Co-Simulation und SiL-Test von verteilten Energiemanagementsystemen am Komplexmodell Fahrzeug-Gebäude-Nutzer

René Unger
EA Systems Dresden GmbH

Torsten Schwan
TU Dresden, Lehrstuhl für Fahrzeugmechatronik

Kurzfassung

Managementsysteme werden für moderne Gebäudeenergiesysteme mit regenerativen Energiequellen und Speichern immer wichtiger. Bei Einbeziehung von Prognosen, Nutzerprofilen und der Versorgung von Elektromobilität werden solche Managementsysteme sehr komplex. Gleichzeitig sind die notwendigen Testzeiträume unter Realbedingungen sehr lang. Im Paper wird vorgestellt, wie Managementsysteme als Software-in-the-Loop am Green Building Modell des Energiesystems getestet werden können. Wichtige Komponente dabei ist ein Kopplungsmodul auf Basis des Functional Mockup Interface (FMI) Standards. Dadurch ist es möglich reale Software mit minimalen Änderungen im Quelltext am Modell in beschleunigter Zeit zu testen.

Abstract

Management systems are increasingly important for modern building energy systems which incorporate renewable energy sources and storages. These managing systems get complex, if prediction, user profiles or charging of electric vehicles are integrated. Yet the time needed for testing under real life conditions is long, while weather is slow. The paper descibes a method to test the management program as software-in-the-loop on a Green Building model of the energy system. An important component is a coupling module based on the Functional Mockup Interface (FMI) standard. Thus it is possible to test real software, using minimal changes, on a faster than realtime model.

Introduction

Since the beginning of the 21st century, the demands on building energy systems are changing rapidly. The focus of system layout extends from the users comfort and energy needs towards a resource and environmentally friendly supply. Smart grid interaction, local energy storage and hubs for electric mobility are some of these new tasks. Diminishing fossil fuel resources and the resultant costs increase as well as new IT solutions for system interaction accelerate the changes.

Because of the plurality of applicable system components (e.g. renewables, storage systems, control algorithms, etc.) simulation based design methods are increasingly used for system layout and optimization. That way, usage and location of optimal systems can be designed at an early stage of the building planning process.

Management systems which integrate the different subsystems into an efficient supply solution are progressively important. Yet the testing of such energy management under real life conditions is difficult because of the long time-spans involved. That's why many solutions are experience based. Software in the loop tests help to improve this situation. The following example shows how to develop an energy management system with the use of SimulationX, the Modelica based Green Building Library and the FMI Standard.

Energy Management System (EMS)

Managing energy in a building and vehicle charging combination means to constantly monitor consumption of electricity as well as heat and to control generators, storages and consumers according to strategy.

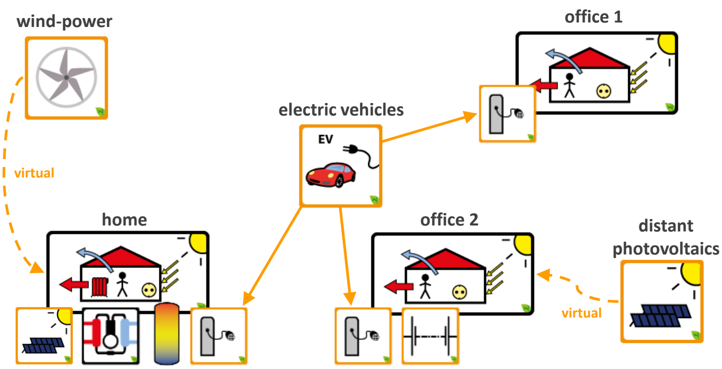

Figure 1: distributed personal energy system with renewable sources

When using renewable energy, the generation profile is usually time-shiffted against the consumption profile. Additionally, many thermal processed (i.e. floor heating) are slow, so if a change becomes visible it is often too late to react. Therefore a good management system needs to incorporate prediction algorithms to plan the trajectories of storages and controllable consumers according to weather forecast and expected user behaviour.

An example for a future personal energy system (Figure 1:) will consist of:

- a single family home with renewable energy and electrical vehicles,

- a charging station at office 1,
- a battery backed renewable charging station at office 2 and
- virtually connected wind power and photovoltaic generators.

The system is overlaid with a management system (Figure 2:) using prediction and classification of the coming energy situation to find a suitable strategy for the day and using heuristic methods for real-time operational control of subsystem setpoints like battery power.

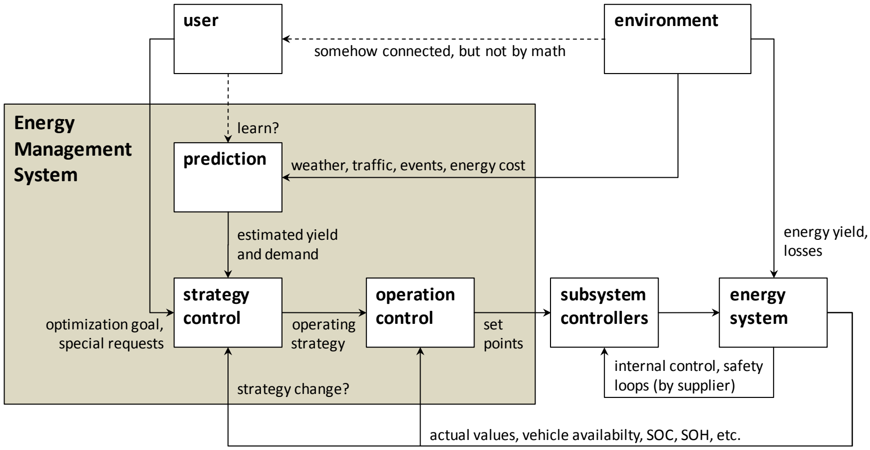

Figure 2: concept of heuristic energy management system [1]

The complex evaluation of such a system are difficult to prove in an analytical way. A more practical approach is to analyse functionality by using stochastic test cases within a simulation environment. For the same reason it is not suitable to represent the EMS in modelica. Therefore a coupling between EMS and the simulation model is a possible solution. To evaluate many test cases and long time spans, a faster than realtime simulation is needed. For this, Green Building models and FMI-Coupling can be used.

Green Building und Functional Mockup Interface

The idea of Green Building is to provide an easy to use libray with compatible models of typical buildings, renewable energy, batteries and vehicle models. The emphasize is on adequate system and control modelling as well as much faster than realtime simulation. To improve modelling speed, most models can be calibrated using datasheet values.

Functional Mockup Interface (FMI) on the other hand is a standard for simulator coupling. Specialized solvers are often much faster for their specific simualtion task than general purpose solvers. The idea is to couple different instances of a simulation system or different simulation systems based on an industry standard as oppossite to individual makeshift solutions. There are two options in FMI:

- model export where a model is exported as an FMU - Functional Mockup Unit and imported into a different simulation system and
- simulator coupling where the export contains also the specific solver.

The FMU contains an interface description and the model as runtime library (DLL). To date, SimulationX has the most complete support of the FMI specification.
The energy management system is implemented as JAVA application on an embedded PC. To test it, the building and its technical configuration were represented using components from the Green Building library. The model was connected to the application using a transparant network layer compatible to FMI at the simulator end.

FMI Manager

The idea behind FMI Manager is to replace the input-/output-datalayer of the tested software with a connection to a simulation model.
Based on the interface description by the user, a FMU and a Java Api are created automatically. Both contain the network interface implementation and therefore are transparent for the user. The next step is to import the FMU into the model and connect it to the system. On the other end, the generated Java class and underlying library needs to be linked to the Energy Management Software.
The same way, multiple JAVA programs can be coupled to a single simulation model or multiple simulators can be coupled to the same program. In a similar way, a c-library is generated to couple microcontrollers or PLCs.

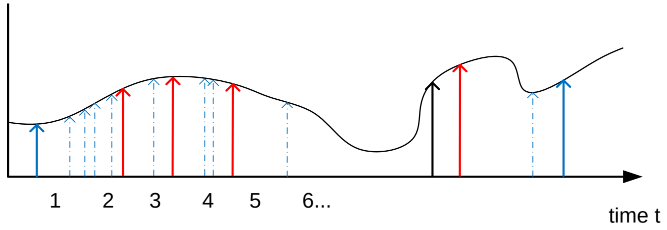

Figure 3: example for communication steps between model and program [2]

As one can imagine, it is a difficult enervating task to get the different programs and simulation instances running at the same time. Therefore the system contains a third module, the negotiator. As the name says the negotiator synchronizes the network connections and IP adresses between the FMUs in the simulator and the corresponding programs under test (PUT).
Timing is an important issue. Depending on the structure of the PUT, the internal timers can be synchronized to the simulation time. Additionally, the time steps, when communication happens, can be configured by the PUT to event triggered, interval triggered or mixed modes. Figure 3: shows one of the mixed modes with events and maximum interval. On the test system with Gigabit LAN cycle times of 20ms were achieved.

Example: Energy management system and building model

The following figure shows the model of the single family home. The FMU has interaction parameters like temperature values, power values going out of the model and parameters like battery control or shade settings going into the model.

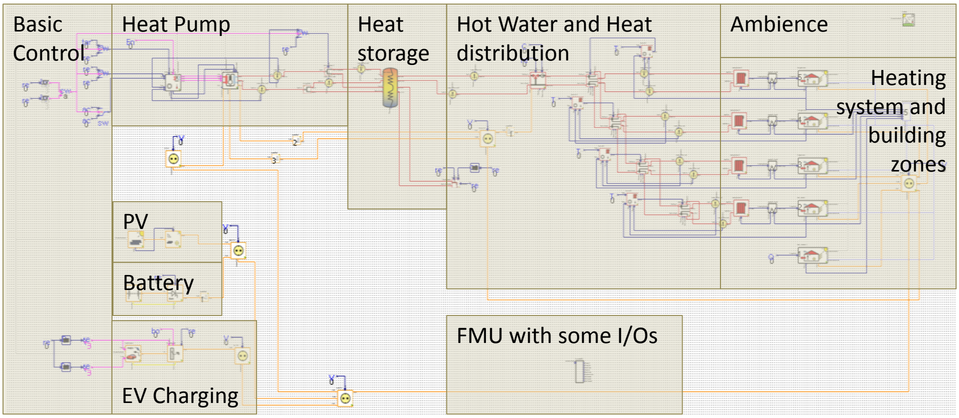

Figure 1: energy system as modeled in SimulationX with Green Building Library

The optimization goal was to achieve a maximum renewable coverage by best use of the storage tank and battery. Secondary objectives were to evaluate the cost of different possible system layouts. Decisions for battery size and energy tariffs were taken based on the simulation results. The heating system was already in place but externally controlled by EMS. The real world values are currently monitored for comparison to simulation results.

Summary

This document shows an example on how new technologies like SimulationX, the Green Building Library and FMI can be used to provide an early and easy to use testbench for complex control software like energy management systems with heuristics. The FMI Manager provides the actual FMI and network implementation for this process. The paper decscribes this approach in more detail. Future work will concentrate on implementing the new FMI 2.0 standard als well as extending the module to cover more platforms for the software under test like Python and Webservices. The research was encuraged by Sächsische Aufbaubank (SAB).

[1] Unger, Schwan, Bäker, Mikoleit; „Residence and Mobility“ Renewable Energy Management in the System “Building-eMobility”; EEVC 2011

[2] Heinrich, Martin: „Modelisar Functional Mockup Interface zur Anbindung von Energiemanagement-Software an SimulationX/Modelica“ 2012