On the Characterization and Evaluation of Flexibilities in Energy Management Systems

Topic: Energy modelling

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Introduction

In recent times, the need for flexibility in the grid increases, because of the growing share of renewable energy resources and it's volatility. Flexibility is the capability of power plants and/or loads to alterate their scheduled injection and/or consumption in reaction of external signals like spot market prices and balancing market opportunities.
Flexibility of distributed Energy Management Systems represents an enormous potential to reduce the energy costs and can be used to provide regulation reserve to the grid. Aggregation of smaller Energy Management Systems allows their participation in wholesale markets. However, a simple and exhaustive description of flexibilities is needed to efficiently coordinate and aggregate multiple flexible actors.
(H. Hao, 2015) presents a method to describe the flexibilities of different technologies as virtual batteries. In this document, we improve its work and describe the flexibility of an Energy Management System as a combination of a non-flexible load and virtual batteries with variable capacities, power inputs and outputs. Furthermore, we define a mathematical optimization problem aimed to minimize the energy costs and to best allocate the flexibilities of the Energy Management System between spot markets, regulation reserve and self-consumption.

Methodology

In this work, we propose a simple and complete method to describe Energy Management Systems-flexibilities and to allocate the aggregated value among the flexible technologies. The main idea of the proposed method is to describe flexibilities of an Energy Management System as virtual batteries with variable capacities and limited power inputs and outputs. Figure 1 shows the flexibility of an electric vehicle as a virtual battery.

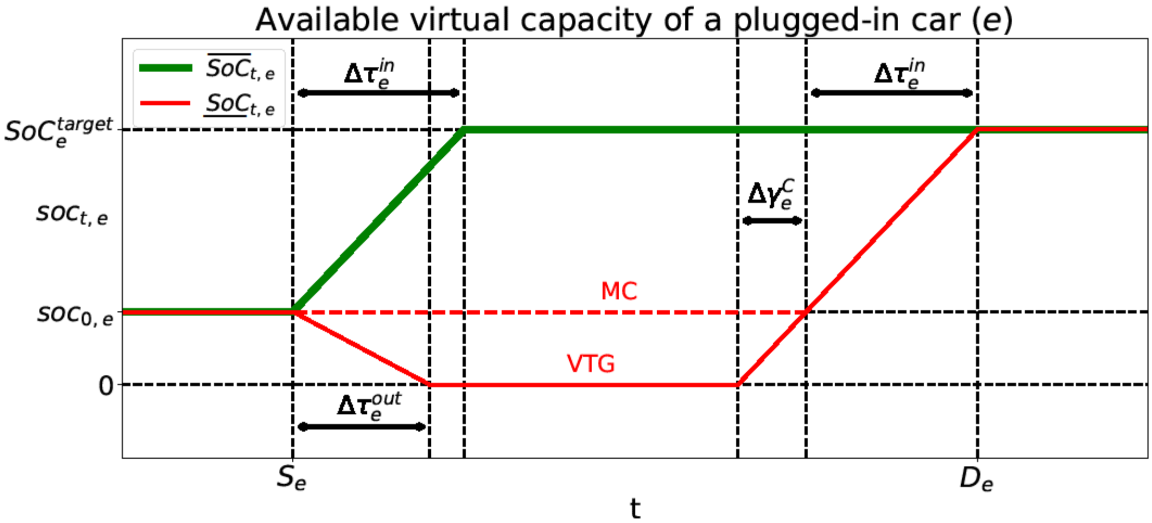

Figure 1 Available virtual capacity of a plugged-in electric car.

The mathematical formulation of virtual batteries allows to best allocate the energy flow of the Energy Management System through an optimization model, which aims to find the most costs-beneficial strategy to employ the aggregated flexibilities. The overall flexibility of the Energy Management System is used to optimize (1) the self-consumption of non-flexible loads, (2) the trading on the energy spot markets and (3) the bids on the balancing markets.

Additionally, this work studies the individual values of each flexibility of the considered Energy Management System. To fairly allocate the created value among the flexible technologies, profit-sharing mechanisms derived from the game theory are applied.

Use Case

The Energy Management System considered in this work and shown in Figure 2 is an office site of an electric utility company in Austria. This case study examines the potential value that the flexibilization of the technologies of an Energy Management System may create in a period of one year.

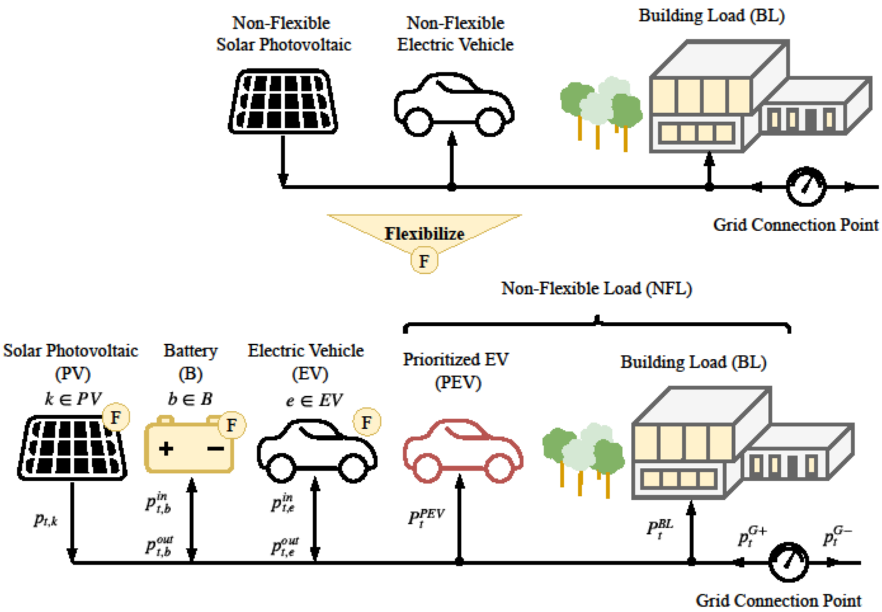

Figure 2 Flexibilization of the technologies constituting an EMS and their power flows

Results and Conclusions

This work presents a comprehensive overview of modeling and evaluating flexibilities of an Energy Management System composed by different technologies. Comparing these different flexible technologies, we identify various diversities and potentials. We describe multiple flexible technologies as virtual batteries and implement them in a mathematical optimization problem. With the experimental results we investigated the value of the flexibilities distinguishing between the single technologies.
We propose to apply the game theoretic solution concept of Shapley value to fairly assign a value to each flexible technology. The results show that flexibilities can individually reduce the energy costs of an Energy Management System.
Moreover, we show how aggregating flexibilities results in further energy costs reduction. In fact, the aggregation of all flexible technologies of the investigated Energy Management System achieves the lowest energy costs. Furthermore, we investigate the marginal values of each flexible technology and we prove that the flexibilization of further charging processes of electric vehicles leads to lower specific energy costs.

Literature

H. Hao, A. S. (2015). Generalized aggregation and coordination of residential loads in a smart community. *2015 IEEE International Conference on Smart Grid Communications*, 67–72.

Aknowledgement: The Flex+ project (No 864996) is being funded under the 4th call of the energy research program of the Austrian Research Promotion Agency (FFG) and the Climate Energy Fund. The authors are particularly grateful for the metered Data provided by F. Mader of the WEB, Windenergie AG, Pfaffenschlag, Austria.