Master Project Proposal

Title: Benchmarking of Energy Management Systems with Optimality Baselines

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Background

An essential topic in energy management systems (EMSs) is benchmarking. It involves the evaluation of controllers of energy systems under various conditions to validate performance, sensitivities, and other critical factors. However, a significant gap in the current state of the art is the absence of a general methodology for such benchmarking [1]. The prevalent practice involves simulation against historical data, typically spanning a calendar year, and comparing a candidate controller against some alternative controller. One reason for the lack of such methodology is the heterogeneity of energy systems, which often necessitates tailor-made solutions and complicates the transfer of approaches and code between systems [1, 2, 3]. Consequently, understanding the benefits and drawbacks of different approaches as reported in literature is difficult.

A closely related challenge can be found in the development process of EMS controllers: Generally, the development process is a tedious and iterative process, which involves simulation against various test scenarios to evaluate controller behavior. This process could be supported by a better benchmarking methodology, by facilitating progress tracking and the selection of relevant test scenarios.

Figure 1: The Honda R&D Facility in Offenbach am Main. (Source: Google Maps)

Figure 2: The hydrogen system at the Honda R&D facility in Offenbach am Main.

This master thesis project aims to fill the existing gap by developing a comprehensive methodology for benchmarking controllers for EMSs. This methodology will be centered around the idea of using “optimality baselines” for the operation of the underlying energy system:

Based on a simplified model of the energy system, an optimal operation plan is derived by optimizing the system operation over a long time horizon. This plan then serves as an optimality baseline – or theoretical upper bound – to how well the system could be operated, given perfect foresight about external influences such as electricity demand and weather. This baseline could then be used to compare the performance of controllers and to determine interesting periods for stress-testing.

To develop this methodology, a number of models of interesting energy systems at our facility can be used, as well as a range of model predictive control-based control approaches for those systems.

Relevant Literature

[1] C. Ceccolini and R. Sangi, “Benchmarking Approaches for Assessing the Performance of Building Control Strategies: A Review,” Energies, vol. 15, no. 4, p. 1270, Feb. 2022

[2] J. Drgoňa et al., “All you need to know about model predictive control for buildings,” Annual Reviews in Control, 2020.

[3] J. Arroyo, F. Spiessens, and L. Helsen, “Comparison of Optimal Control Techniques for Building Energy Management,” Frontiers in Built Environment, vol. 8, 2022.

Research/Technical Target

Targets

- Evaluation of the proposed idea of generating optimality baselines:
    - For general comparability of EMS control approaches
    - For supporting the development process of EMS control approaches
- Identification of challenges for applying the methodology
- Development of a framework for benchmarking controllers against optimality baselines

Plan

- Literature study on controller and EMS benchmarking (1 month)
- Methodology conceptualization (1 month)
- Implementation of conceptualized benchmarking methodology (2 months)
- Simulation study (1 month)
- Writing of the master’s thesis (1 month)

Partner

TBD

Requirements

- Good knowledge of Python
- Background in control engineering
- Knowledge on optimal control, especially model predictive control, is a plus
- Experience with building and solving numerical optimization problems is a plus

Specific Project Needs

No specific hardware needs. No special safety or (data) security needs anticipated.