Modelica based Design and Optimisation of Control Systems for Solar Heat Systems and Low Energy Buildings

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The goal of the research project enerMAT is the reduction of energy consumption and CO2 emissions of buildings. Especially solar heating systems are installed in more and more buildings. This paper introduces a novel approach for simulation and optimisation that aims to improve the performance of building controllers and especially solar heating controllers such as the UVR 1611 by simulation and model-in-the-loop tests. A new generation of energy-aware optimised building energy management systems (BEMS) will be discussed and its advantages over the older controllers highlighted. The energy-aware optimisation will be shown on a model-based approach with an overall building system model enabling the assessment of the energy performance for different design and operation alternatives of the building automation system in interaction with the building. This system model will allow a simulation-based, energy-aware, global, dynamic, multi-criterial optimisation of BEMS. In this paper, the idea, the approach, and the actual state of the project research is presented with a focus on solar heating controllers.

The UVR 1611 is a control unit for HVAC and solar heating systems. Its function can be edited by using pre-programmed function blocks (FB) such a PID controllers, timers, counters, logical and arithmetic functions. For the implementation of a sophisticated BEMS the UVR functionality is however not sufficient and an additional top-level controller is required. The UVR FB's were modelled in Modelica by using a detailed specification as template. They are stored in a library and were tested on their own and by comparing simulation with measured data from UVR controllers. The UVR FB library enables the model-in-the-loop test of UVR programs along with complete building models. Preconfigured building models along with standard UVR application models will be employed by civil engineers to obtain optimised parameters for the control units to be installed in new houses.

A building model of an existing solar-heated office building with controller, solar collectors, heat storage, building zones and heating systems is composed of an energy source model and a heat consumption model. Both models are validated with measured data from the real building to find inaccuracies and modelling errors. The complete model is used for the validation of the buildings energy characteristics and to improve utilisation of the solar energy. Certain strategies for saving energy such as temperature setback were simulated and analysed. Because of the limited functionality of the solar heat controllers the requirements for a top-level BEMS were established and implemented in a control model within the building model. The BEMS model features functions which contain certain optimisation parameters. A particle swarm optimisation was executed to find parameter values that result in low energy consumption while maintaining comfort. Because the building model is quite large a reduced model for the optimisation was developed. The optimised parameters were then verified with the full scale model.