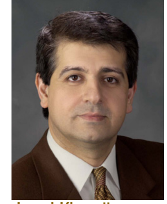

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Performing Probabilistic Energy Modeling

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In my November column, I discussed the necessity of performing a probabilistic energy modeling process instead of a deterministic one for an ASHRAE/IES Standard 90.1, Appendix G, design building. To be able to run a probabilistic energy model, the first step is to develop a tolerance margin library for all the construction material that would be used in constructing a building and for its associated equipment.

Clarke, et al.,[1] have developed a considerably strong data source in which they have depicted the uncertainty that resides in thermal properties within a handful of construction materials. This data can be used to begin generating a comprehensive library of the uncertainties.

AHRI standards provide manufacturing allowable test tolerances for most HVAC equipment that can be used as a source of uncertainty evaluation in the equipment. For example, ANSI/AHRI Standard 430-2009, *Standard for Performance Rating of Central Station Air-Handling Units,* allows the tested brake horsepower of the fan to be as high as 107.5% of the nameplate, and AHRI Standard 550/590-2011, *Standard for Performance Rating of Water-Chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle,* allows a tolerance of [0.105 – (0.07× Percent Load)] + [0.15/(Chilled water temperature difference) × Percent Load] for centrifugal chillers. This implies that the actual air-handling unit and chiller power consumption could fall in a margin between the nameplate (deterministic energy model input) and the maximum allowable test tolerances.

In addition, allowable tolerances for consumed power by lighting and appliances should be derived from the proper resources to make sure the majority of the existing probabilities have been considered.

Another source of uncertainty that is worthy of evaluating is the effect of accuracy of different sensors throughout the network of the HVAC system. For example, temperature sensors located inside the occupied room or at the cooling coil leaving air position usually are set to 75°F or 55°F (24°C or 13°C), respectively. Generally, each sensor has an allowable tolerance of 0.5°F (0.28°C). Also, a temperature sensor located outside the building as a measuring reference of the outdoor air temperature usually has a 1°F (0.55°C) tolerance. These tolerances can contribute to the total uncertainty in the output of the energy model as well. This evaluation also can be useful for validating the use of micro-electro-mechanical systems (MEMS) sensors in HVAC applications due to their smaller accuracy margins in comparison with the currently used sensors in the buildings and its systems.

After gathering a comprehensive library of the associated uncertainty margins for construction materials and equipment, the next crucial step is to assign proper probability distribution to each of these uncertain input data. This requires collecting manufacturing data, studying the data and, finally,

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allocating proper probability distributions to each item based on the studied data. Probability distribution should express how the construction material, HVAC equipment, lighting, appliances, and sensors' possible selected occurrences are expected to be distributed inside the tolerance margin of each item. Probability distributions such as uniform, normal, and lognormal are a few samples of probability distributions that should be assigned to each uncertain input value based on the collected data. This is probably the most critical and also most demanding part of this procedure.

The next step is work that really falls on the shoulders of the software developers. What software developers need to add to their current commercial deterministic simulation programs is the capability to randomly select each input from its probability distribution curve, then stay on the selected curve throughout the full (one) run of the simulation, and generate the (one) output, based on random selection of all the input components.

Simulation should be repeated based on different random selections from the library collection (usually between 80 to 500 times), and the probability distribution of the output shall be generated based on the results of all the performed simulations. That depicts the possible range and its percentages of occurrences of the final output or the building energy consumption (cost). Such approaches in statistics are known as the Monte Carlo Simulation, or Latin Hypercube Sampling, which are common sampling simulation methods.

References

1. Clarke, J.A., P.P. Yaneske, A.A. Pinney. 1990. "The Harmonisation of Thermal Properties of Building Materials." BRE Publication; BEPAC Research Report. http://tinyurl.com/2b7q5bm. ■