PhD: Capturing the long-term value of flexibility in smart buildings to respond to a smart distributional grid

Kasper Emil Thorvaldsen

Department of Electric Power Engineering (NTNU), Norway.
Affiliated with FME ZEN and FME CINELDI

Challenge and objectives

To create a smart future grid, there is potential and a need to include the flexible resources that are existing within the grid. Therefore, the flexible units that exist within needs to be investigated to find their value and contribution to the total distributional grid. Some of the possible contributors to this is the Zero Emission Neighborhoods (ZEN) that FME ZEN is working on. However, the level of flexibility and their value for flexibility is something that must be found. Some of the objectives that are expected to be investigated are:

- What is the relation between long-term and short-term value of flexibility for building scheduling, and how can this be represented and calculated to improve short-term operation?
- How does different flexible assets in building scheduling impact long-term value of flexibility?
- What is the potential of CO_{2eq} emission savings for a ZEB/ZEN during the operational phase over the course of a year considering uncertainty?
- How can accurate operational strategies for seasonal flexible assets be represented for overall optimal usage?
- What is the value of flexibility in a local distributional grid with congestion problems?

Research tasks

- Development of an algorithm using Stochastic Dynamic Programming to capture the long-term effects of flexibility usage for a ZEB, with detail on different flexible mechanisms
- Analyze the long-term effects of flexibility usage for different price signals, as monthly measured peak grid tariff, net-zero emission during operation, and strategy for seasonal storage
- Extend on the SDP framework to consider multiple price signals at once, to capture their influence on each other

Approach

- The plan is to make use of Stochastic Dynamic Programming (SDP) to capture the long-term effects different flexible assets have in their surroundings. This can be used to see how a ZEB, ZEN or other parts of a local distributional grid have the capability to utilize flexibility based on the surroundings and the price signals exposed to.
- Analyze different price signals and the influence this has on operational decisions and operational strategies
- Investigate how the operational strategy assist in utilizing seasonal storage and long-term flexible assets
- Based on the results from the SDP approach, the value of flexibility in the system can be analyzed and investigated. Then, combining the SDP together with a rolling horizon operational model will enable to see the forecasting accuracy of this approach.

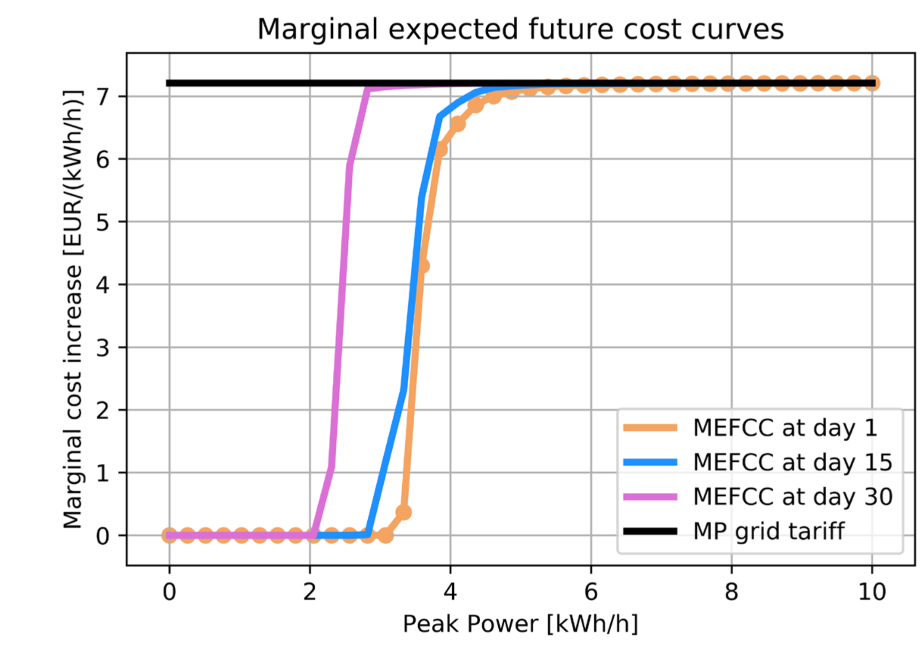
Significant results

A Zero-emission building (ZEB) has been used to investigate how flexible assets contribute on electricity usage when exposed to long-term price signals. This has been combined with the SDP method mentioned for a case study where a monthly power tariff based on highest peak power has been included. The household demand is considered uncertain. The aim is to find the optimal peak power for the household to minimize total electricity cost.

The results from this test shows that the SDP method develops future cost curves, that presents the future added cost of operational decisions taken now. This assists in making a more global optimal operational decision. These curves help find the cost-optimal level for the building, based on the cost of utilizing flexibility. The peak power level is set based on the value of allowing more flexibility in electricity scheduling versus the added cost from the power tariff. Figure 1.a showcases how the future costs change based on different stages in the month, while Figure 1.b showcases the future cost curves for a case study surrounding the goal of achieving net-zero emission during operation for a whole year.

The study has been investigated further, where Space heating, EV charging, and a stationary battery has been analyzed for a ZEB. Each flexible asset has been controlled individually, to see how each asset differs in flexibility contribution on the same case study as described above. The results showcased high peak shaving potential from EV charging, and that space heating has high capability to cut peak to a level where Real-time pricing savings combined with peaks shaving is co-optimized, depending on the temperature boundary. Figure 2 showcases how the cost and peak shaving changes for each flexible asset.

Illustrations



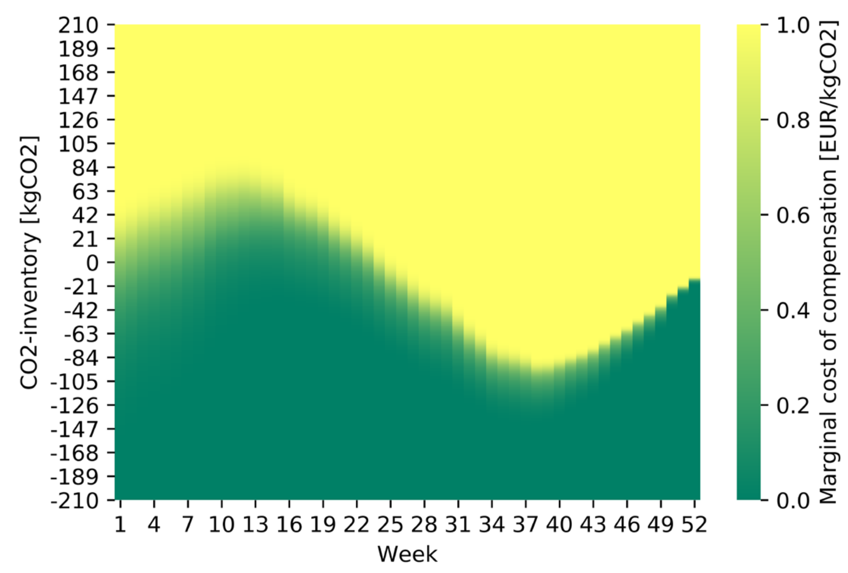
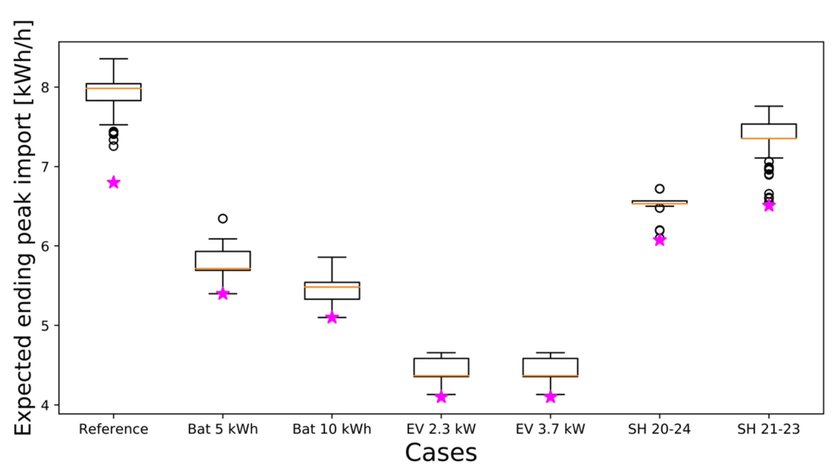


Figure 1.a: Marginal future cost curve for different stages in a month.

Figure 1.b: Heatmap of future cost curves over a year for a net-zero emission goal



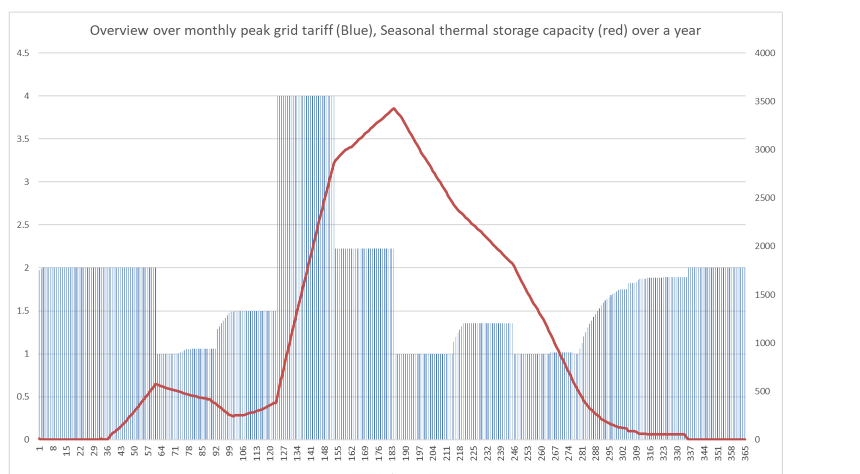


Figure 2.a: Boxplot of ending peak level for a building with different flexible assets enabled

Figure 2.b: Overview over the operational performance of a building with seasonal storage unit when exposed to a monthly measured-peak grid tariff over a year (WIP).

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