Center for Sustainable
Future Mobility (CSFM)

RailPower
Power and Energy for the future railways

Michael Nold[1], Georgia Pierrou[2], Robert Strietzel[3], Roland Schäfer[3], Pascal Bühlmann[3], Markus Zimmermann[3], Francesco Corman[1], Gabriela Hug[2]
[1]Institute for Transport Planning and Systems, ETH Zürich; [2]Power Systems Laboratory, ETH Zürich; [3]SBB CFF FFS

1 Introduction

The electricity consumption of the transportation sector is expected to rise. This results primarily from the electrification of private cars and secondarily from an increasing number of passenger and freight in public transport. The RailPower project aims to provide:

- a comprehensive view on the electric energy needed by the railway
- a coordination of local renewable generation with the optimal charging of Electric Vehicles (EVs) at the train station

2 Methods

- Modeling the Electric Train Demand – Working Packages (WP) 1-3

→ WP1: Simulate a complete network with several hundred trains.

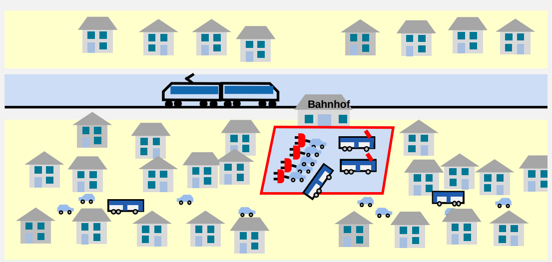
→ WP2: Include probabilistic effects (delays, driving style, weight, etc.).

→ WP3: Future influences and scenarios are taken into account.

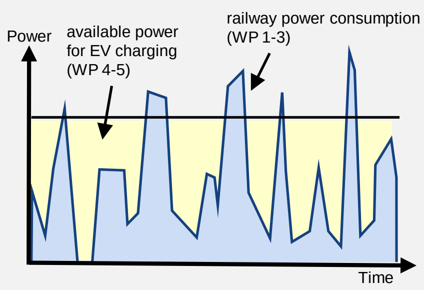
- Designing the Electric Infrastructure – Working Packages (WP) 4-5

→ WP4: Design AC/DC connections connecting PV and chargers to the 16.7Hz railway grid

→ WP5: Coordination of EV charging with PV output, train demand



Connection of the 16.7Hz railway grid with the inner-city network.



Railway power consumption and the available EV charging power.

3 Material

- **Modeling the Electric Train Demand:** A simulation has been developed. This tool is designed for high parallelization. It simulates single sections, which contain several hundred trains and can be merged. Measurement data are used to calibrate the simulated power consumption. The probabilistic effects of the rail operation are determined based on real operation data.
- **Designing the Electric Infrastructure:** Stochastic Energy Management (EMS) for Optimal EV Charging

$$\min \sum_{s} \sum_{t} \pi_s \left(P^{grid}_{t,s} \lambda^{buy}_t - P^{sell}_{t,s} \lambda^{sell}_{t,}\right) \Delta T_t$$

Subject to:

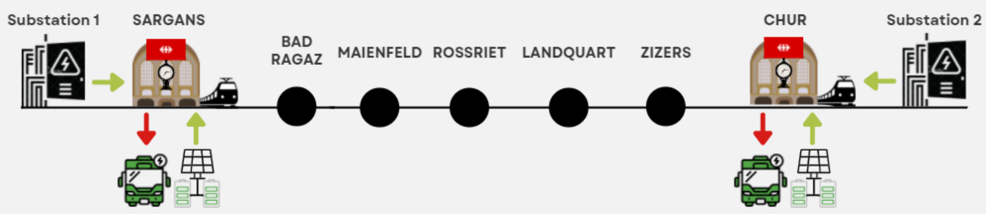
→ Power Balance: $P^{grid}_{t,s} + P^{PV}_{t,s} + P^{RBE}_t = P^{train}_t + P^{EV}_{t,s} + P^{sell}_{t,s}$

→ Power Exchange limits: $\max P^{grid}_{t,s}$, $\max P^{sell}_{t,s}$

→ Peak Load Reduction (PLR): $P^{PLR}_{t,s} \leq P^{EV,ref}_t - P^{EV}_{t,s}$

4 Results and discussion

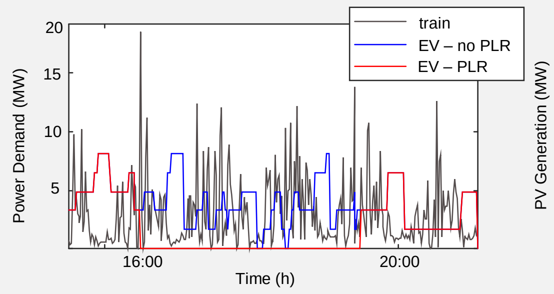
Case Study: Route from **Sargans (SA)** to **Chur (CH), Switzerland**



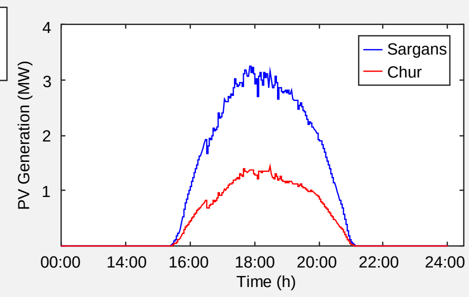
Simulation of a complete network with several hundred trains and considering probabilistic effects.

EMS Results:

Up to **~14% cost savings** in terms of daily operating cost are expected, thanks to the intelligent management of PV and EV charging and PLR.



The power consumption profile when PLR holds (16:00-19:00).



Power generated by PVs at the train stations.

5 Conclusion and expected impact

- A forecast of the railway network power consumption in short- and long-term level, based on different uncertainties for:

→ Supporting dimensioning of a cost and resources efficient traction power network

→ Providing the energy consumption for optimal charging

- An EMS algorithm of a Smart Railway Station for Optimal EV charging is proposed:

→ PLR is activated to avoid system stress caused by EV charging during train rush hours

→ Daily operating cost is minimized

→ PV uncertainty is incorporated in the scenarios considered

References

1. Corman, F; Nold, M (2022) ÖV der Zukunft: Überall, jederzeit, nahtlos und komfortabel. Mobilität der Zukunft (VHS Ringvorlesungen 2022).
2. M. Brenna, F. Foiadelli and H. J. Kaleybar, "The Evolution of Railway Power Supply Systems Toward Smart Microgrids: The concept of the energy hub and integration of distributed energy resources," in IEEE Electrification Magazine, vol. 8, no. 1, pp. 12-23, 2020.
3. Şengör et al., "Energy Management of a Smart Railway Station Considering Regenerative Braking and Stochastic Behaviour of ESS and PV Generation," in IEEE Trans. Sustainable Energy, vol. 9, no. 3, 2018.

Partner: