Test aspects of building energy management systems within the simulated model and in reality

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Kurzfassung

Regenerative Versorgung von Gebäuden und Kraftfahrzeugen gewinnt zunehmend an Bedeutung. Durch die knappe Ressource Energie sowie teure Speicherung bei stark schwankenden regenerativen Erträgen und Verbräuchen steigen auch die Anforderungen an die Regelungstechnik. Hinzu kommen die oft sehr individuellen technischen Konfigurationen von Wohnhäusern, welche unterschiedlichste Anforderungen an eine optimale Steuerung stellen.

Gleichzeitig ist die reale Testumgebung, das jährliche Wetter, wöchentliche Nutzungsschwankungen, etc. sehr langsam und im Fehlerfall teuer Dadurch werden Simulationen im Vorfeld sehr wichtig.

Am Beispiel eines Gebäudes in Dresden wird ein solches domänenübergreifendes Energiemanagementsystem vorgestellt. Weiterhin werden Testaspekte mit der Green Building Library in SimulationX sowie einem FMI Abstraktionslayer beschrieben.

Abstract

The importance of renewable energy supply of buildings and vehicles is growing. With these limited resources, fluctuations in supply together with expensive storage systems increase the requirements for the control systems.

The testing in a real world environment with annual weather and weekly usage profiles is slow and expensive in case of modifications.

Using a building in Dresden as an example, this paper shows aspects of such control systems and of the simulation assisted development process using, SimulationX, Green Building Library and an FMI abstraction layer.

Introduction and Motivation

EA EnergieArchitektur GmbH desings and realizes buildings with highly integrated confort and energy management systems. In Dresden the company constructed a multifunctional building for testing and demonstration of new technologies.

Figure 1: Reference building in Dresden, renewable energy management with photovoltaics, heat pump , electric mobility and storage [EASD13]

The building houses two high quality appartements, an office and showrooms for a manufactory of luxury goods. Most of the electrical systems are highly automated to provide a maximum of comfort. Some examples are a homecoming scenario where doors are opened, charging station display and lighting is switched on or a presentation scenario where lighting is dimmed, shades are closed, and beamer as well as silverscreen are brougt into position.

There are multiple energy storage sytems in the building: stratified heat tank, the concrete mass, electrical battery in the vehicle and a planned peak load stationary battery. The energy is provide by photovoltaics, heat pump and multi tariff grid connection.

The management system has to provide optimal trajectories for the storage sytems based on usage scenario and weather prediction. It also has to accommodate the many rulesets for the comfort functionality.
The energy and building control data is monitored for a regular update and optimization.
Modelica based simulation helped in component layout as well as module testing and still assists in the interpretation of the monitoring data.

Modelling the Building

The energy system was modelled using the Green Building Library in the SimulationX environment. This Library contains models for the photovoltaic system, the heat pump, the storage system, several thermal zones as well as extras like charging station and electric vehicles.
Each of the models has a similar granularity with regard to calculation speed and easy to get datasheet parameters.

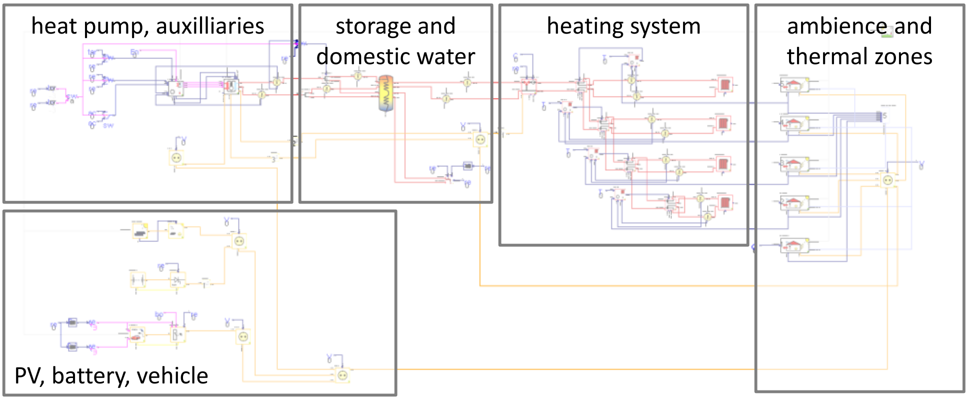

Figure 2: Overview of the building model

The parameters for the building zones were taken from the standard EnEV heat-load calculation, an heat energy demand comparison required by legislation. To effectivly represent the big thermal reflective windows, a submodel calculating a window shading factor based on incidence angle was added.
For the heat pump, photovoltaics, battery and the electrical vehicles (Opel Ampera, Toyota Prius), datasheet values were used. For the heat storage, a stratified storage tank was used. This model is the best representation of the solution in the building where hot water is stored in the upper part the tank and the lower part acts as an hydraulic decoupling for the floor heating heat pump. All these models were used with the typical module control blocks provided by the library. In the last step, the ambience model with the dataset Dresden was added.

With this model differen simulation runs were made:

- a complete reference year and
- typical day profiles and stress situations.

After these runs, based on the results, components were revised, for example heat storage hydraulics, stationary battery size or heat pump operational concept. The final concept now runs the heat pump purely on night tariff ecxept if there is enough renewable photovoltaic power during the day. Elsewise it is switched off during the daytime. The concrete floors have enough storage mass to compensate the heat losses during this time.

The Metering Instrumentation

To gather real word operational data for the validation of the system model and for future optimizations, most of the electrical and thermal parameters are monitored with time resolution between 1 and 5 minutes depending on the subsystem.
Additionally there are detailed sensors for indoor climate, building usage and the EV-charging process as well as a 'virtual' power line to two micro wind turbines in gorbitz and ottendorf okrilla near Dresden.
One important aspect for the energy management system is to gather data of the vehicle usage and the charging process. With this data, the energy demand of this process can be planned better with regard to the energy forecast. The following figures show some examples.

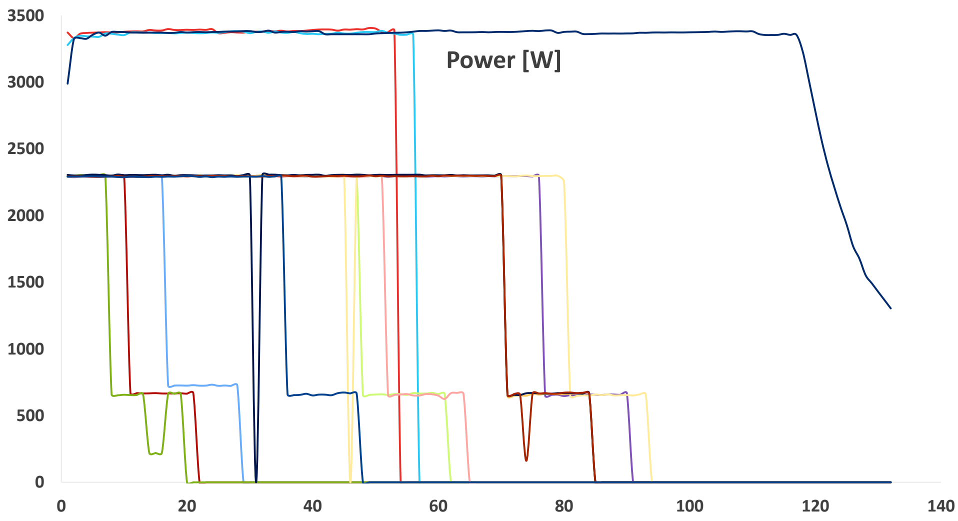

Figure 3: Charging power vs. time (minutes); Ampera starts with 3.5 kW, Prius with 2.3 kW; curves show different internal charging control algorithms

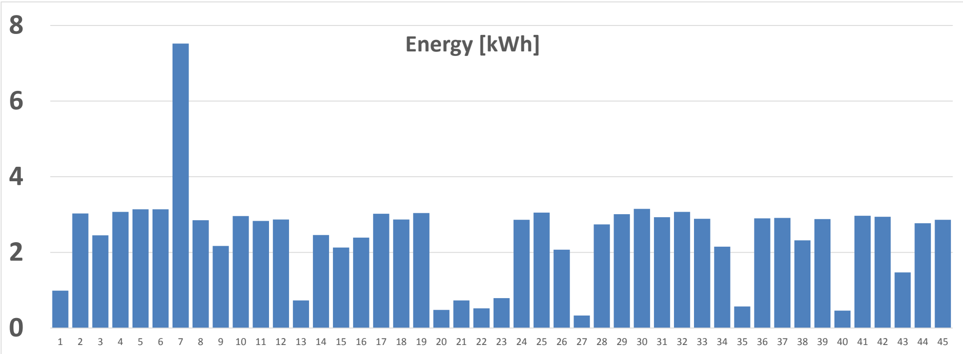

Figure 4: Energy demand for each separate charging process; typical charge of 3 kWh into the empty battery of the Prius PlugIn

Energy Management System

The energy management system in this building is a combination of rulesets and probability functions as descibed in [NEUBAUER12] and in [UNGER11].

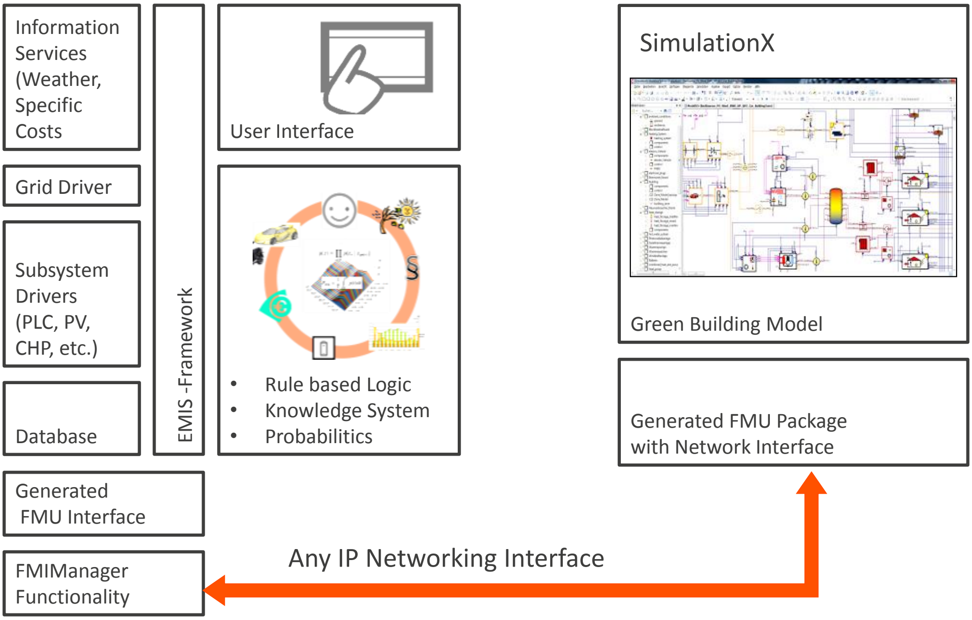

Figure 5: Block diagram of energy management system prototype within the simulated testing environment (SimulationX, GreenBuilding, FMI)

To test the control algorithms, the management software was coupled to the simulation model using an Functional Mockup Interface (FMI)

abstraction layer (FMIManager). This layer replaces real world hardware interfaces with model values for in the loop testing. A main advantage of FMIManager is the coupling via a socket connection, so programmable components with IP-Interface can be connected. Drivers for C and Java are available.
One of the aspects researched were a better control of the office heatup process, where predictive control of the shades has helped to reduce the heat and cooling demand. Another aspect was a cost optimization in with the combined control of storage systems, thermal inertia and heat pump based on photovoltaics prediction and grid power cost.

Summary

The paper showed showed aspects where simulation of the building helped to layout the energy system components in the first step. The same models were reused in the testing of control algortihms during the second step. The project showed how important an easy model calibration with datasheet values is, but also that where the important differences to the real world are.
Moderrn building automation systems often have the sensorics integrated, needed to monitor those differences. Future work will concentrate on better automation of the modelling and calibration process with real world monitoring data. Technologies like FMI and Building Information Modelling will be important facets of these ongoing developments.

[NEUBAUER2012] Neubauer, M.; Regelbasiertes Energiemanegementsystem, Diploma Thesis 2012

[EASD2013] EA Systems Dresden; information material for simulation services, 2013

[UNGER2011] Unger, R.; Schwan, T.; Mikoleit, B.; Bäker, B.; Residence and Mobility" – Renewable Energy Management in the linked System "Building-eMobility", EEVC 2011, Dresden June 2011