump to a multi-zone of a building complex. The components are configured through the graphical user interface known as TRNSYS Simulation Studio. In the simulation software tool energy TRNSYS the construction of the building can be achieved by the introduction of data on dedicated visual interface, known for TRNBuild.

The software tool sets the time intervals

which may vary from 15 minutes to an hour, but may be able to perform simulations in the time interval of 0.1 seconds.

The library software tool in addition to a multi zone, allows the use of many commonly used components, including: solar panels, photovoltaic systems, HVAC systems, cogeneration systems, hydrogen, among others.

It also allows the creation of routines to manipulate weather data and other data by changing the simulation results. The modular nature of this software tool facilitates the addition of mathematical models to the software tool.

The components can be shared among multiple users without having to recompile the software tool due to the use of DLL technology. In addition, this energy simulation software tool allows the user to incorporate other components developed in software tools such as Matlab, Excel, VBA, etc.. Moreover, the software tool includes the possibility of adding HTML views through a software tool called TRNSED, which enable non-users to view and do parametric studies of TRNSYS files, in a simplified representation of a web page.

```

Zone,
SPACE1-1,          !- Name
0,                 !- Direction of Relative North {deg}
0,                 !- X Origin {m}
0,                 !- Y Origin {m}
0,                 !- Z Origin {m}
1,                 !- Type
1,                 !- Multiplier
,                  !- Ceiling Height {m}
,                  !- Volume {m3}
,                  !- Zone Inside Convection Algorithm
;                  !- Zone Outside Convection Algorithm

```

Fig. 1. Introduction of coordinates of a building in EnergyPus simulation software [3]

3. The Steps of Simulation with Energy Plus Software Tool

3.1. Creation of a building

The creation of the building is the first step of an energy simulation.

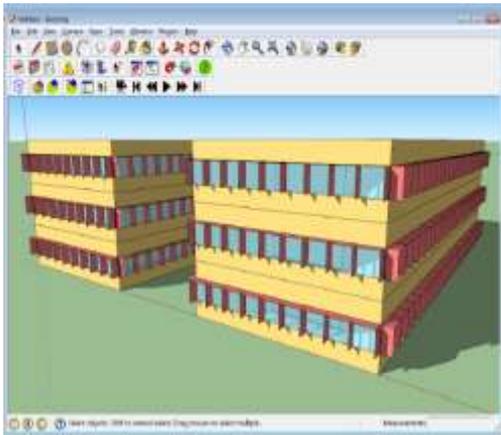


Fig. 2. Edit geometry in EnergyPlus simulation software [3]

This process can be accomplished in two ways: by inserting the coordinates in the software tool – as is Energy Plus simulation software (see Figure 1), or by

uploading files from other software, such as AutoCAD – as is ESP-r simulation software.

In EnergyPlus, to define the architecture of the building, type of surface to be inserted (walls, roofs, floors, windows, doors, etc.).

3.2. Building simulation

In this step, first, it is established which variables are to consider in the simulation of the building and next, the simulation is performed.

Thermal performance of any studied building may vary depending on the: type of building (office, housing, etc.), location of the building, the human activities carried out, their daily schedules, the existing equipment (heating, cooling, air conditioning systems, lighting, etc.) (see Figure 3).

The define of these parameters allows establishing the internal heat or cooling load, the ventilation flow rate, lighting level, etc. Window launch simulation can be seen in Figure 4.

```
Chicago O'hare Intl Ap Ann Cig .48 Condns DB=>MWB,      !- Name
7,              !- Month
21,            !- Day of Month
SummerDesignDay, !- Day Type
33.3,         !- Maximum Dry-Bulb Temperature (C)
10.5,        !- Daily Dry-Bulb Temperature Range (C)
DefaultMultipliers, !- Dry-Bulb Temperature Range Modifier Type
              !- Dry-Bulb Temperature Range Modifier Schedule Name
Wetbulb,      !- Humidity Condition Type
23.7,        !- Wetbulb at Maximum Dry-Bulb (C)
              !- Humidity Indicating Day Schedule Name
              !- Humidity Ratio at Maximum Dry-Bulb (kgWater/kgDryAir)
              !- Enthalpy at Maximum Dry-Bulb (J/kg)
              !- Daily Wet-Bulb Temperature Range (deltaC)
98934.,      !- Barometric Pressure (Pa)
5.2,        !- Wind Speed (m/s) design conditions vs. traditional 3.35 m/s (7mph)
230,       !- Wind Direction (Degrees; N=0, S=180)
No,         !- Rain (Yes/No)
No,         !- Snow on ground (Yes/No)
No,         !- Daylight Savings Time Indicator
ASHRAETau, !- Solar Model Indicator
              !- Beam Solar Day Schedule Name
              !- Diffuse Solar Day Schedule Name
0.455,     !- ASHRAE Clear Sky Optical Depth for Beam Irradiance (taub)
2.050,     !- ASHRAE Clear Sky Optical Depth for Diffuse Irradiance (taud)
```

Fig. 3. Sizing period: design day, cooling example [3]

The define of these parameters allows establishing the internal heat or cooling load, the ventilation flow rate, lighting level, etc.

Window launch simulation can be seen in Figure 4.



Fig. 4. Window launch simulation [3]

3.3. Analysis of results

After running the simulation, it should be checked if there are any error in the variables set. In some cases the simulation software tool issues its own warnings in a

final report containing the results.

Whatever simulation software is used, the results that interests are:

- hygrothermal behavior of the buiding;
- the occupant comfort (indoor air temperature and humidity, level of natural/artificial illumination, indoor air quality);
- the thermal response of the building and air flow (heating and cooling loads, air distribution and ventilation flow rate);
- energy consumption of building.

The simulation results can be obtained in the form of tables, containing the interested quantities (see Figure 5), some graphics, etc.

3.3. Conclusion

- The software tools from buildings energy simulation have had developments over the years. Today there are many energy simulation software tools with different levels of complexity and response to different variables. Among the most used energy simulation software tools are: the

Date/Time	Environment:Outdoor Dry Bulb [C](Monthly)	ZONE ONE:Zone/Sys Sensible Heating Energy[J](Monthly)	ZONE ONE:Zone/Sys Sensible Cooling Energy[J](Monthly)	ZONE ONE:Zone/Sys Air Temp[C](Monthly)
July	25.58495468	0.00E+00	19028775.23	24.4112152
January	-17.77778	253868837.1	0.00E+00	20.28659003
January	-4.63546707	4144370093	0.00E+00	20.43495965
February	-2.23312872	3151142586	0.00E+00	20.46221742
March	1.603242608	2545318797	0.00E+00	20.54348182
April	8.370677083	1431785319	324853.0522	21.20071107
May	15.30398185	639305402.1	51404202.22	22.43806808
June	21.09550347	164326207.4	145308752.2	23.40095162
July	23.49973118	65628804.19	244539864.1	23.81873695
August	21.75707325	96943677.86	103740404	23.32673507
September	18.11458333	346023544.8	45088296.07	22.40959675
October	11.73642473	1065565115	714539.5928	21.18788477
November	4.232118056	2260965068	0.00E+00	20.49516327
December	-2.566599462	3853388966	0.00E+00	20.46126771

Fig. 5. Window launch simulation [3]

EnergyPlus, the ESP-r (Energy Simulation Software), the IDA ICE (Indoor Climate Energy), IES-VE (Integrated Environmental Solutions-Virtual Environment) and TRNSYS (Transient System Simulation).

Among the energy simulation software tools presented in this paper, TRNSYS is the most complete, but depending on the user perspective and final purpose the other software tools could be more appropriated. The major limitation of TRNSYS is to not being able to connect with AutoCad software tool, for importation and exportation of files. From this point of view, Energy Plus, ESP-R și IDA ICE, are easier to use.

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