Selection of Energy Conservation Measures in Building Design Phases Considering Level of Details

Mina Choi, Gahee Kim, and Sean Hay Kim

Abstract—Building energy simulation plays an important role in the design process by predicting building performance. Yet practitioner designers often feel frustrated during preparing simulations, if they are not sure of design variables of an Energy Conservation Measures (ECMs) requiring accurate information about building and systems. To help practitioners, this paper provides a guideline to select ECMs, evaluation simulation tools, and detailed inputs for modeling of ECM at each building design phase as a format of Level of Detail (LOD).

Index Terms—Energy conservation measure, level of detail, energy simulation, building modeling guideline.

I. BACKGROUND AND OBJECTIVE

A global warming caused by an increasing use of fossil fuels begins to cause a serious environmental problem. Buildings take up to 30% of national energy consumption as in lighting, electrical equipment, heating ventilating and air conditioning (HVAC) system, and refrigeration systems. To effectively and efficiently regulate building energy use, it is important to select appropriate Energy Conservation Measures (ECMs) in building design process, rather than to add some actions after construction. In a design stage, building energy simulation is a useful tool to analyze the energy performance of a building model containing ECMs. Most energy simulations, however, require an expert level of system knowledge as well as simulation knowledge. It is, thus, hard for practitioners to actively employ building energy simulations during design process.

II. RESEARCH PROCESS

The aim of this study is to suggest a guideline that improves a use of energy simulations in each design phase. This study proposes what simulations are appropriate to capture features of ECMs and when Level of Detail (LOD) of each ECM starts being discussed and confirmed in the design process. Fig. 1 briefly elaborates how this study has proceeded.

Fig. 1. Process of the research.

First, we have examined major tasks at each design phase and formulated a basic framework of the design process based on interviews with design engineers. Next, we have explored literature and selected ECMs available in the market and then classified them into passive measures applied to a building and Mechanical Electronic and Plumbing (MEP) measures. In the third step, LOD of each ECM has been factorized and then analyzed in which design phase the LOD can be decided. Lastly major simulation tools that have a sufficient capability of evaluating ECMs in each design stage in terms of algorithm and usability have been investigated. The final artifact of this study is well described in Table I. Readers can find a useful information concerning a choice of ECMs, evaluation tools, and information availability of the ECM at each design phase.

III. BUILDING DESIGN PHASES

The building design process can be divided into phases in Table II. Also, it elaborates primary tasks of each design stage in order to identify when LOD starts to be discussed and confirmed.

IV. ENERGY CONSERVATION MEASURE (ECM)

Factors affecting energy consumption of a building can be divided into architecture, MEP, and controls as shown in Fig. 2. Architectural design can be classified into mass and layout plan, building envelope and materials. MEP design can be classified into heat source, air conditioning system, lighting system, renewable energy system, equipment. Controls mean an operation method of buildings and equipment such as scheduled ventilation and night purge that means ventilating. Most ECMs in this paper were selected based on [1]-[7].

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<th>ECM</th>
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<th>Sub-Object</th>
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<th>LOD</th>
<th>Cons/ Ocup.</th>
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<td>Building mass minimizing envelope area and taking advantage of solar gain and heat loss</td>
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</table>

<p>| ECM Simulation | Object | Sub-Object | LOD | PS | SD | D | CD | Cons/Occup |
| High efficiency plant | EnergyPlus, eQUEST, TRNSYS | Heat exchanger for district heating | Placement, Capacity | Efficiency, Heat source type |
| | Water/Steam boiler | Placement, Heating capacity | Fuel type, Tube type, Efficiency |
| High efficiency refrigerator | EnergyPlus, eQUEST, TRNSYS | Vapor compression chiller | Placement, Capacity | COP, Compression refrigeration type, Compressor type, IPLV, Performance curve, Compressor control |
| | Absorption chiller | Placement, Cooling capacity, Hot water capacity | Heat source connection, Fuel for direct fire, External heat source, Cooling COP, Heating COP, IPLV, Performance curve |
| | Ice storage | Placement, Heat capacity | Volume, Ice making type, Insulation, Refrigerant type |
| | CHW storage | Placement, Heat capacity | Volume, Insulation |
| Variable speed compressor, condenser, pump, fan | EnergyPlus, eQUEST, TRNSYS | Heat pump/Variable Refrigerant Flow (VRF) | Compressor | Speed control |
| | | Fan | Flow control |
| | | Vapor compression chiller | Compression refrigerator type, Compressor type, Compressor control |
| Absorption chiller-heater | EnergyPlus, eQUEST, TRNSYS | Absorption chiller | Placement, Cooling capacity, Hot water capacity | Heat source connection, Fuel for direct fire, External heat source, Cooling COP, Heating COP, IPLV, Performance curve |
| District heating and cooling | EnergyPlus, eQUEST, TRNSYS | Heat exchanger | Placement, Capacity | Efficiency, Heat source type |
| Optimal on/off for plants | EnergyPlus, eQUEST, TRNSYS | Water/Steam boiler | HW reset, On-demand control |
| On-demand operation for plants | EnergyPlus, eQUEST, TRNSYS | CHW, CW, HW Pump | On-demand control |
| Outside air and load reset for CHW, CW, HW | EnergyPlus, eQUEST, TRNSYS | CHW, CW, HW Pipe | Placement, Diameter, Length | U-value, Inlet outlet water delta t, Pressure drop per unit length, Pressure drop by fitting, Pressure drop by plant, Pressure drop by equipment/device, Pressure drop by control and balancing |</p>
<table>
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<th>System</th>
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<td></td>
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<td>Ground heat exchanger</td>
<td>Placement, Land area, Length, Number, Pipe diameter, Distance between pipes Type Capacity, Grouting conductivity</td>
<td>Efficiency, Performance curve (Flow rate, Head) Flow control</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Primary and Secondary pump</td>
<td>Placement, Power</td>
<td>Efficiency, Performance curve (Flow rate, Head) Flow control</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Expansion tank</td>
<td>Placement, Volume, Heat capacity</td>
<td>Efficiency, Performance curve (Flow rate, Head) Flow control</td>
<td></td>
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</tbody>
</table>
First, we have investigated the design phases at which design elements and attributes of architectural and MEP objects are determined according to the building design process in Table III.

<table>
<thead>
<tr>
<th>TABLE II: PHASES OF THE BUILDING DESIGN PROCESS</th>
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</thead>
<tbody>
<tr>
<td>Phase</td>
</tr>
<tr>
<td>Pre-Schematic Design (PS)</td>
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<tr>
<td>Schematic Design (SD)</td>
</tr>
<tr>
<td>Design Development (DD)</td>
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<tr>
<td>Construction Document (CD)</td>
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<tr>
<td>Construction/Post occupancy (Cons/Ocup)</td>
</tr>
</tbody>
</table>

V. LEVEL OF DETAIL (LOD) OF AN ECM

In the pre-schematic design phase, layout and mass planning (such as location, orientation, height and area of a building) are mainly discussed with a feasibility study and then confirmed in the schematic design phase. Design criteria and conditions are already fixed (such as the surrounding terrain and climate of the building) before the design process begins. For MEP, it is very little to be determined at this stage because no specific design values are available yet. Since a ground heat exchanger is, however, installed in the site, the position and area of the geothermal system need to be considered together within the building layout.

In the schematic design stage, an overall shape, structure and materials of a building (such as envelopes, story height, stairs) are determined. In the MEP, user schedule, lighting and ventilation can be captured considering the use and size of the building. In addition, properties such as location and area are discussed for design entities located outside the building such as solar panels or underground heat exchangers.

Designers who lack expertise in simulation tools, such as design engineers, are somewhat reluctant to understand unfamiliar simulations. Therefore, in this paper, we have tried to propose a guideline of simulation use in order to encourage the simulation practitioners in easily evaluating the building energy performance. We have investigated a functionality of DOE-2.1, ECOTECT, EnergyPlus, eQUEST, ESP-r, HAP, IDA ICE, IES <VE>, Tas, TRACE and TRNSYS to determine what simulation tools best capture ECMs at each design stage. But only EnergyPlus, eQUEST and TRNSYS are marked in Table I, because they are mostly used simulations in Korea.

VI. SIMULATION PROGRAMS FOR EVALUATING BUILDING ENERGY PERFORMANCE

Building energy simulation has been developed since 1970, and a use of simulation tools has been highly encouraged for green building designs. However, contrary to the advocacy group who goes for a new technology of building simulation, the pragmatist groups such as design engineers are somehow reluctant to understand unfamiliar simulations.

Therefore, in this paper, we have tried to propose a guideline of simulation use in order to encourage the simulation practitioners in easily evaluating the building energy performance. We have investigated a functionality of DOE-2.1, ECOTECT, EnergyPlus, eQUEST, ESP-r, HAP, IDA ICE, IES <VE>, Tas, TRACE and TRNSYS to determine what simulation tools best capture ECMs at each design stage. But only EnergyPlus, eQUEST and TRNSYS are marked in Table I, because they are mostly used simulations in Korea.

VII. CONCLUSION

To encourage energy simulations in building design, this paper proposes a guideline concerning what simulation is appropriate for each ECM to practitioners who are lack of the expertise in energy simulation. We hope to convince the people who have a sense of discomfort with unfamiliar simulations, such that various applications of building energy simulation can be tried out in the design phase. We also expect a convergence between architectural designers who lack the expertise of equipment, and MEP designers who lack the expertise of architecture. Therefore a systematic and integrated design can be implemented from the initial planning phase to the operation and maintenance phase.

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REFERENCES


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