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SLOVENSKO ZDRUŽENJE za ENERGETSKO EKONOMIKO

Energy Challenges for the Next Decade

#IAEE19LJ

School of Economics and Business, University of Ljubljana, Slovenia

Energy markets are becoming increasingly complex. Over the past decades, we have witnessed tremendous changes in the industry's fundamentals induced by policy and technological advancement, which required redesigning of markets. Climate policies aimed at decarbonisation extensively contributed to the changed energy mix. Recent shifts in geopolitical relations with the EU partners additionally add to the industry's complexity and uncertainty. The EU energy policy in the next decade continues to be directed towards achieving competitive, secure and sustainable energy system, which calls for huge investments in infrastructure and low-carbon technology with increased involvement of private capital.

The central topic of this conference will be to assess the impacts and identify the main challenges of these events for all energy segments: oil, natural gas and power markets through the entire value chain in order to design a sustainable policy for the following decade. The main question to be addressed is: Have we learned from the experience how to design effective policies for the next decade together with all stakeholders – consumers, companies and governments? We invite you to be a part of this debate by attending this conference and exploring the vibrant city of Ljubljana, the capital of Slovenia and the seat of the EU Agency for the Cooperation of Energy Regulators (ACER).

We proudly present the following sponsors:

General conference sponsor

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On the Characterization and Evaluation of Flexibilities in Energy Management Systems

Carlo Corinaldesi

TU Wien, Energy Economics Group, Austria

16 th IAEE European Conference, Wednesday, 28th Aug. 2019, 09:00 - 10:30 (CEST) , “Energy Modelling III”, Ljubljana

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.*

Investigated Use Case:

$$p_t^{G+} - p_t^{G-} = \sum_{b \in \mathcal{B}} (p_{t,b}^{in} - p_{t,b}^{out}) + \sum_{e \in \mathcal{EV}} (p_{t,e}^{in} - p_{t,e}^{out}) + P_t^{BL} + P_t^{PEV} - \sum_{k \in \mathcal{PV}} p_{t,k}$$

$\forall t.$

Objective Function: *minimize*

$$\sum (p_t^{G+} C_t^{Retail} - p_t^{G-} C_t^{Infeed}) + p_{max}^{G} C^{Power}$$

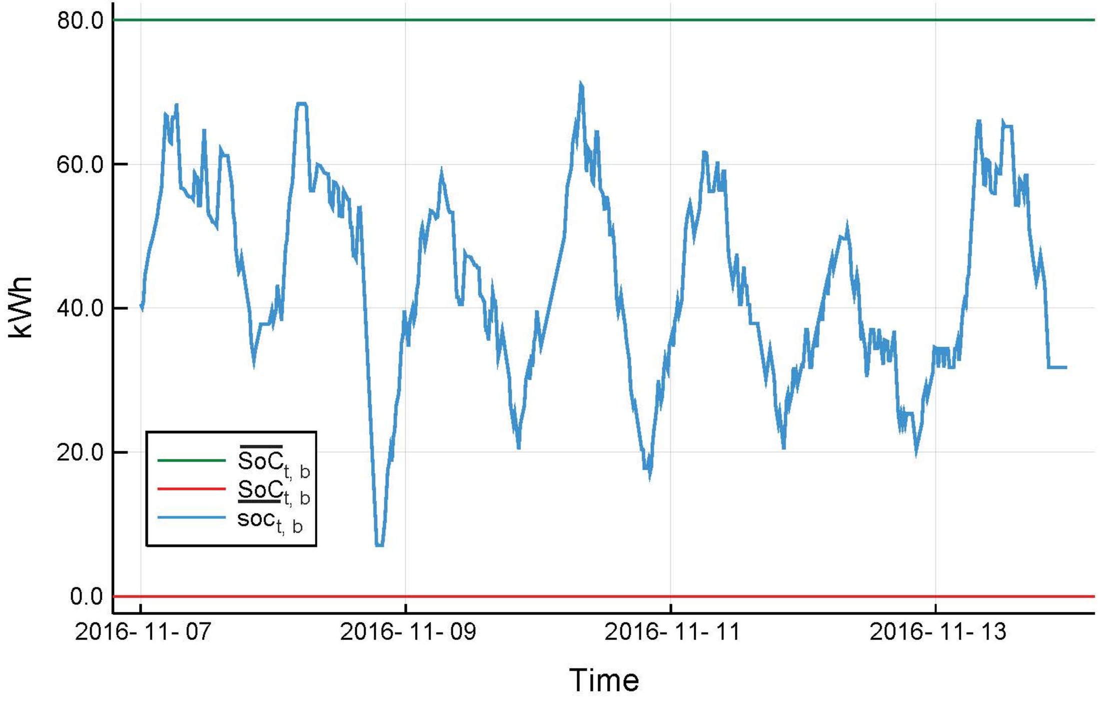
WEB, Windenergie AG, Pfaffenschlag, Austria
Coordinates: N 48.843594, E 15.200681

Batterie

$$p_t^{G+} - p_t^{G-} = \boxed{\sum_{b \in \mathcal{B}} (p_{t,b}^{in} - p_{t,b}^{out})} + \sum_{e \in \mathcal{EV}} (p_{t,e}^{in} - p_{t,e}^{out}) + P_t^{BL} + P_t^{PEV} - \sum_{k \in \mathcal{PV}} p_{t,k}$$

Flexibility Modelling: *Batteries (II)*

Optimized charging and discharging processes of B

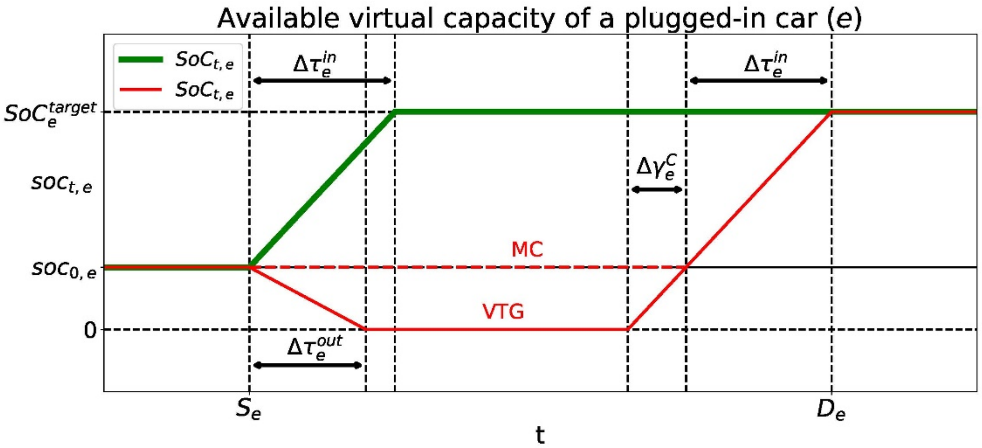


$$Flex_b = (P^{in}_{b,max}, P^{out}_{b,max}, soc_{0,b}, Q_b)$$

Elektromobilität

$$p_t^{G+} - p_t^{G-} = \sum_{b \in \mathcal{B}} (p_{t,b}^{in} - p_{t,b}^{out}) + \boxed{\sum_{e \in \mathcal{EV}} (p_{t,e}^{in} - p_{t,e}^{out})} + P_t^{BL} + P_t^{PEV} - \sum_{k \in \mathcal{PV}} p_{t,k}$$

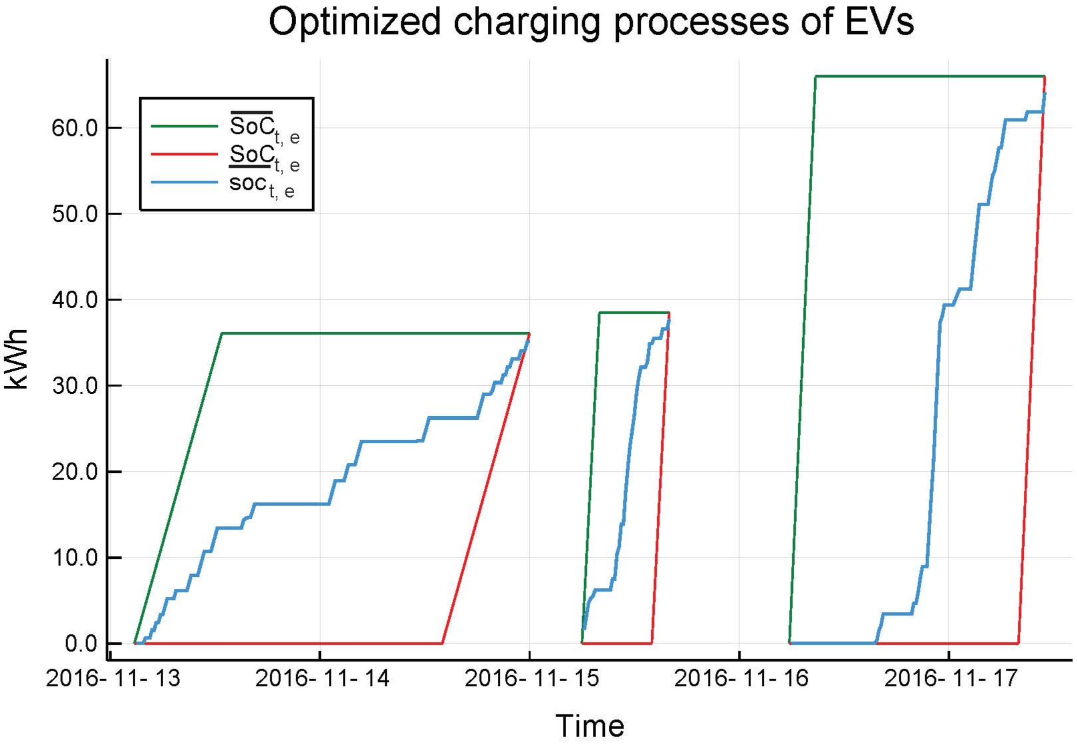
Flexibility Modelling: *Electric Vehicles*



MC … Managed Charging
VTG … Vehicle-to-Grid

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

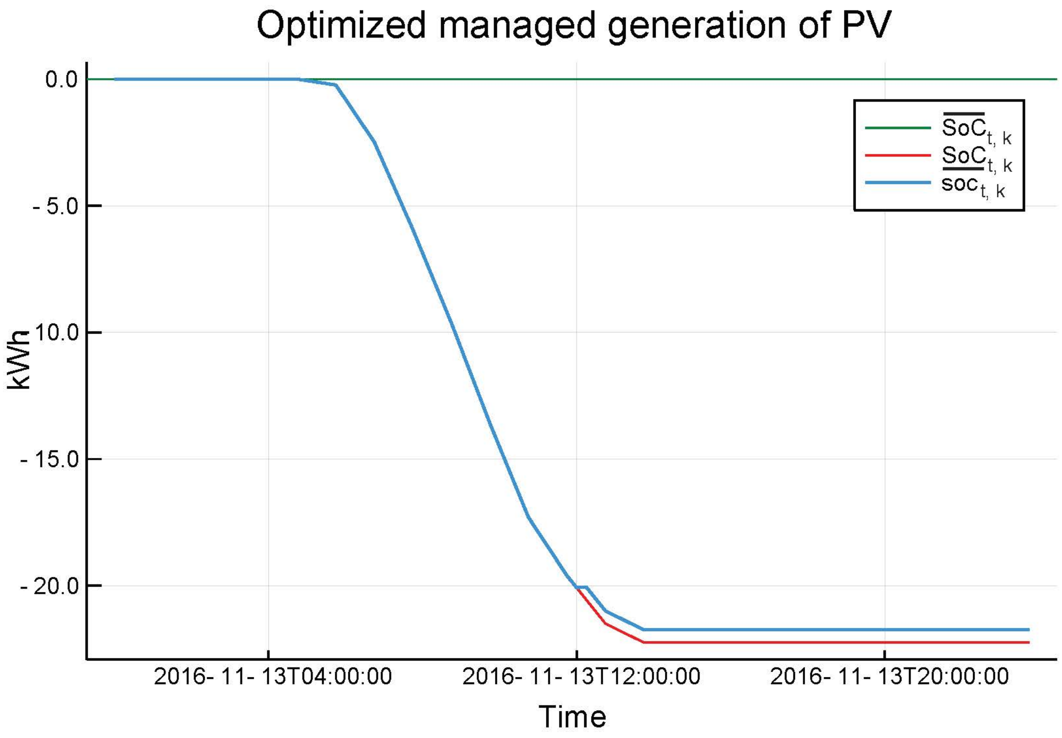
Flexibility Modelling: *Electric Vehicles*



PV

$$p_t^{G+} - p_t^{G-} = \sum_{b \in \mathcal{B}} (p_{t,b}^{in} - p_{t,b}^{out}) + \sum_{e \in \mathcal{EV}} (p_{t,e}^{in} - p_{t,e}^{out}) + P_t^{BL} + P_t^{PEV} - \boxed{\sum_{k \in \mathcal{PV}} p_{t,k}}$$

Flexibility Modelling: *Photovoltaic Panel*



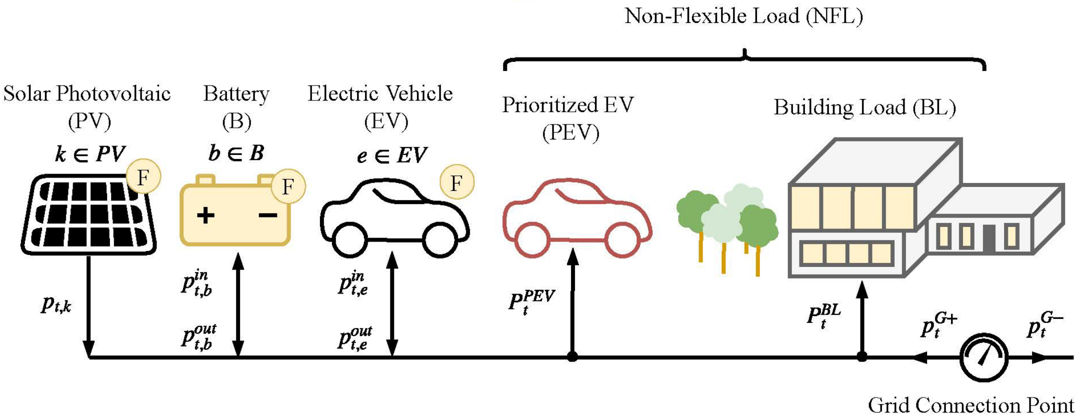
$$\boxed{Flex_k = (\overline{P}_{t,k})}$$

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

Flexibilities

- 30 charging stations with 3740 charging processes
- 1 Battery (80 kWh, 80 kW)
- 6 Photovoltaic panels (90 kWp)

Optimization Framework:
The Optimization problem is implemented in Julia and Python and solved with the *Gurobi* solver.



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.

The market oriented optimization Framework

- The aim is to optimize the flexible power flows of multiple loads and generators on multiple energy markets with different market designs.

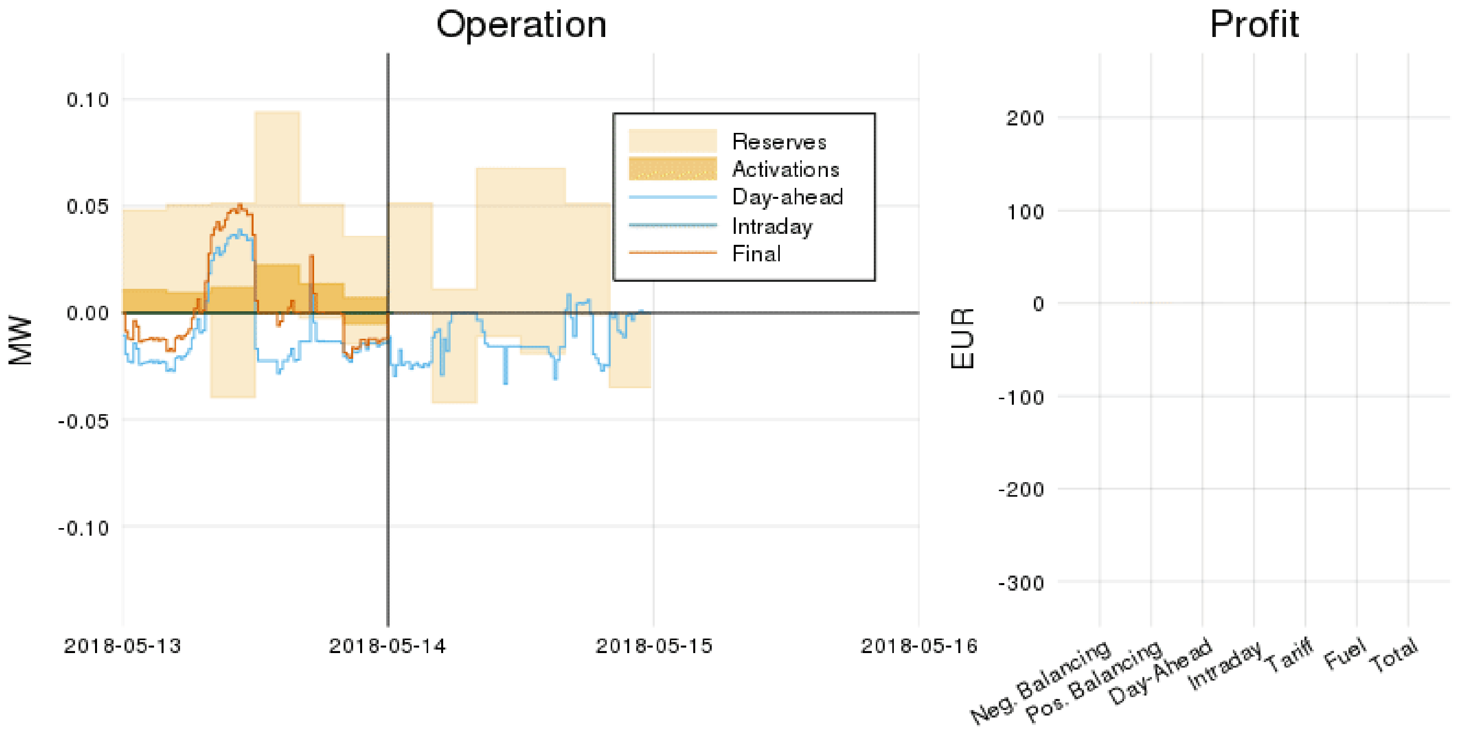
Use Case 1:

Considered energy markets:

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

- Perfect load and price foresight.

Use Case 1: Market-oriented optimized flexible power flows of the Energy Management System



The market oriented optimization Framework

- The aim is to optimize the flexible power flows of multiple loads and generators on multiple energy markets with different market designs.

Use Case 1:

Considered energy markets:

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

- Perfect load and price foresight.

Use Case 2:

Considered energy markets:

- Day-ahead spot market (EPEX)
- Intraday spot market (EPEX)

- Imperfect load and price foresight.

UNDER CONSTRUCTION

<u>Use C</u>
Energ

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

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 case study 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

Carlo Corinaldesi

→ Follow up the Project on https://www.flexplus.at/!

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