Flexibility of an Energy Management System

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IEWT 2019, Wednesday, 13th Feb. 2019, 17:30 - 19:15 (CET) , “Flexibilität & Sektorkopplung I”, Wien

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.

About the Project „Flex+“

- **Target country:** Austria
- **Start:** 05.2018
- **Duration:** 36 Months (04.2021)
- **Coordinator:** AIT Austrian Institute of Technology GmbH (AIT)
- 15 Partners

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Motivation

- *“The need for flexibility in the grid is increasing, because of the growing share of renewable energy resources and it’s volatility. (R.A. Verzijlbergh et al. 2017)“*

- *“The power system is moving from a central to a decentralized energy system. The new system includes more distributed generation, energy storages and requires a more active involvement of consumers, e.g. through demand response. (P. D. Lund et al. 2015)“*

- *“In the last years, power system regulators and operators create conditions for encouraging the participation of the demand-side into reserve markets lowering the minimum size of the balancing power market bids. (R. J. Bessa et al. 2013)“*

Literature

- *“A simple and exhaustive description of flexibilities is needed to efficiently coordinate and aggregate multiple flexible actors (Valsomatzis et al. 2017).“*

Research question 1: How to formulate flexibilities of different technologies?

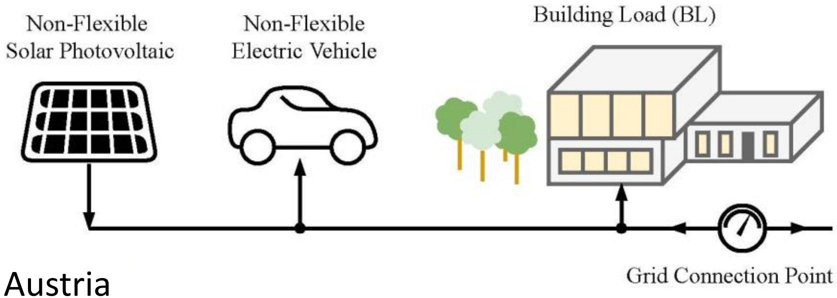
- Hao et al. (2015) models the flexibilities as virtual battery models. This work improves this approach by the introduction of new technologies and functionalities.

- *“The profits of aggregated RES cannot be suitably distributed (e.g., per capacity or generated electricity) without the need of advanced algorithms (P. Chakraborty et al. 2016).“*

Research question 2: How to allocate the value of aggregated flexibilities among the flexible technologies?

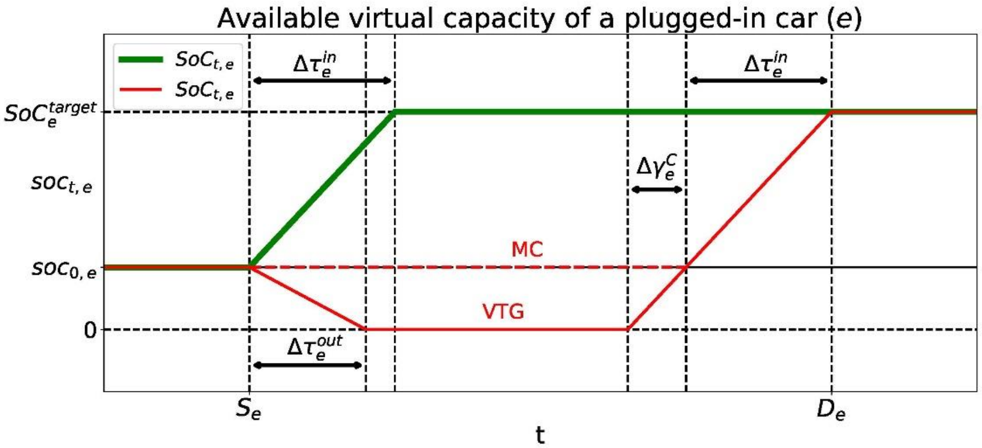
- Saad et al. (2012) conclude that (cooperative) game theoretical methods are a promising tool to share the value. This work uses the *Shapley Value.*

Motivation by a Real Life Use Case



WEB, Windenergie AG, Pfaffenschlag, Austria
Coordinates: N 48.843594, E 15.200681

Flexibility Modelling: *Electric Vehicles*

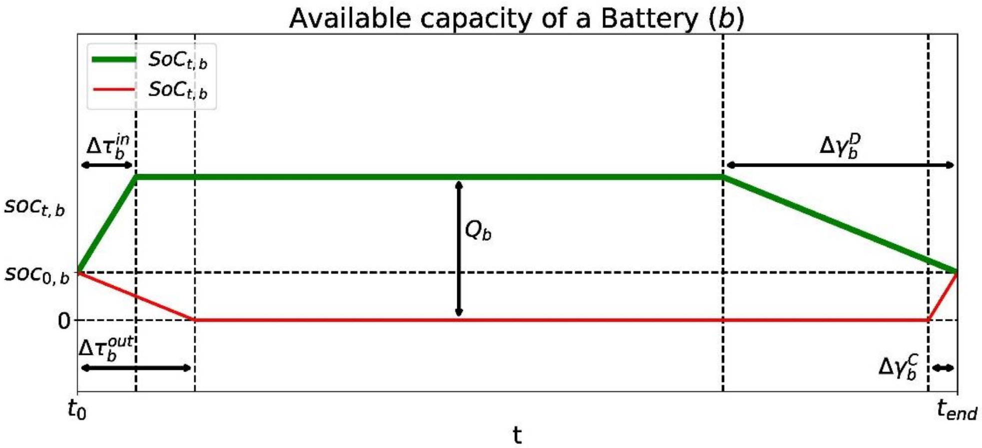


$$Flex_e = (S_e, D_e, P_{e,max}^{in}, P_{e,max}^{out}, soc_{0,e}, SoC_e^{target})$$

MC … Managed Charging

VTG … Vehicle-to-Grid

Flexibility Modelling: *Batteries*

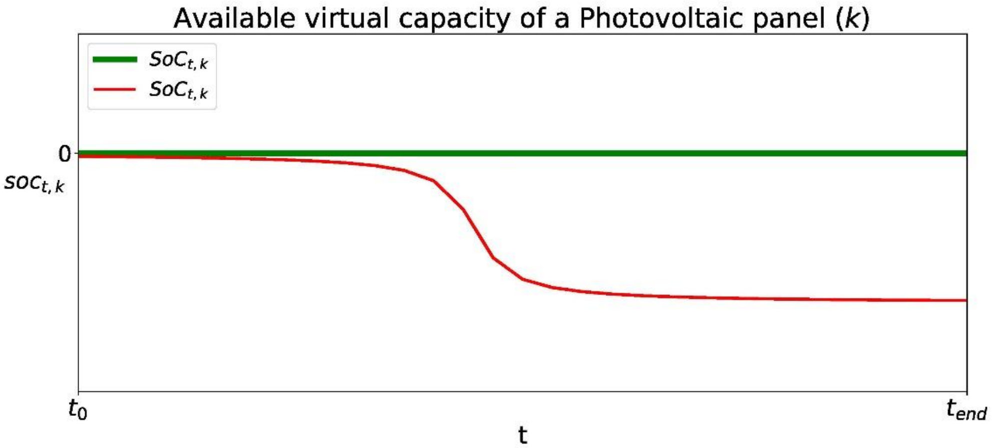


$$Flex_b = (P_{b,max}^{in}, P_{b,max}^{out}, soc_{0,b}, Q_b)$$

$$\underline{SoC}_{t,b} = \begin{cases} soc_{0,b} - P_{b,max}^{out}(t - t_0) & \text{for } t_0 \le t \le (t_0 + \Delta\tau_b^{out}) \\ 0 & \text{for } (t_0 + \Delta\tau_b^{out}) \le t \le (t_{end} - \Delta\gamma_b^{C}) \\ P_{b,max}^{in}(t - (t_{end} - \Delta\gamma_b^{C})) & \text{for } (t_{end} - \Delta\gamma_b^{C}) \le t \le t_{end} \end{cases}$$

$$\overline{SoC}_{t,b} = \begin{cases} soc_{0,b} + P_{b,max}^{in}(t - t_0) & \text{for } t_0 \le t \le (t_0 + \Delta\tau_b^{in}) \\ Q_b & \text{for } (t_0 + \Delta\tau_b^{in}) \le t \le (t_{end} - \Delta\gamma_b^{D}) \\ Q_b - P_{b,max}^{out}(t - (t_{end} - \Delta\gamma_b^{D})) & \text{for } (t_{end} - \Delta\gamma_b^{D}) \le t \le t_{end} \end{cases}$$

Flexibility Modelling: *Solar Photovoltaics*



$$\overline{P}_{t,k} = \{\overline{P}_{1,k}, \overline{P}_{2,k} \ldots, \overline{P}_{T,k}\}$$

$$\underline{SoC}_{\ t,k} = -\Omega \sum_{\tau=0}^{t} \overline{P}_{\tau,k}$$

$$\overline{SoC}_{\ t,k} = 0$$

$$\boxed{Flex_k = (\overline{P}_{t,k})}$$

Optimization Framework: ***Femto*** *(developed by D. Schwabeneder)*

- In order to settle the optimization problem of the Energy management System, we use the *Julia* toolbox *Femto* to implement the model and the *Gurobi* solver to solve it.

- This toolbox allows to optimize the power flows of multiple loads and generators on multiple energy markets with different market designs.

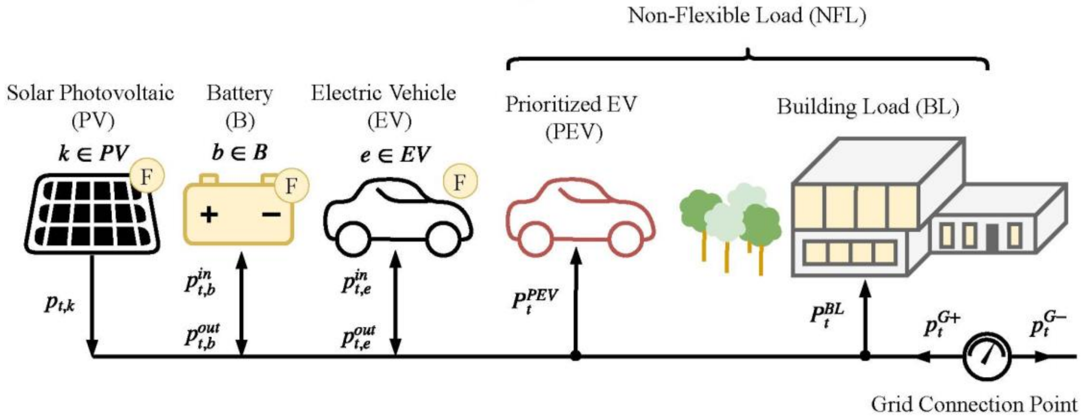
Real life Use Case: WEB, Windenergie AG, Pfaffenschlag, Austria

Flexibilities

- 30 charging stations with 3740 charging processes
- 1 Battery (80 kWh, 15 kW)
- 1 Photovoltaic panel (30 kWp)

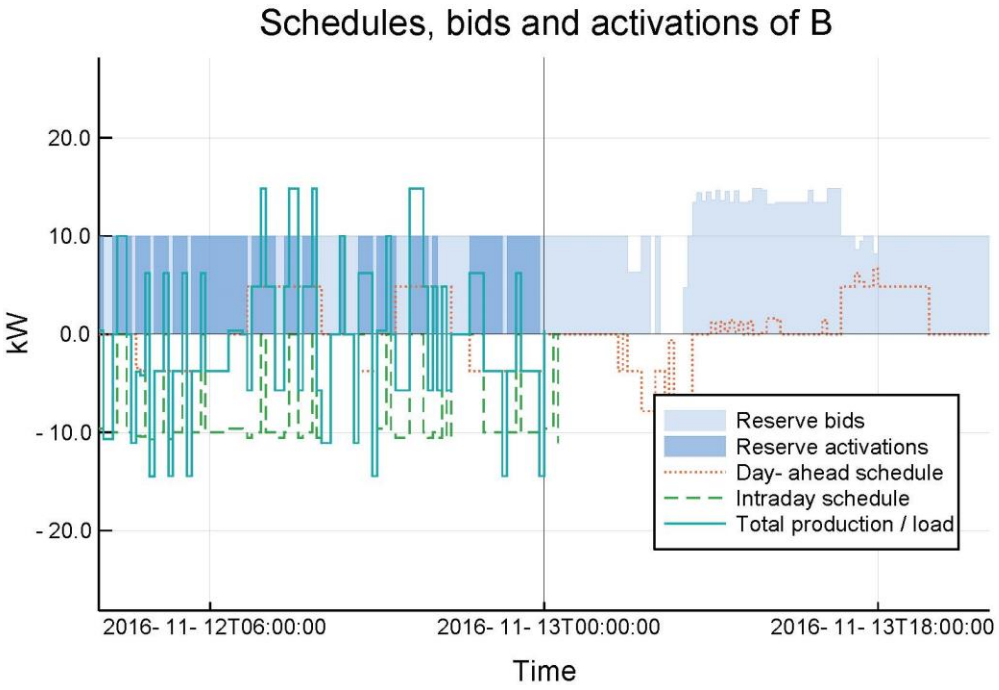
Energy markets:

- Day-ahead spot market (EPEX)
- Intraday spot market (EPEX)
- Secondary reserve market (APG)



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.

Results of Flexibility Activation



Allocation of the Created Value via *Shapley value*

- The Shapley value concept offers a solution to allocate the created value among multiple players.
- Energy Management System with flexible technologies:

$$i \in S \subseteq I = \{\text{Electric vehicles , Photovoltaics, Batteries}\}$$

- The Energy Management System with a set of flexibilized technologies $S \subseteq I$ generates value v_S.

Flexibilized set of technologies *S:*	Created value v_S in €
{Photovoltaics}	7
{Electric vehicles}	1287
{Batteries}	3388
{Photovoltaics, Electric vehicles}	1296
{Photovoltaics, Batteries}	3395
[Electric vehicles, Batteries}	5008
{Photovoltaics, Electric vehicles, Batteries}	5017

Technology i	Shapley Value y_i in €
{Photovoltaics}	8
{Electric vehicles}	1454
{Batteries}	3555

Conclusions

- Our work presents a comprehensive overview of modeling and evaluating the flexibilities of an Energy Management System.
- We describe multiple flexible technologies as virtual batteries and implement them in a mathematical optimization problem.
- We used the game theoretic solution concept of Shapley value to assign a value to each flexible technology based on its contribution.
- We applied our proposed methods to a real-life use case in Austria with metered data.
- Our work shows, how aggregating flexibilities results in energy costs reduction.

It's all very well to have principles, but when it comes to money you have to be flexible.
(Eugene Ormandy - Hungarian-American conductor and violinist)

Thank you for your attention

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