Karlsruhe Institute of Technology

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Determination of Simultaneity Factors in PEV Charging Processes

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Introduction

- One main challenge caused by the grid integration of electric vehicles (EV): Relatively high additional load and the resulting grid impacts.

- Simultaneity of charging processes and local network situation are key parameters.
  - The network load resulting from EV charging processes is dependent on two factors:
    1. The number of EV, their charging profiles and the simultaneity resulting from their charging behavior.
    2. The specific local situation in the respective distribution network.

Simultaneity Factors in PEV Charging Processes

- Simultaneity factor which describes the percentage of EV charging at the same day.

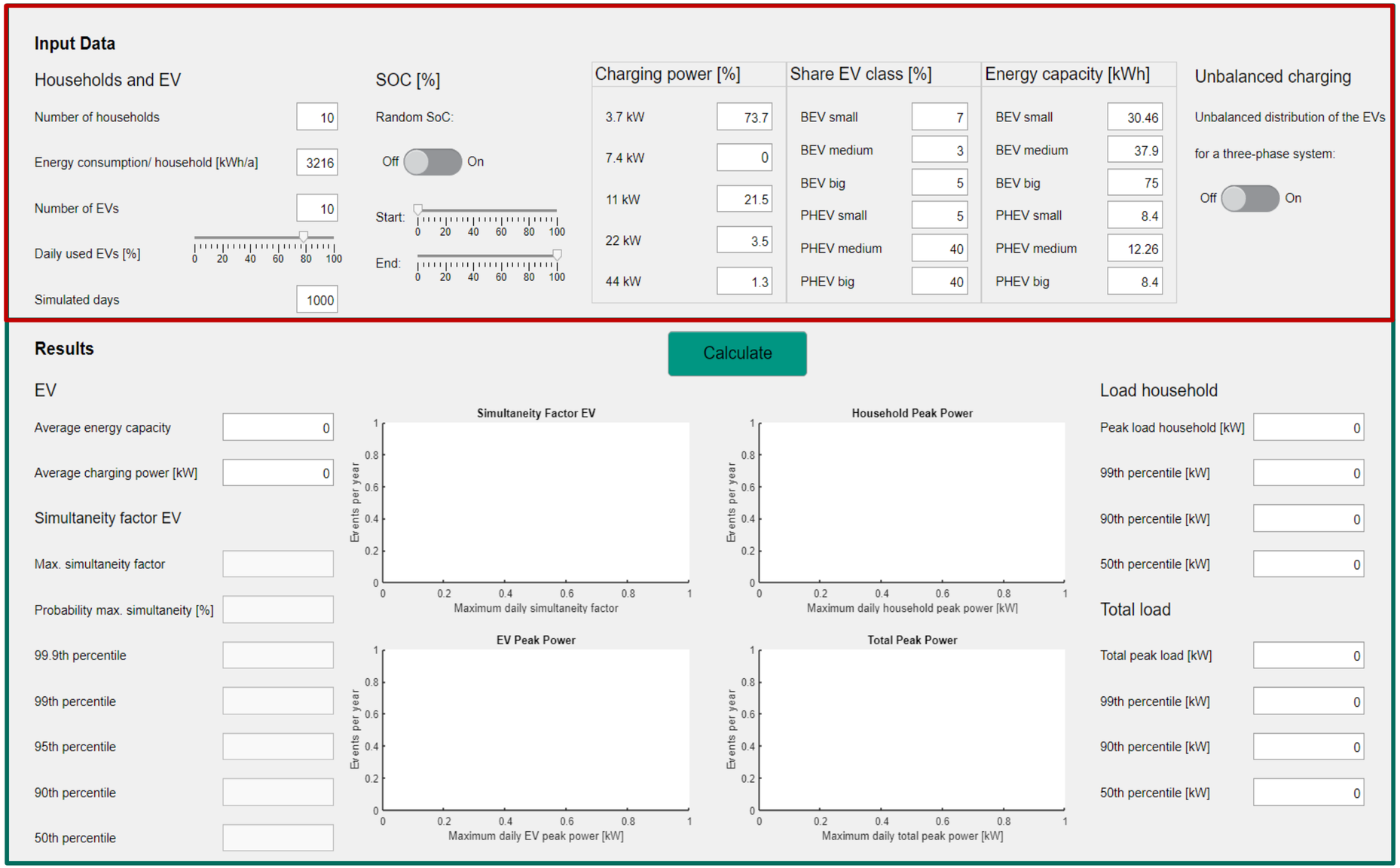
- Simultaneity factor of the charging processes taking place within one day.

- Development of a Tool which will be offered as an open-source Tool to download from a public website:

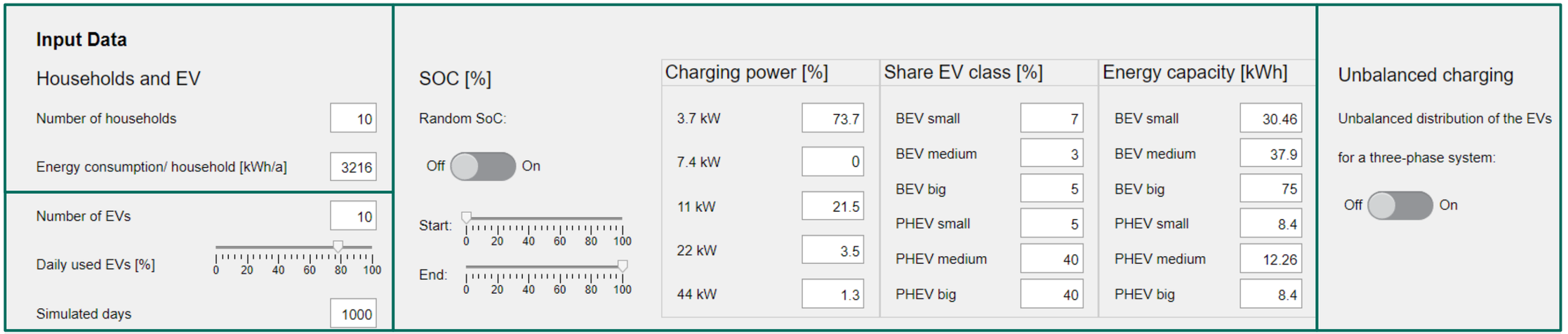
  https://doi.org/10.5281/zenodo.3364366

- Goals of the Tool:
  - Max. simultaneity factor for a given number of households.
  - Probability of max. simultaneity.
  - EV peakload, household peakload, total peakload.

Tool – User Interface



Input Data



- Household Data:
  - Number of households
  - Yearly energy consumption [kWh/a]
- EV Data I:
  - Number of EV
  - Daily used EV [%]
  - Simulated days
- EV Data II:
  - SoC: Random SoC limits vs. Individual SoC limits
  - Charging power distribution (3.7kW, 7.4kW, 11kW, 22kW, 44kW)
  - Share EV class (PHEV and BEV, small medium, big)
  - Energy capacity
- EV Data III:
  - Unbalanced charging

Calculations in the Tool

Daily simultaneity factor for EV	EV Peak power on a daily level	Household peak power on a daily level	Total peak power on a daily level

Sorting the results on a daily level for each of the simulated days to determine the maximum value, the distribution as well as some percentiles.

Max. simultaneity factor	EV peak power	Household peak power	Total peak power

Maximum simultaneity factor

Daily simultaneity factor for EV

Individual charging profiles

Number of vehicles per vehicle class i: $N_{EV,i} = N_{EV,total} * S_{EV,i}$	Arrival time $T_{Arrival}$	Charging duration/ Charging end time I. SOC_{Start} , SoC_{End} I. Randomly allocation II. Individual values II. Average energy capacity: $E_{EV,Avg.} = \sum_{i=1}^{6} E_{EV,i} * SEV_{,i}$ III. Charging energy: $E_{Charging} = (SoC_{End} – SoC_{Start}) * E_{EV,Avg.}$ IV. Charging duration: $T_{Charging} = E_{Charging} * T_{Char.,Avg.}$ V. Charging end time $T_{End} = T_{Arrival} + T_{Charging}$

→ **Collective load profiles** $N_{EV,Collective}$

→ **Number of maximum simult. charging EV** $N_{EV,Simul.}$

→ **Daily simultaneity factor** = $N_{EV,Simul.}/N_{EV,Total}$

Household peak power and total peak power

Household peak power on a daily level

Individual household profiles

Randomly chosen energy consumption profile for each household.

Scaled according to the average annual electricity consumption of households considered.

→ **Collective load profiles** $E_{Household,Collective}$

→ **Household peak power** $P_{Household,Day}$

Total peak power on a daily level

Collective Profile (EV + Household)

Collective EV profiles $E_{EV,Collective} = N_{EV,Collective} * P_{Char.,Avg.}$

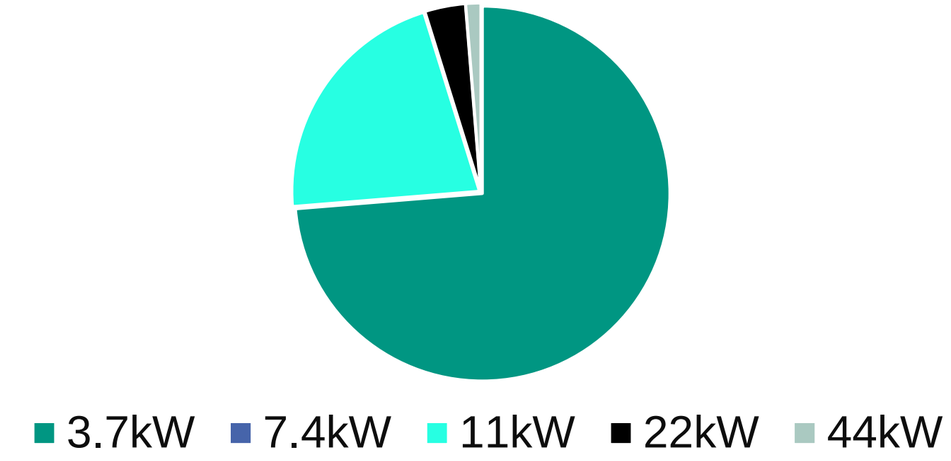
Collective household profiles $E_{Household,Collective}$

→ **Total peak power** $P_{Total,Day}$

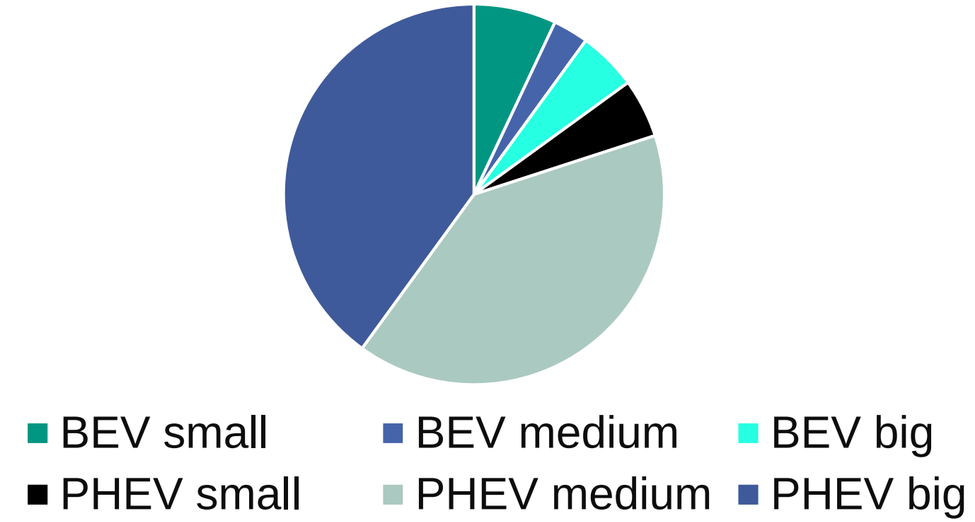
Case Study

- 10 households
  (yearly energy consumption: 3,216 kWh/a)
- 10 EV
- Probability that a car is charged on the selected day: 78%
- Simulated days: 1000
- SoC_{Start} = 0%, SoC_{End} = 100% (extrem scenario)
- Charging power distribution [%]
- Share EV class [%]

Charging power distribution [%]



Share EV class [%]



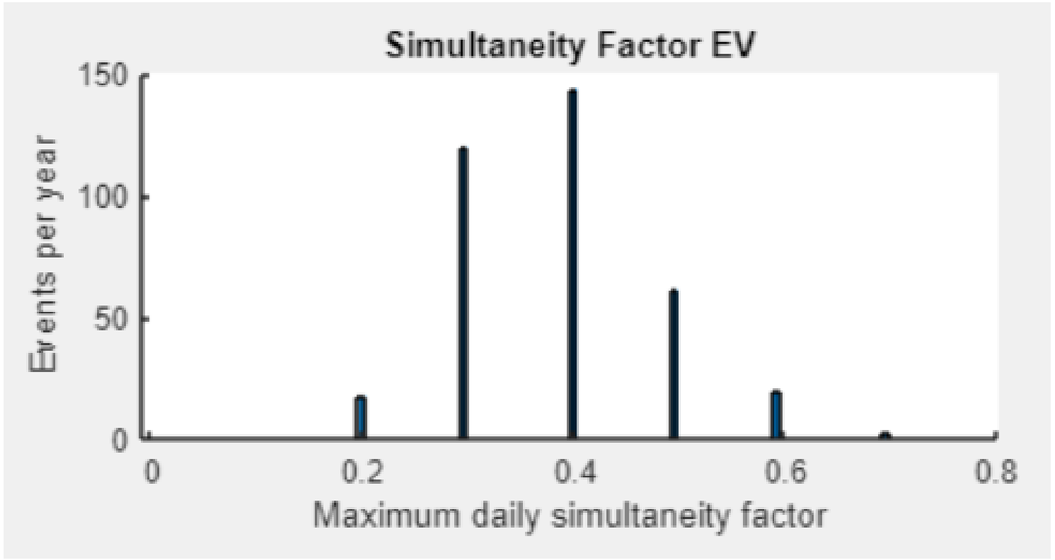
Case Study – Results I

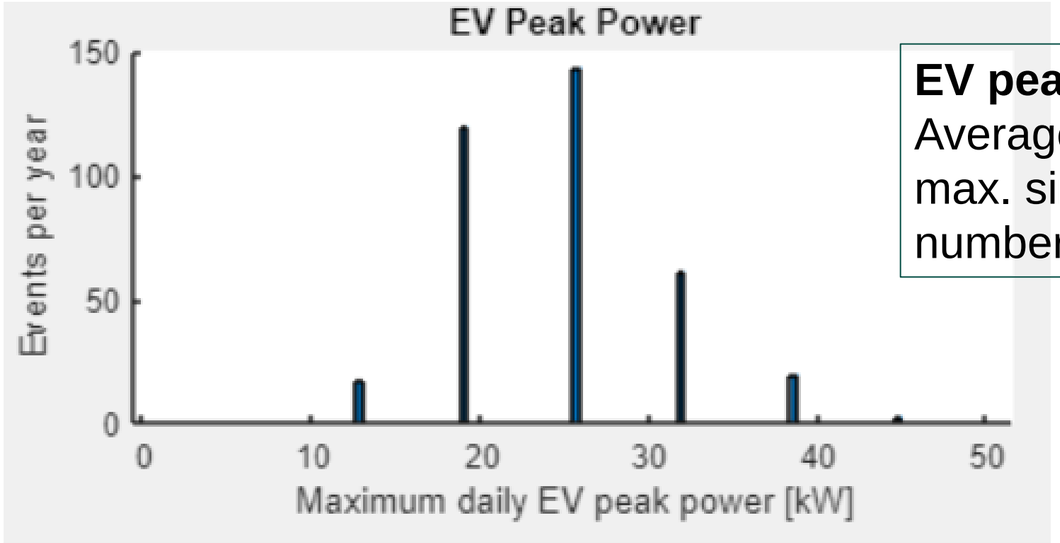
EV

Average energy capacity	15.7
Average charging power [kW]	6.434

Simultaneity factor EV

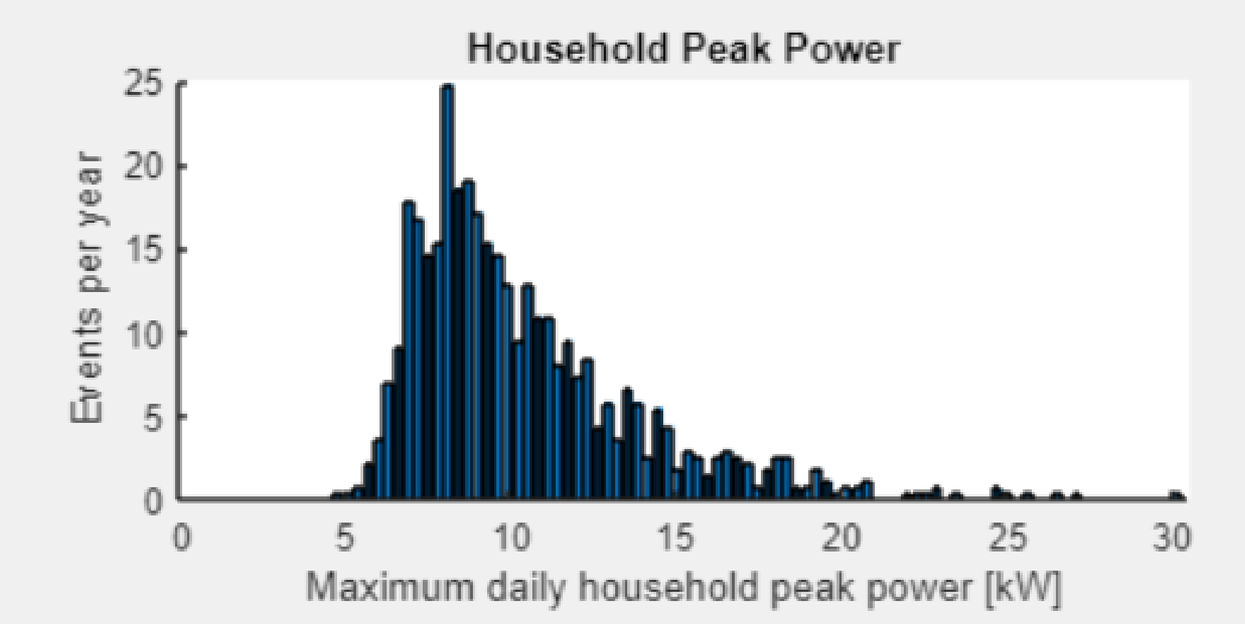
Max. simultaneity factor	0.8
Probability max. simultaneity [%	0.1
99.9th percentile	0.7
99th percentile	0.6
95th percentile	0.6
90th percentile	0.5
50th percentile	0.4

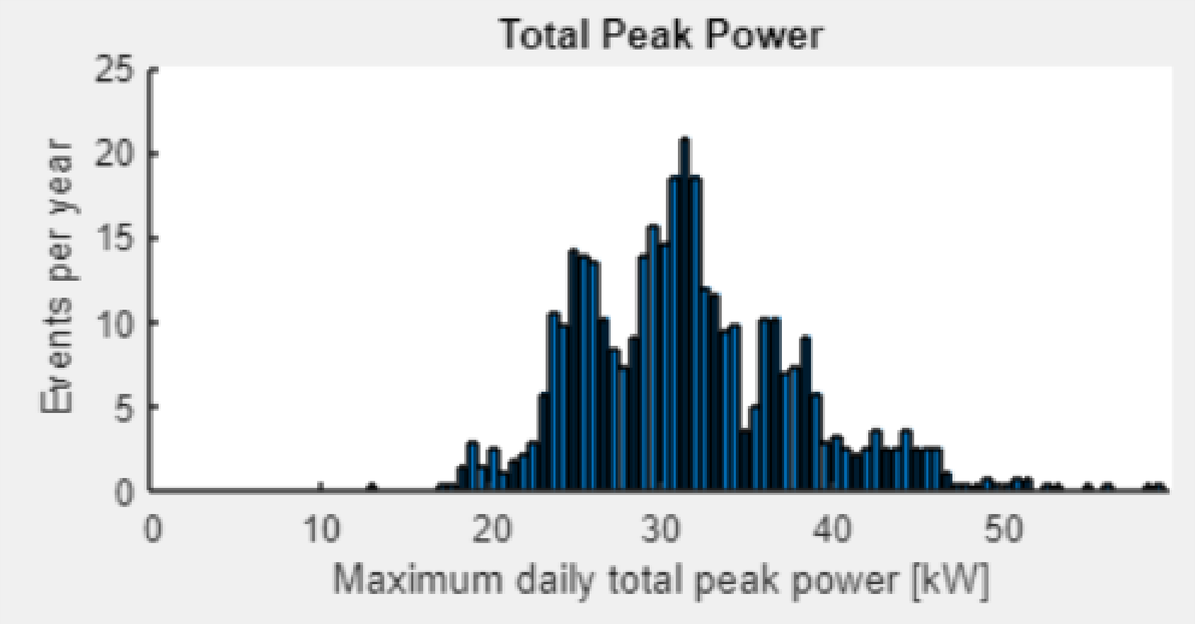




EV peakload =
Average charging power * max. simultaneity factor * number of EV = **51.44 kW**

Case Study – Results II





	Households	Total
Peakload [kW]	30.15	59.26
99th percentile [kW]	22.58	49.84
90th percentile [kW]	15.09	39.9
50th percentile [kW]	9.34	30.78

Case Study – Results III

- Specific simultaneities of household and charging processes are considered.

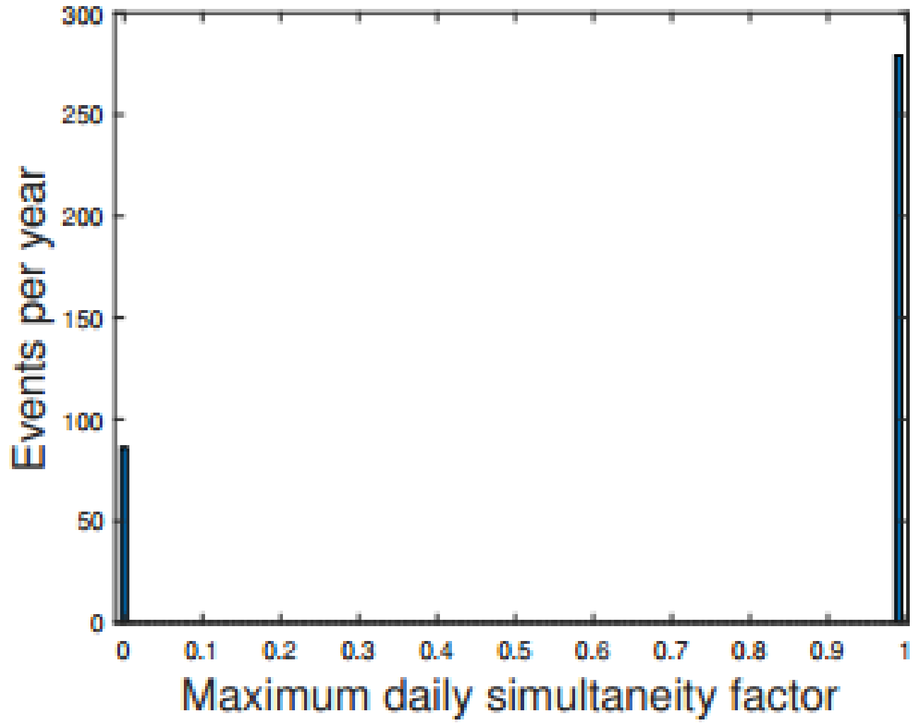
EV peak	Household peak	Total peak
51.44 kW	30.15 kW	59.26 kW

- Results are strongly dependent on underlying assumptions.

  → The following slides: Checking different assumptions.

Assumption I: Number of EV

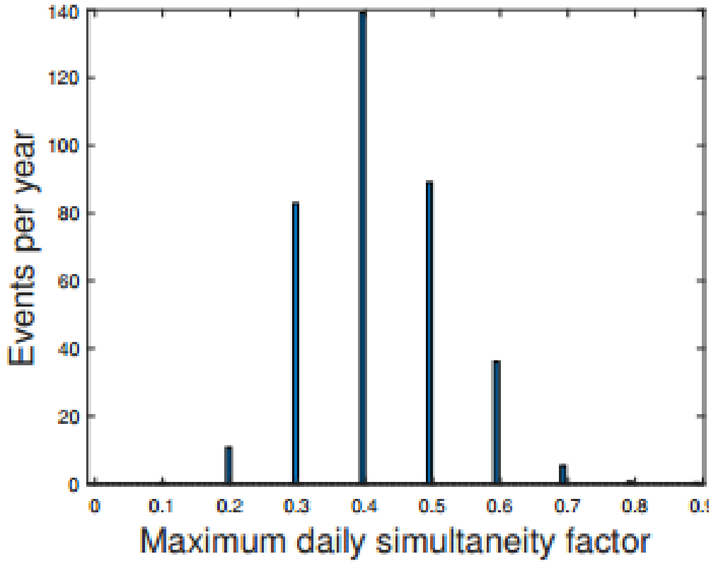
Number of EV	1	10	20
Max. simult. factor	1	0.8	0.6
Prob. max. simult. factor [%]	78	0.1	0.1
EV peakload [kW]	6.43	51.44	77.16
Total peakload [kW]	30.83	59.26	85.71



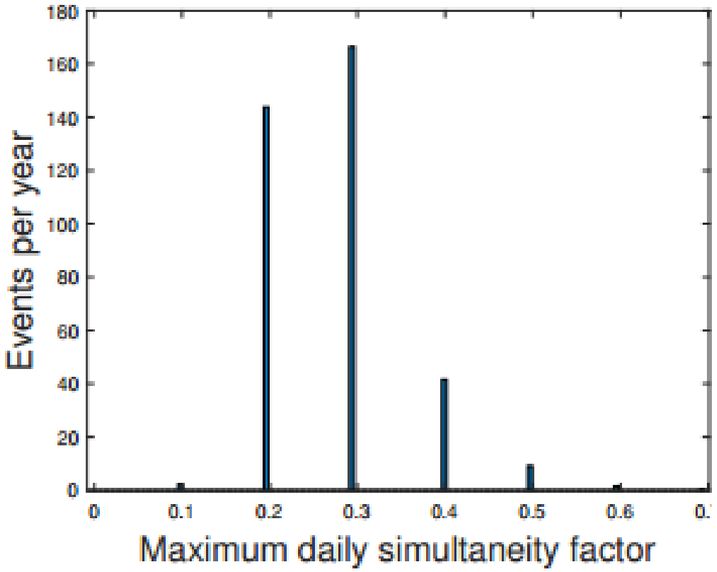
- The max. simultaneity factor and the corresponding probability decrease with an increasing number of EV.
- The EV peak load and total peak load increase with an increasing number of EV (simultaneity!).

Assumption II: Distribution of charging rates

Charging rate [kW] (100%)	3.7	11
Max. simult. factor	0.9	0.7
Prob. max. simult. factor [%]	0.1	0.1
EV peakload [kW]	33.30	77
Total peakload [kW]	40.38	82.28



Charging rate: 3.7 kW

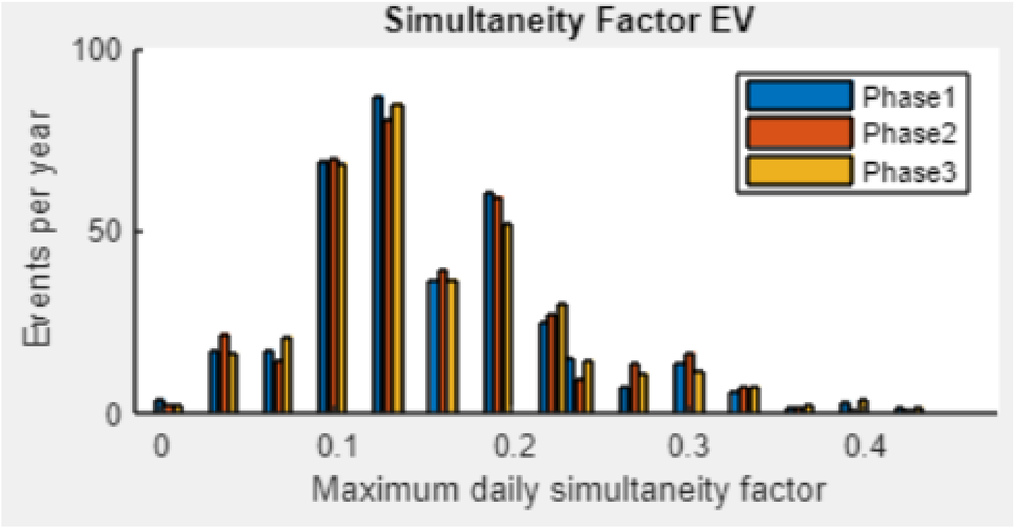


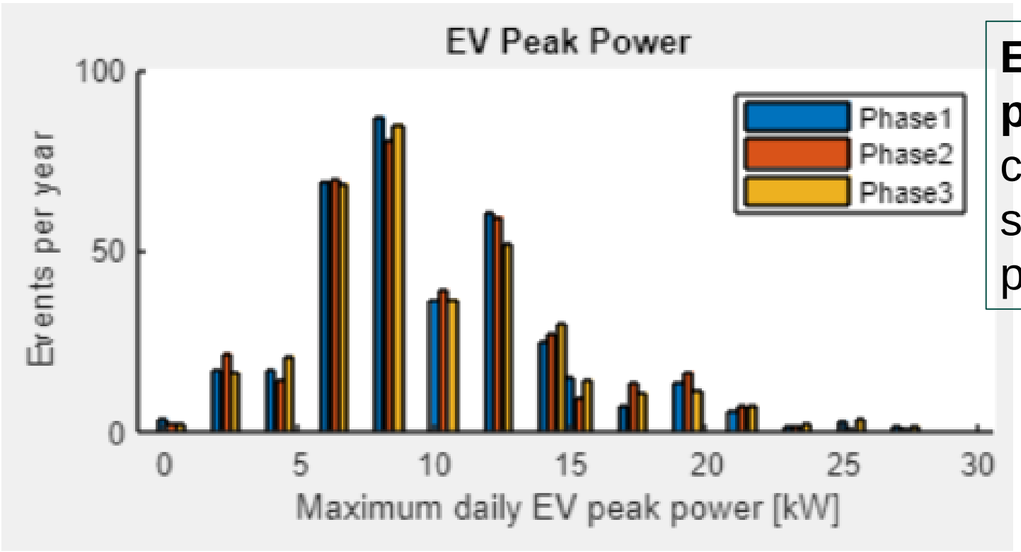
Charging rate: 11 kW

- The simultaneity decreases with an increasing charging rate (shorter charging duration).
- The EV load and total load increase with an increasing charging rate.

Additional Feature: Unbalanced Charging

EV		
Average energy capacity	15.7	
Average charging power [kW]	6.434	
Simultaneity factor EV	P1 /P2 /P3	
Max. simultaneity factor	0.47 /0.43 /0.43	
Probability max. simultaneity [%	0.1 /0.2 /0.2	
99.9th percentile	0.43 /0.43 /0.43	
99th percentile	0.4 /0.33 /0.4	
95th percentile	0.3 /0.3 /0.3	
90th percentile	0.23 /0.27 /0.27	
50th percentile	0.13 /0.13 /0.13	





EV peakload per phase = Average charging power * max. simultaneity factor per phase * number of EV

Comparison unbalanced vs. balanced charging

	Unbalanced	Balanced
Max. simult. factor	0.43/0.43/0.5	0.8
Prob. max. simult. factor [%]	0.1/0.1/0.1	0.1
99th percentile	0.43/0.4/0.47	0.6
90th percentile	0.23/0.27/0.23	0.5
50th percentile	0.13/0.13/0.13	0.4

- The sum of the simultaneity factors of the individual phases exceeds the simultaneity of balanced charging.

Summary

- Simultaneity of charging processes plays a significant role in the analysis of network effects of EV.
- Due to time differences between EV peak loads and household peak loads, the total peak load is lower than the sum of the individual peaks.
- Unbalanced vs. balanced charging.
- Results are strongly dependent on assumed assumptions.

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Thank you!

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