IEWT 2019

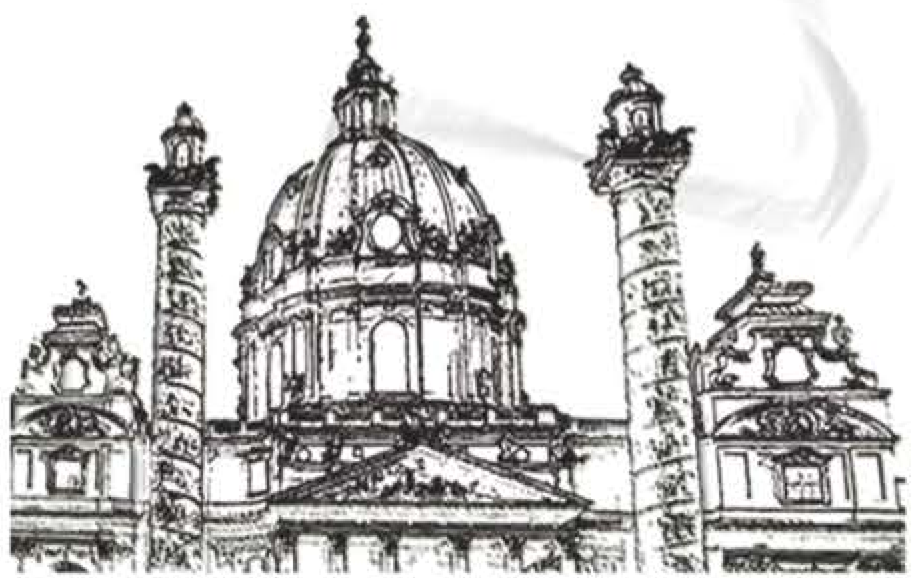
11. Internationale Energiewirtschaftstagung

"Freiheit, Gleichheit, Demokratie: Segen oder Chaos für Energiemärkte?"

Freiheit, Gleichheit, Demokratie: Segen oder Chaos für Energie-märkte?

IEWT 2019

11. Internationale Energiewirtschaftstagung an der TU Wien



13. – 15. Februar 2019
Wien, Österreich

Tagungsort:
Campus Gußhaus / TU Wien
Gußhausstraße 25-29
1040 Wien

Veranstalter:
Energy Economics Group - Institut für Energiesysteme und Elektrische Antriebe der TU Wien
AAEE (Austrian Association for Energy Economics)

Das Energiesystem befindet sich im Umbruch – In Österreich, in Europa, weltweit. War jenes von gestern durch eine Einbahn von den großen Kraftwerken bis zu den Endverbrauchern gekennzeichnet, so prägt heute eine Vielzahl von dezentralen Erzeugungsanlagen, vor allem im Bereich der Stromversorgung, das Bild. Nähert sich also die Zeit der großen Energiekonzerne dem Ende oder kratzen sie noch einmal die Kurve zu Dienstleistungsunternehmen? Sind die Prosumagers und Endkundenpartizipation Zukunftsmodelle oder Wunschdenken? Energiepolitisch sind das Clean energy – Paket der EU, die Klima- und Energiestrategie der Bundesregierung und der Fortschritt bei der Energiewende die heißen Eisen in der Diskussion.

Die **11. IEWT** spannt den großen Rahmen um das Thema **„Demokratisierung des Energiesystems“** und allen wesentlichen Themen, die damit zusammenhängen. Weiters werden auch nationale und internationale Entwicklungen auf Energiemärkten und alle wesentlichen weiteren aktuellen Herausforderungen der Energiewirtschaft thematisiert und Lösungsansätze auf wissenschaftlicher Basis diskutiert.
Wir laden herzlichst ein, Beiträge zu den angeführten Themen einzureichen – in Präsentations- oder Posterform – und freuen uns auf interessante Diskussionen bei der **11. Internationalen Energiewirtschaftstagung** an der TU-Wien – wieder am **Campus Gußhaus.**

Herzlichst

Hans Auer
Reinhard Haas
Albert Hiesl

Flexibility of an Energy Management System

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PhD Day 2019, Tuesday, 12th Feb. 2019, 13:15 - 15:35 (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.

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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

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.

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?

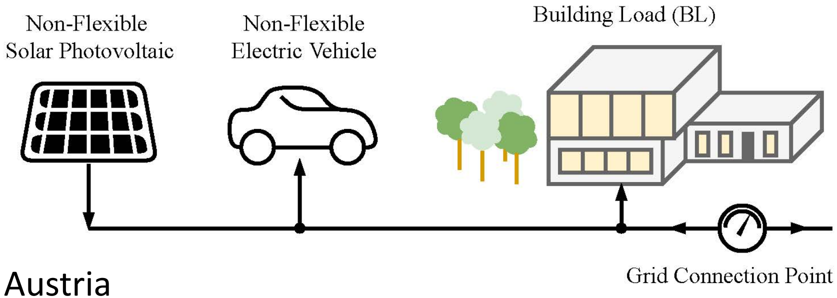
- Hao et al. (2015) models the flexibilities as virtual battery models. This work improves this approach by the introduction of new technologies and functionalities.

- 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.*

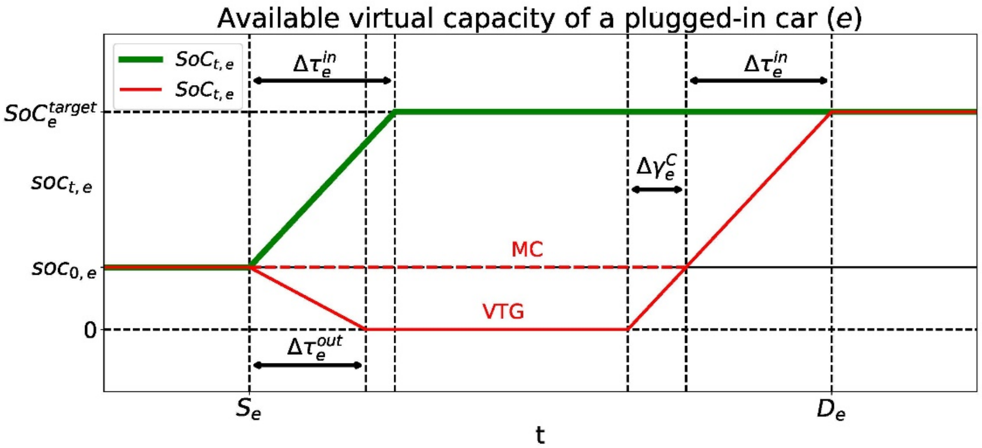
Motivation by a Real Life Use Case



WEB, Windenergie AG, Pfaffenschlag, Austria

Coordinates: N 48.843594, E 15.200681

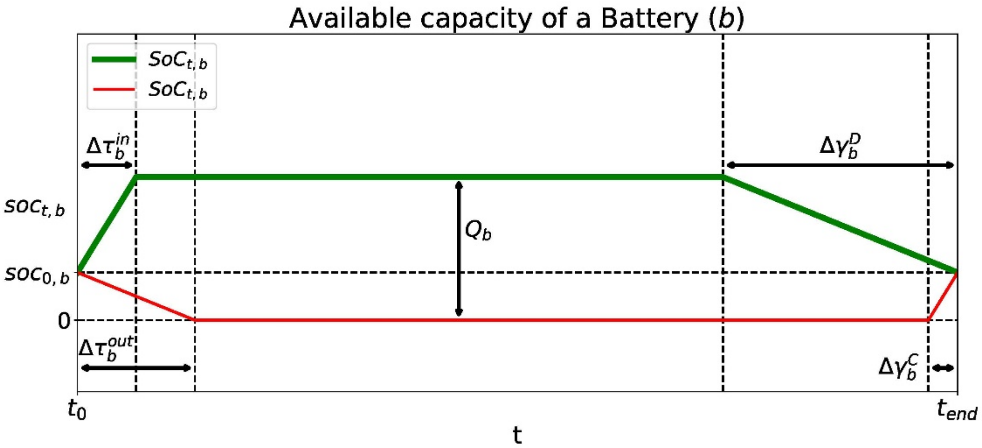
Flexibility Modelling: *Electric Vehicles*



$$Flex_e = (S_e, D_e, P^{in}_{e,max}, P^{out}_{e,max}, soc_{0,e}, SoC^{target}_e)$$

MC … Managed Charging
VTG … Vehicle-to-Grid

Flexibility Modelling: *Batteries*

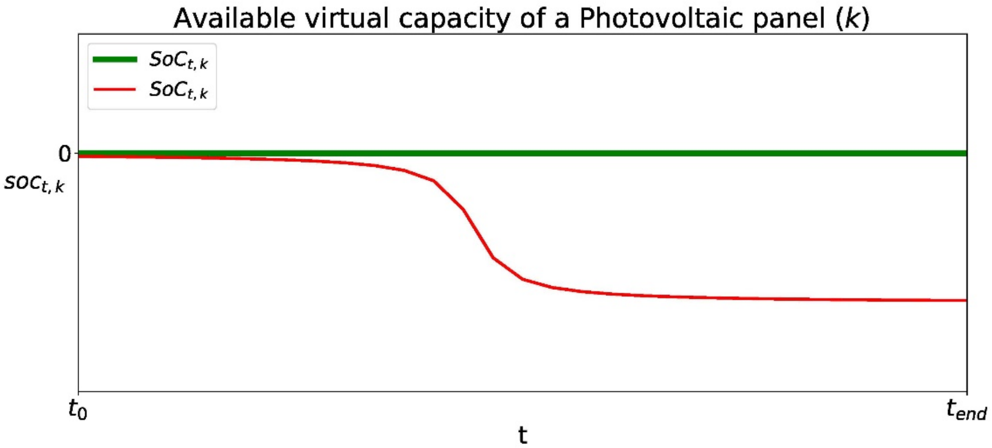


$$\underline{SoC}_{t,b} = \begin{cases} soc_{0,b} - P^{out}_{b,max}(t - t_0) & \text{for } t_0 \leq t \leq (t_0 + \Delta\tau_b^{out}) \\ 0 & \text{for } (t_0 + \Delta\tau_b^{out}) \leq t \leq (t_{end} - \Delta\gamma_b^{C}) \\ P^{in}_{b,max}(t - (t_{end} - \Delta\gamma_b^{C})) & \text{for } (t_{end} -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

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

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

Flexibility Modelling: *Solar Photovoltaics*



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

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

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

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

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.

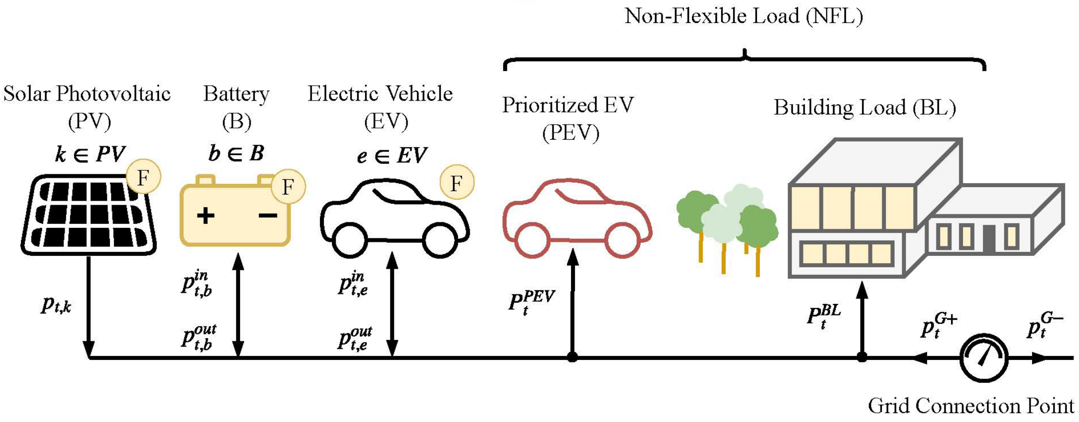
Real life Use Case: WEB, Windenergie AG, Pfaffenschlag, Austria

Flexibilities

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

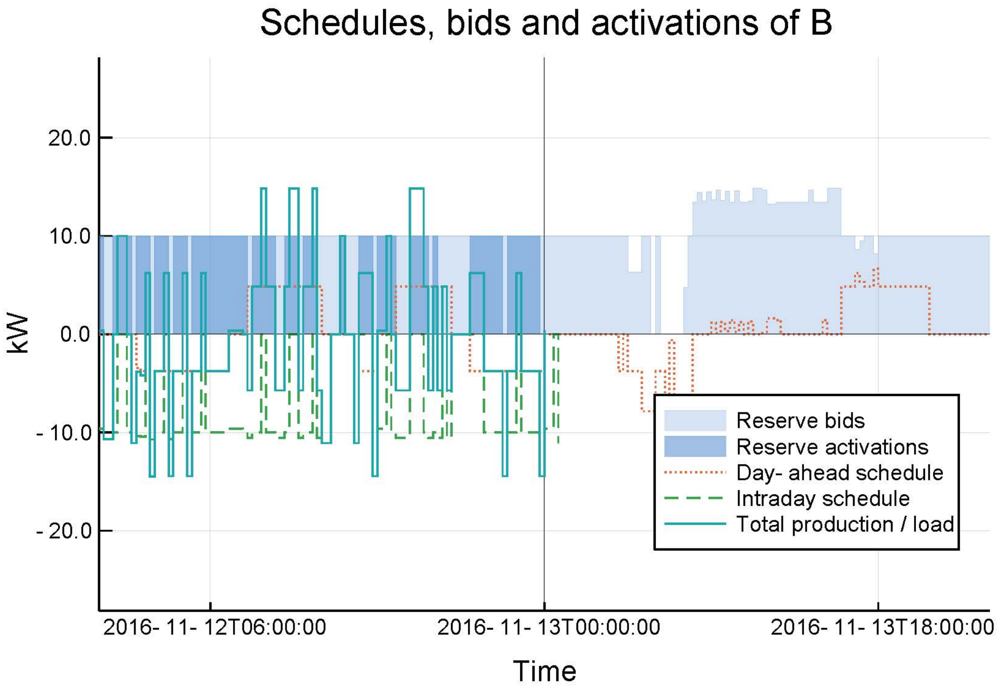
Energy markets:

- 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:

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

- 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

Relative Value of Flexibility Aggregation

- A single technology i achieves an individual value v_i.
- If forming a portfolio all flexible technologies increases the value by Δ with

$$v_I = \sum_{i=0}^{I} v_i + \Delta$$

The relative value of aggregation of technology i shows, how the aggregation of its flexibilites contribute to the aggregated created value Δ.

$$v_{i\%}^{Agg} = \frac{y_i - v_i}{\Delta}$$

Technology	Relative Value of aggregation $v_{i\%}^{Agg}$ in %
{Photovoltaics}	0.15
{Electric vehicles}	50.1
{Batteries}	49.75

The aggregation of the car pool flexibilities is the one that most influences the overall created value: 50.1%

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.

Thank you for your attention

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