On Modeling and Estimation Techniques Towards On-line Applications in Building Energy Management Systems

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Abstract

Various factors create an evident gap between the intended design in terms of energy efficiency and the measured energy consumption in buildings. The hypothesis of this study is that this gap can be reduced by using energy simulation tools. Having in mind an optimization platform where building energy simulations can be used during the operation time of a building, we look at a framework which integrates the building energy models and the optimization tools with the building energy management system through an internet-based data platform. The focus of the project is to explore various buildings modeling techniques which can describe the building dynamics in order to facilitate the transition towards on-line applications such as monitoring, control, fault detection, predictive maintenance, energy use optimization, and others. We have investigated very complex models, using specialized simulation tools as well as reduced order models described by very simple structures.

Several tools for modeling the energy dynamics of buildings are available on the market, e.g. EnergyPlus, Modelica, BSim, Transys, GreenBuildings, each with its particular features. EnergyPlus was selected as it allows the development of a whole building model with a high number of thermal zones, simultaneously presenting proper capabilities to perform an on-line building analysis. The Green Tech House building, located in Vejle, Denmark represents the subject for the case study, as it will be used to evaluate the possibility of using the proposed model on-line. After understanding the building's architecture and its systems, the model was developed and implemented using SketchUp, Open Studio and EnergyPlus, followed by an in-depth evaluation of the compatibility between the model and the integration requirements. A preliminary model validation was carried out using real measurements from the considered site. Though not appropriate for direct on-line control and optimization due to some limitations imposed mainly by the simulation tool, the developed model can be successfully used for applications as continuous on-line monitoring and visualization.

Reduced order models (ROM) are proposed as an extension to the first approach, allowing for the on-line control and optimization problems to be tackled. When using these very simple representations of a building, expressed most of the time through a resistance-capacitance (RC) analogy, the complexity of the problem as well as the required resources are considerably reduced. A critical point in defining good ROMs is the estimation of the lumped parameters. These parameters can be approximated by using real measurements and estimation techniques. To perform this task, we use the modulating function (MF) method which has the advantage of being applicable on-line, directly on noisy measurements, without any requirements for initial conditions. To investigate this method yet not explored in a building energy modeling perspective, two case studies are presented - estimation of a building model and estimation of an air handling unit. We perform both parameter and state estimation. The good results obtained from simulations with artificial inputs and similar to real inputs as well as real-time experiments using noisy measurements, open a new interesting path and prove the potential and applicability of the MF method in an on-line setup.

Both approaches can be used separately, in parallel or can be even interconnected by using the high capabilities of co-simulation available nowadays. They would complement each other adding value to the overall energy assessment and building performance.