Dimensioning of battery storage as temporary equipment during grid reinforcement caused by electric vehicles

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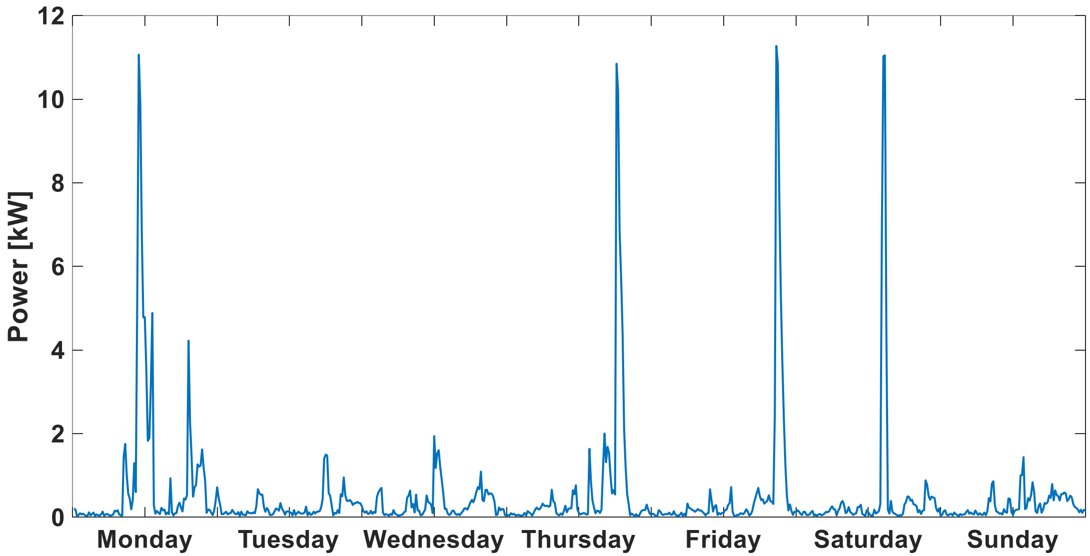
Influence of EV charging on distribution grids

- EV charging stresses power grids significantly
  - Especially low-voltage grids are concerned
  - High simultanities in charging processes



- The local and temporal distribution of EVs is difficult to predict

→ Problems can not be foreseen

Influence of EV charging on distribution grids

- EV owner want to charge their car immediately after the purchase

- Distribution system officer should be informed when charging infrastructure is installed
- Grid expansion (3 – 6 months duration) will be necessary in several distribution grids

➡ A stopgap measure has to be found to enable EV charging until grid expansion is completed

➡ Battery storage is one possibility

Project „E-Mobility-Allee“

- Netze BW GmbH (German distribution system operator) tests the influence of EV charging on distribution grids in a existing street
- 10 households that are connected to the same feeder line are equipped with an EV
- Project period: May 2018 - March 2019
- Project partner: Netze BW GmbH
  Karlsruhe Institute of Technology
  RWTH Aachen
  TU Dresden

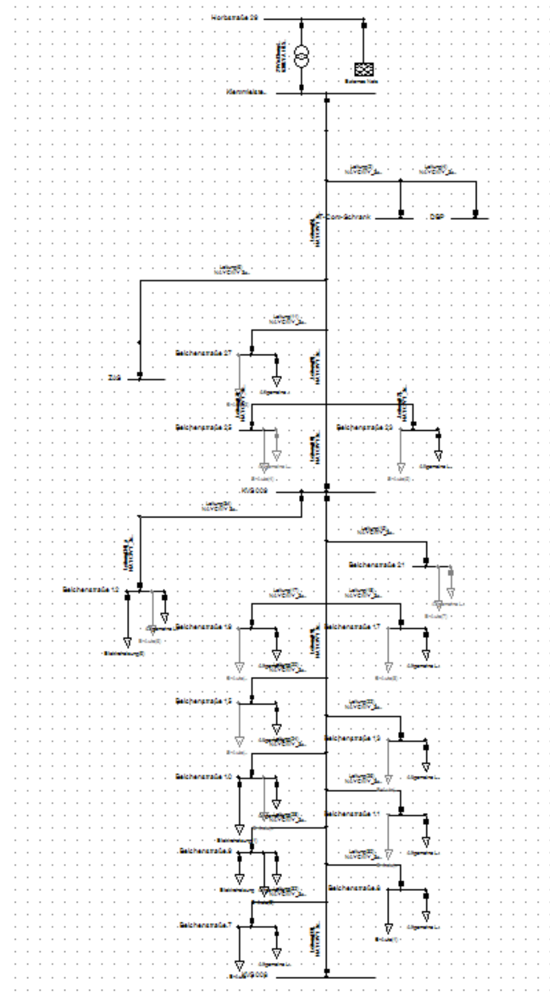
Project „E-Mobility-Allee“

- The following topics are in the focus of the project
  - User acceptance
  - User behaviour
  - Power quality measurements
    - Voltage limits
    - Harmonics
    - Voltage unbalance
  - Charging management
    - Time-based approaches
    - Measurement-based approaches
  - Battery storage
    - One central storage
    - Several decentral storages

Grid data

- Project area is a 400V low-voltage grid in a suburban area
- Different population structure
- Consists of 14 houses
- In total 15 similar low-voltage grids are connected via 630 kVA transformer to the MV

$$S_{\mathrm{tr,\,max}} = \frac{630\ kVA}{15 * 0.7} = 60\ kVA$$

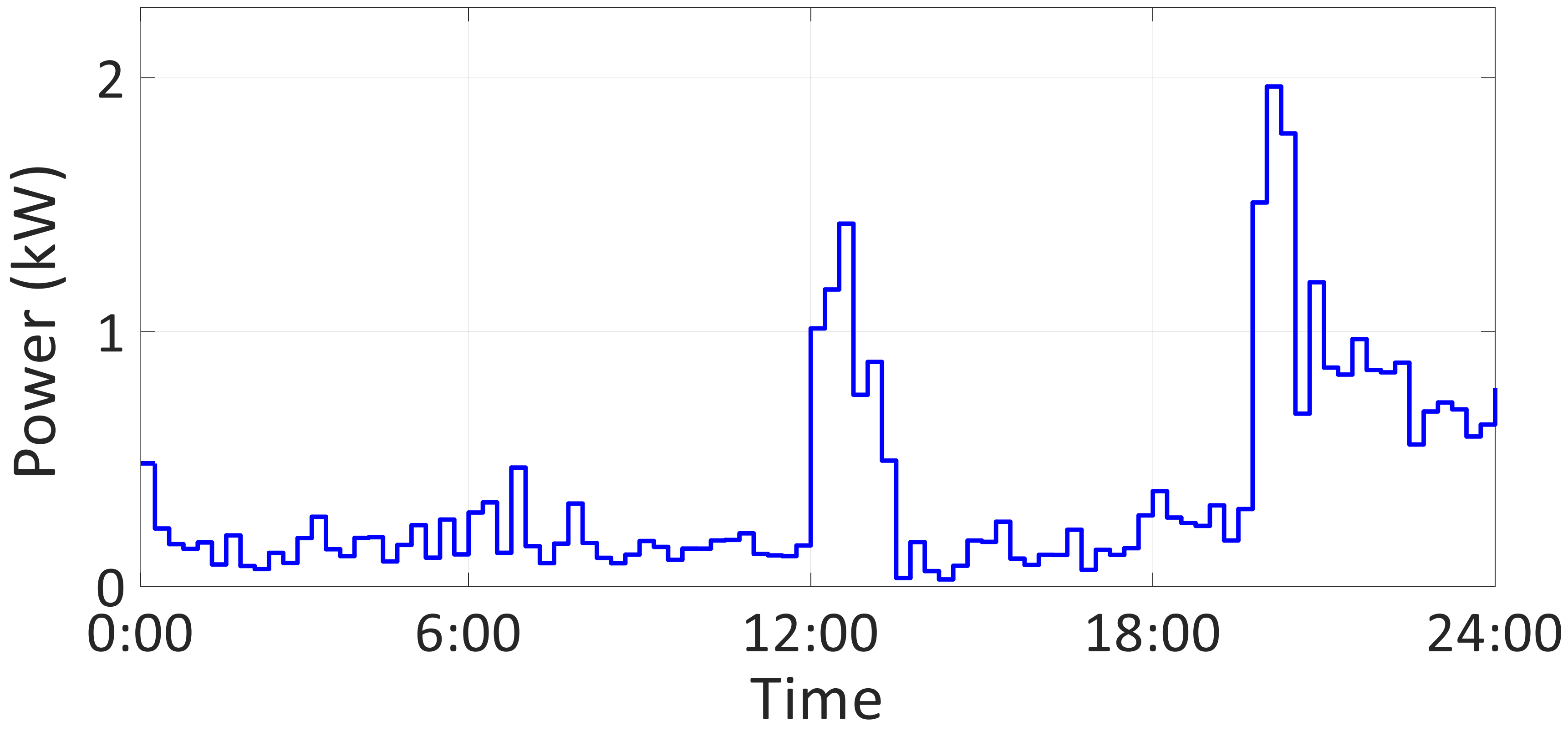


Simulation framework

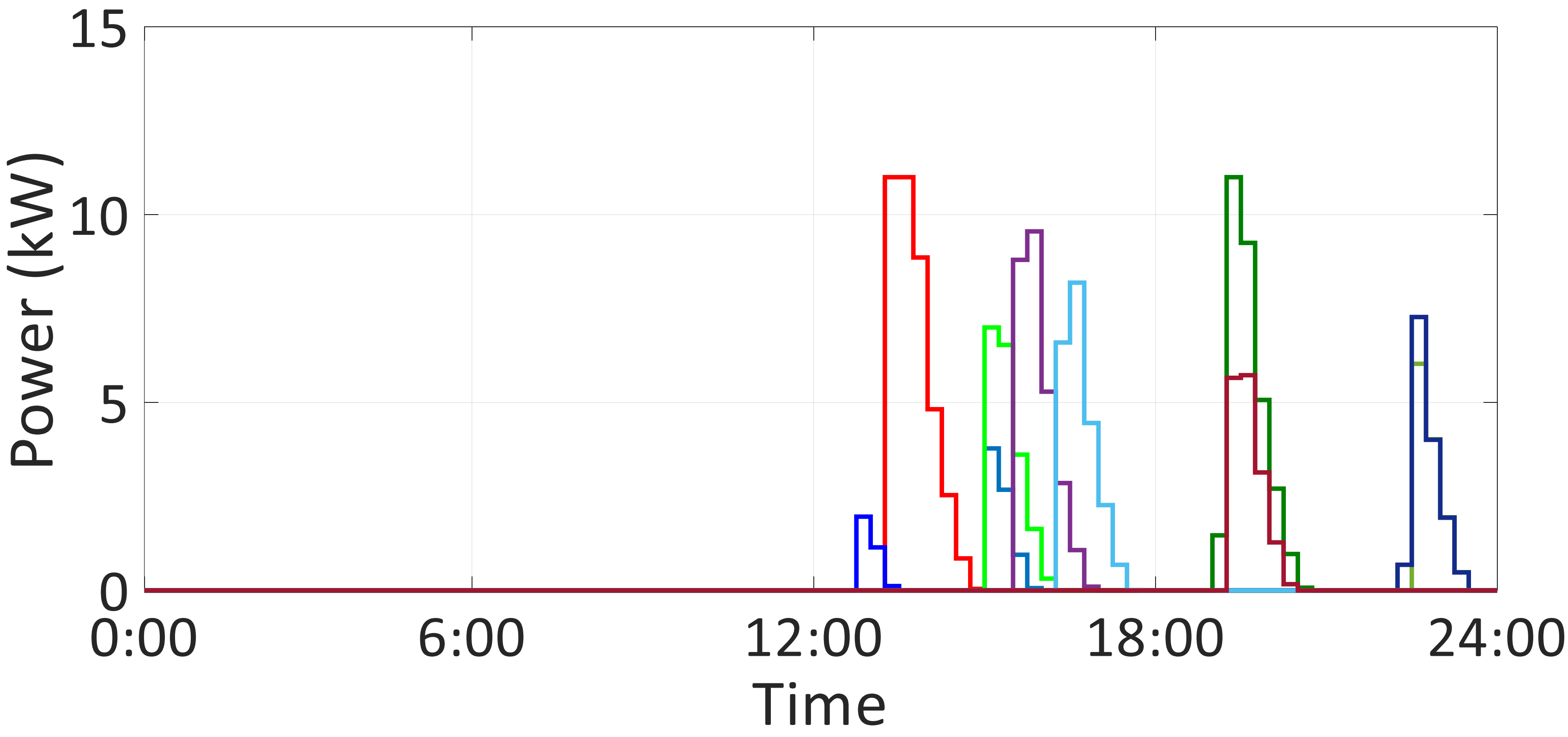
- Simulations are performed over one year to take seasonal effects into account
- A receding horizon with an intervall of one day and a horizon of two days is used
- Time series data with a resolution of 15 min are used

- Input
  - Profiles for EV charging
    - Different charging profiles depending on the weekday
  - Profiles for the energy consumption
  - Profiles for Electric heating
    - Electric heating is used depending on the season
- The input profiles are chosen randomly for each day

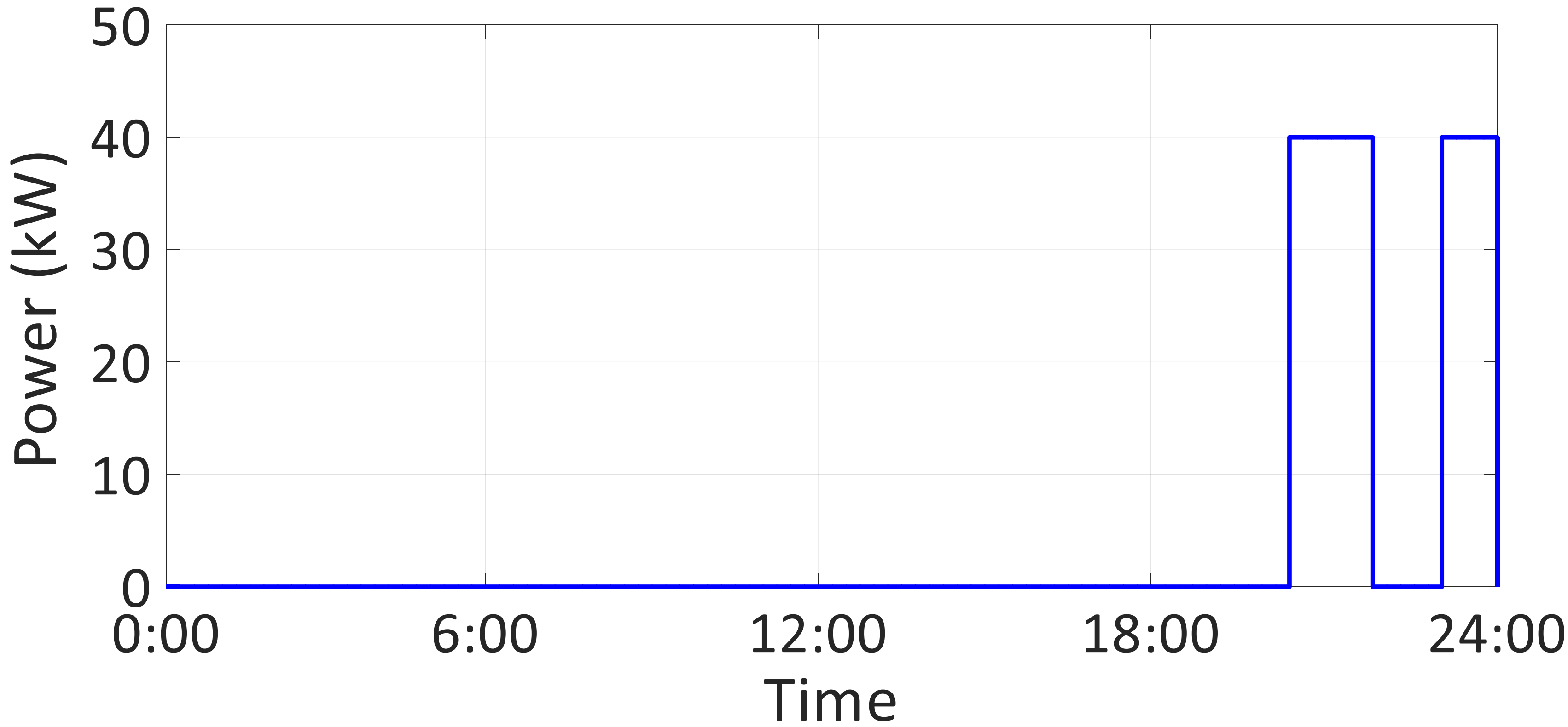
Input profiles: Energy consumption



Input profiles: EV charging



Input profiles: Electric heating



Grid operation limits

Voltage limits

- The standard EN 50160 defines that the voltage has to be within +/- 10 % of the nominal voltage at a household
- For the low-voltage grid the maximum allowed voltage drop is assumed to be 5 % in this presentation

Overloading of equipment

- Equipment (lines, transformers, etc.) may not be overloaded

Optimal power flow algorithm

- A dynamic optimal power flow algorithm is used to dimension the battery storage

$$E_s^t = E_s^{(t-1)} + \Delta E_s^t$$

$$\Delta E_s^t = (\eta_C P_{SC}^t - \eta_D^{-1} P_{SD}^t)\, \Delta t$$

- Two generators are used to model import and export from the MV grid

$$0 \leq P_{G1}^t \leq S_{tr,max}$$

$$- S_{tr,max} \leq P_{G2}^t \leq 0$$

- Objective function

$$F^t = (\, c_{exp} P_{G2}^t + c_{imp} P_{G1}^t\,)\, \Delta t$$

$$c_{imp} > c_{exp}$$

$$F = \sum F^t$$

Optimal power flow algorithm

- Constraints:

$$(\underline{S}_{br}{}^{t})^2 \leq (\underline{S}_{br,max})^2$$

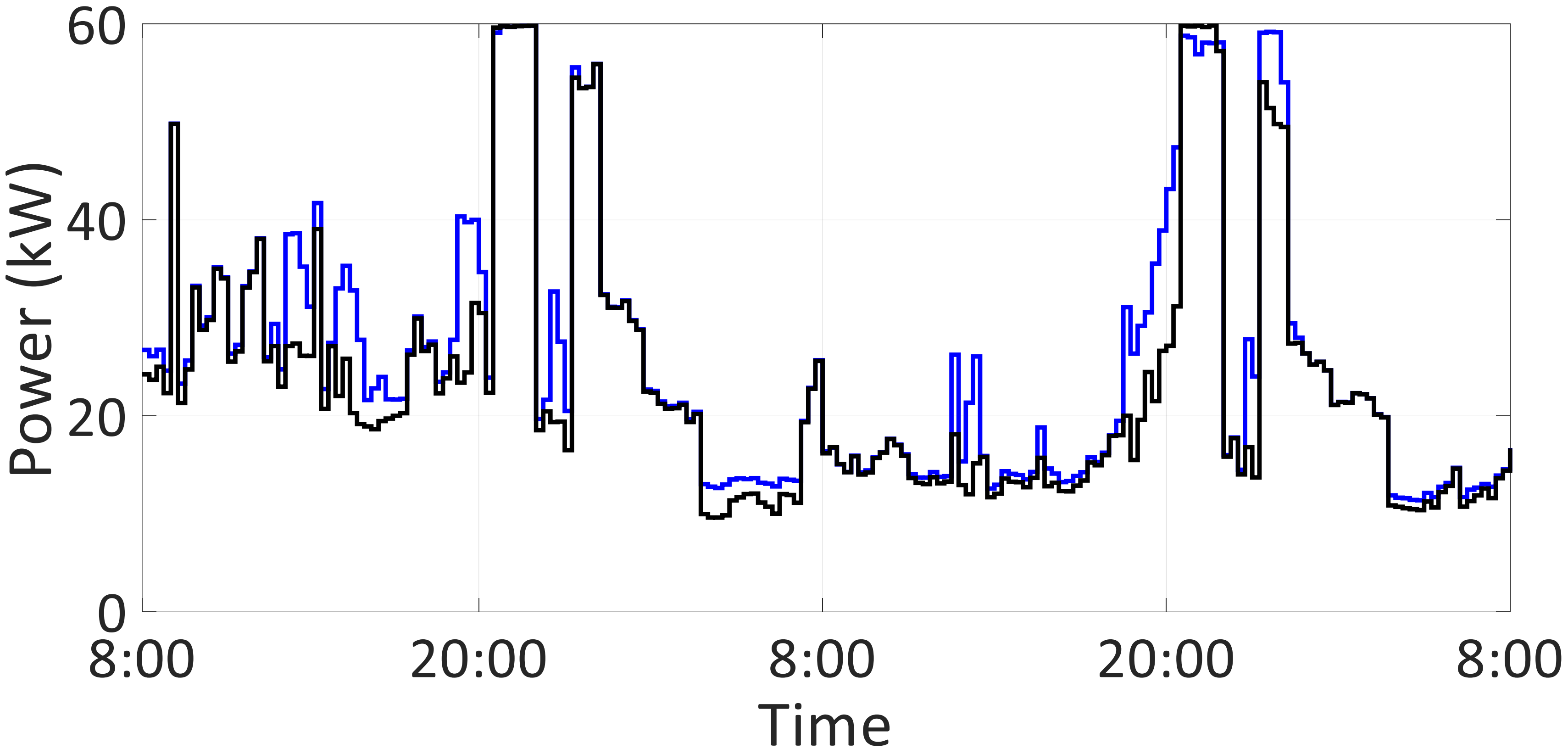
$$(\underline{S}_{tr}{}^{t})^2 \leq (\underline{S}_{tr,max})^2$$

$$(V_{min})^2 \leq (e^t)^2 + (f^t)^2 \leq (V_{max})^2 \text{ with } \underline{V} = e + jf$$

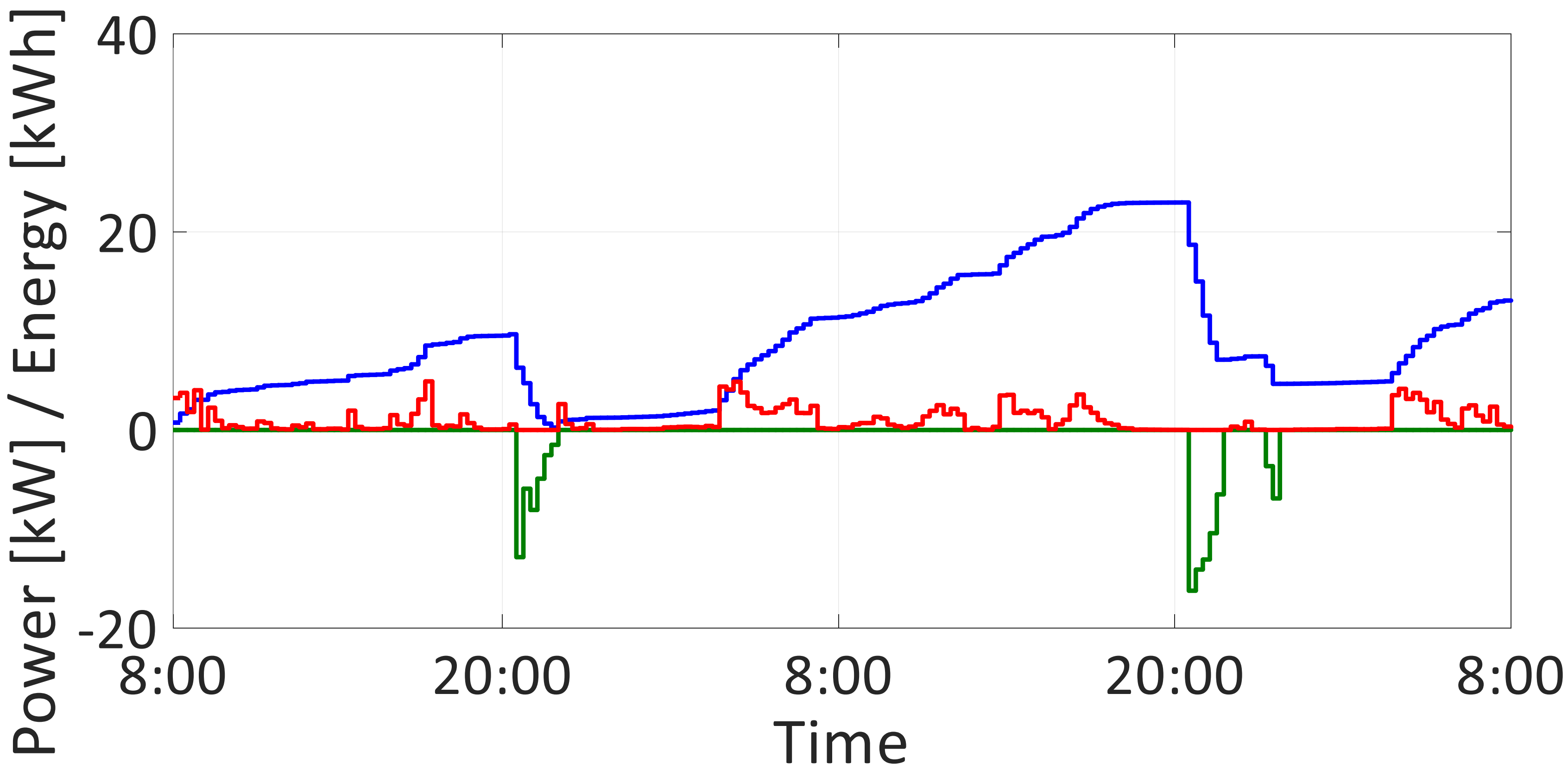
- $E_s{}^t$, $P_{sc}{}^t$, $P_{sd}{}^t$ not constrained or part of the objective function

- Solver: MIPS (MATPOWER Interior Point Solver)

Simulation results



Simulation results



Results: Without EV charging

	Minimum	Average	Maximum
Minimum voltage	0.9754 pu	0.9766 pu	0.9778 pu
Maximum line utilization	47.9 %	64.6 %	80.9 %
Maximum transformer utilization	100.0 %	100.0 %	100.0 %
Maximum stored energy	27.0 kWh	33.2 kWh	38.2 kWh
Maximum charging power	6.6 kW	7.3 kW	8.0 kW
Maximum discharging power	39.1 kW	49.3 kW	60.2 kW

- Results of ten simulations with a horizon of one year

Results: 5 EVs with 11 kW charging power

	Minimum	Average	Maximum
Minimum voltage	0.9754 pu	0.9764 pu	0.9774 pu
Maximum line utilization	47.9 %	65.0 %	80.9 %
Maximum transformer utilization	100.0 %	100.0 %	100.0 %
Maximum stored energy	37.0 kWh	43.9 kWh	54.8 kWh
Maximum charging power	7.5 kW	8.6 kW	9.3 kW
Maximum discharging power	45.3 kW	53.1 kW	61.6 kW

- Results of ten simulations with a horizon of one year

Results: 10 EVs with 11 kW charging power

	Minimum	Average	Maximum
Minimum voltage	0.9751 pu	0.9764 pu	0.9775 pu
Maximum line utilization	48.6 %	63.8 %	80.9 %
Maximum transformer utilization	100.0 %	100.0 %	100.0 %
Maximum stored energy	49.5 kWh	60.7 kWh	74.6 kWh
Maximum charging power	7.6 kW	10.3 kW	12.8 kW
Maximum discharging power	52.8 kW	67.6 kW	79.8 kW

- Results of ten simulations with a horizon of one year

Outlook

- Measurement data is used to improve input profiles
- First test phase for central battery storage started last week

- Methodology shall be used also for other grids in the future
- Modelling of the charging process has to be improved

- Control strategy for the battery storage

Thanks!