Institute of Energy and Climate Research
Energy System Engineering (IEK-10)

JÜLICH Forschungszentrum

Degradation-cost-aware scheduling of electric vehicle charging and discharging

Lea Riebesel (l.riebesel@fz-juelich.de)

Operation of electric vehicles (EV) for vehicle-to-grid (V2G)

Goals Federal Government Germany until 2030[1-3]

15 mio. Electric vehicles

215 GW PV systems

6 mio. Heat pumps

Renewable energy resources will dominate electricity generation soon. Half of photovoltaic systems are planned to be connected within the distribution grid. With heat pumps and electric vehicles, **additional consumers** are added to the **distribution grid**, which is not designed for large generators and consumers.

Smart control of local electricity consumption and feed-in into the grid can help distribute energy **efficiently** and **cheaply**. This avoids both overloading the distribution grid and high losses.

V2G services make use of available EV energy storage capacity. However, these services contribute to degradation possibly leading to a shorter battery life which is a drawback for EV owners.

Goal: Consider battery degradation costs in operational optimization of V2G

Optimal scheduling

Forecasts

- Weather
- Local power generation
- Energy demand
- EV availability
- EV state of charge boundaries

Short-term scheduling

Operational Optimization

Constraints
- Operating limits of the controlled components
- User requirements and comfort boundaries

Objective
- Minimal energy costs
- Minimal battery degradation costs
- Minimal grid charges

Measurement values

Setpoints

District model

Buildings

Local power generation

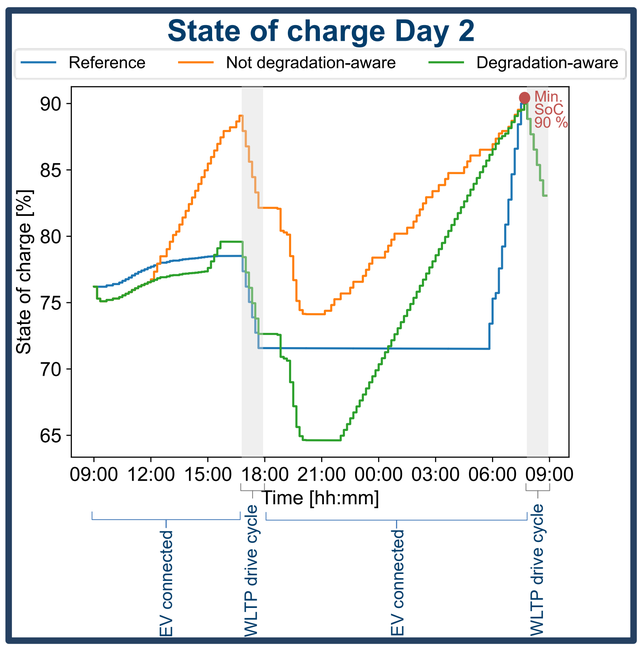
Battery storage

EV charging stations

Operational optimization of charging and discharging of EVs can be used for cost minimization and services for the distribution grid.

Case Study Peak Shaving

- 3 typical load days
- 4 person family household
- 2 kW_p PV system
- charging station for Nissan Leaf (62 kWh)



Day-Ahead scheduling

Objective Mixed-Inter Linear Program

$$\min \sum_{t \in T} \underbrace{p_t^{demand} \cdot c_t^{electricity}}_{\text{Electricity costs}} + \underbrace{c_t^{batt}}_{\text{Degradation costs [4]}} + \underbrace{c^{grid\ charge}}_{\text{Grid charge costs}}$$

$$c_t^{batt} = cycles_t \cdot \frac{c^{batt,invest}}{cycles^{max}} + c^{cal}(SOC_t)$$

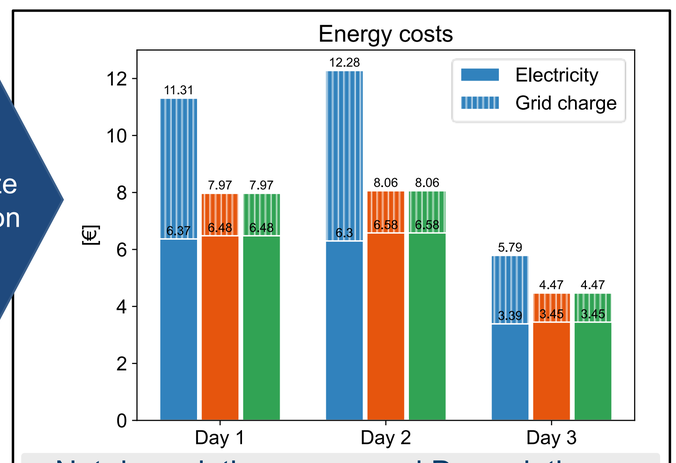
MILP models with variation in objective function and constraints:

Reference: Not V2G-enabled, not degradation-aware

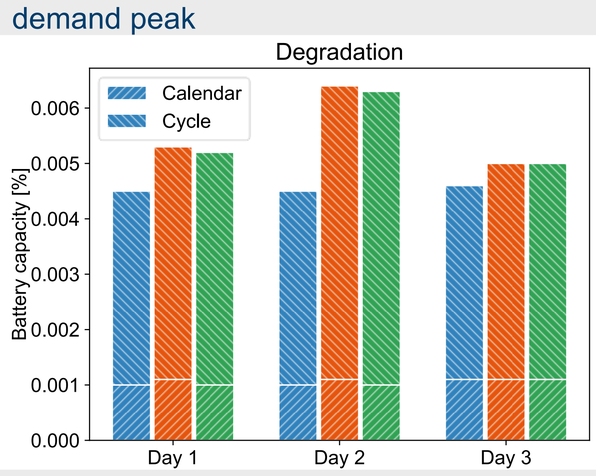
Not degradation-aware: V2G-enabled, not degradation-aware

Degradation-aware: V2G-enabled, degradation-aware

Optimize operation



Not degradation-aware and Degradation aware MILP achieve a decrease of the demand peak



Degradation-awareness can reduce the modeled degradation

Both V2G-enabled models increase the amount of energy taken from the electrical grid. However, they can achieve lower total energy costs by reducing grid charge based on daily peak power.
Degradation-aware model leads to operation in lower states of charge compared to the other models.

[1]: Press and Information Office of the Federal Government, https://www.bundesregierung.de/breg-de/themen/klimaschutz/eenergie-und-mobilitaet/faq-umweltbonus-1993830, accessed 04.04.2023
[2]: Federal Ministry for Economic Affairs and Climate Action, Überblickspapier Osterpaket, version 04/2022
[3]: Federal Ministry for Economic Affairs and Climate Action, Gemeinsame Absichtserklärung - Mehr Tempo bei der Transformation der Wärmeversorgung: Wir brauchen schneller mehr Wärmepumpen, 29.06.2022
[4]: J. Schmalstieg, S. Käbitz, M. Ecker, D. U. Sauer, A holistic aging model for Li(NiMnCo)O2 based 18650 lithium-ion batteries, Journal of Power Sources, 2014, https://doi.org/10.1016/j.jpowsour.2014.02.012.

Acknowledgement: The author gratefully acknowledges the financial support of LLEC::VxG by the German Federal Ministry of Education and Research (BMBF) under grant no. 03SF0628.

Bundesministerium für Bildung und Forschung