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A Comparison of the Influence of Electric Vehicle Charging on Different Types of Low-Voltage Grids

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Contents

Introduction

- The research project IILSE is funded by the German Federal Ministry for Economic Affairs and Energy
- Institute of Industrial Production and Institute of Electric Energy Systems and High-Voltage Technology at Karlsruhe Institute of Technology

- What are the impacts on the grids caused by an increasing market penetration of EV depending on different regions?
- Are there substantial regional differences in distribution grid topologies which are relevant for EV charging?

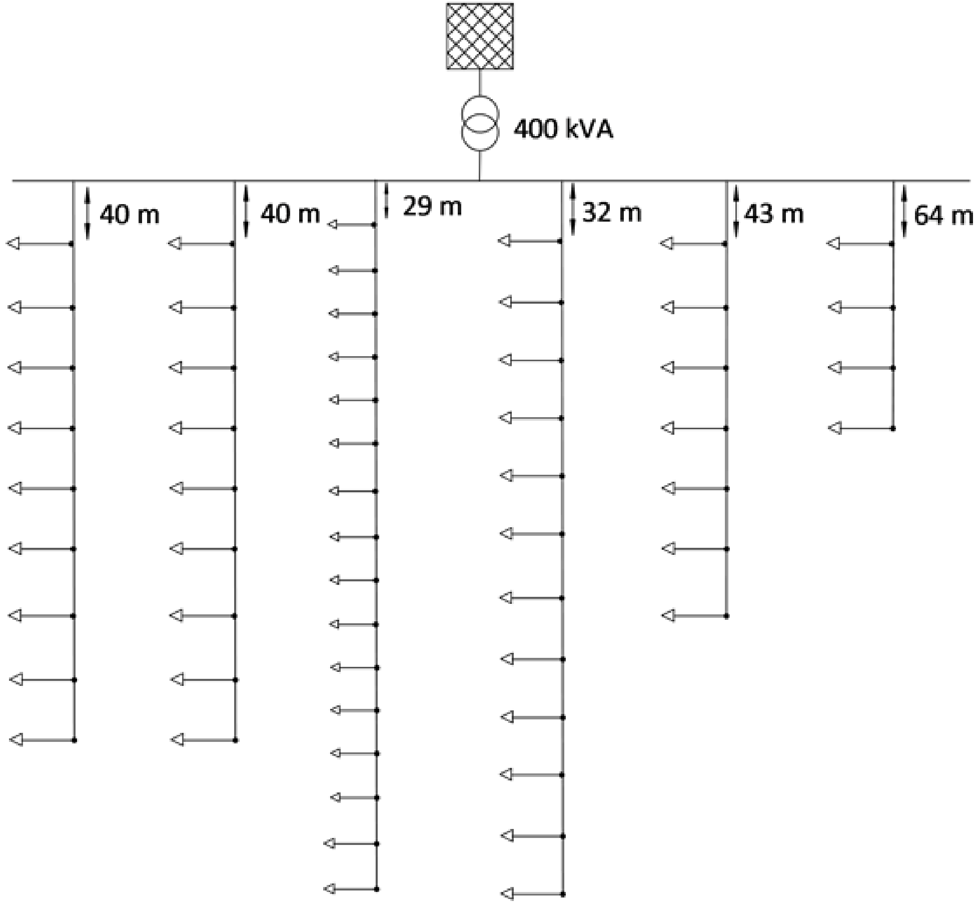
Limits for grid operation

- Standard EN 50160:2010/A1:2015 defines the valid regulations for grid operation in Germany
  - Maximum voltage deviation in the grid is +/- 10% of the nominal voltage
  - Maximum voltage drop in the low voltage grid is set to 5% of the nominal voltage
  - Nominal capacity of the equipment must not be exceeded (Limits of transformers and lines are taken into account in our simulations)

Low voltage grids

- Typical grids for different agglomerations
  - Suburban area
  - Rural area
  - Campestral area

- Penetration of 100 % corresponds to 1 EV per grid connection point



Energy consumption

- The high-load scenario is considered as extreme scenario for the low voltage grid as EV are an additional load

⇒ If the limits are fulfilled in the high-load case, they are fulfilled all the time

⇒ It is sufficient to validate the given limits for the high-load time

- The contribution of each load P(n) to the total high-load is calculated as follows

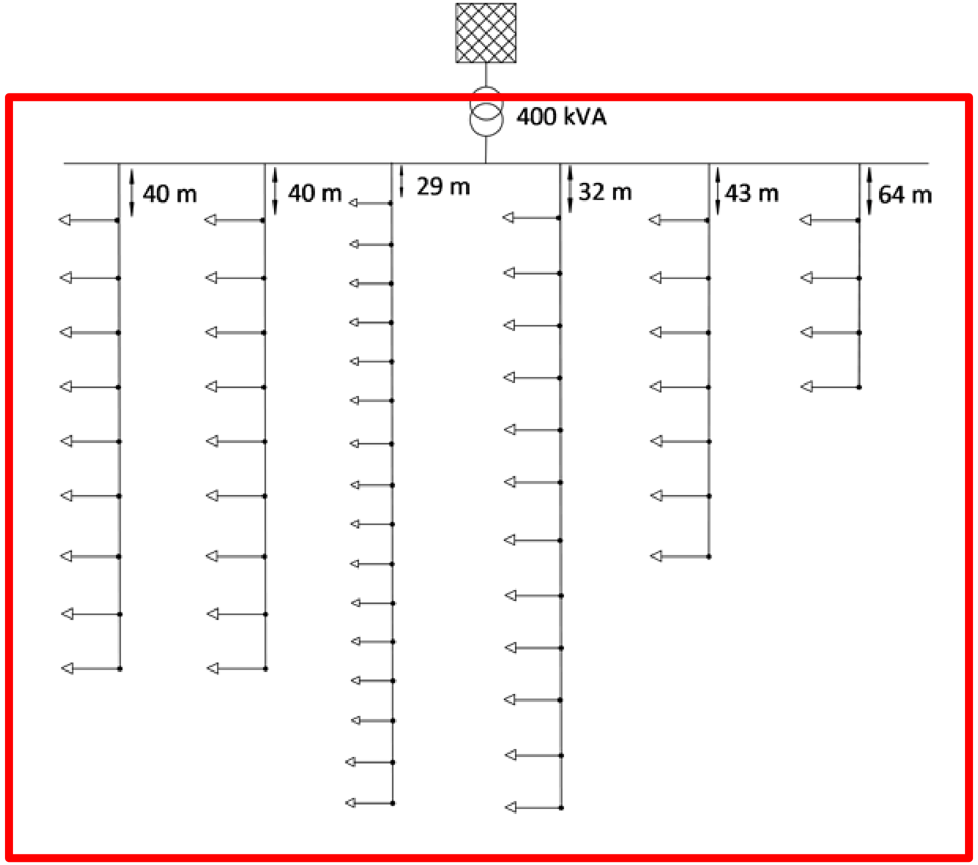
$$P(n) = c(n) \times P_{Peak}$$

P_{peak}: Individual peak power

c(n): Concurrency factor (depends on the number of involved households n)

Concurrency factor

- The number of involved grid customers n depends on the limit for grid operation, which has to be verified
  - To calculate the utilization of the transformer, the number of involved grid customers n is equal to all grid customers in the regarded grid
  - To calculate the utilization of the lines and cables and the voltages, the number of involved grid customers n is the number of grid customers that are connected to the same feeder



Concurrency factor

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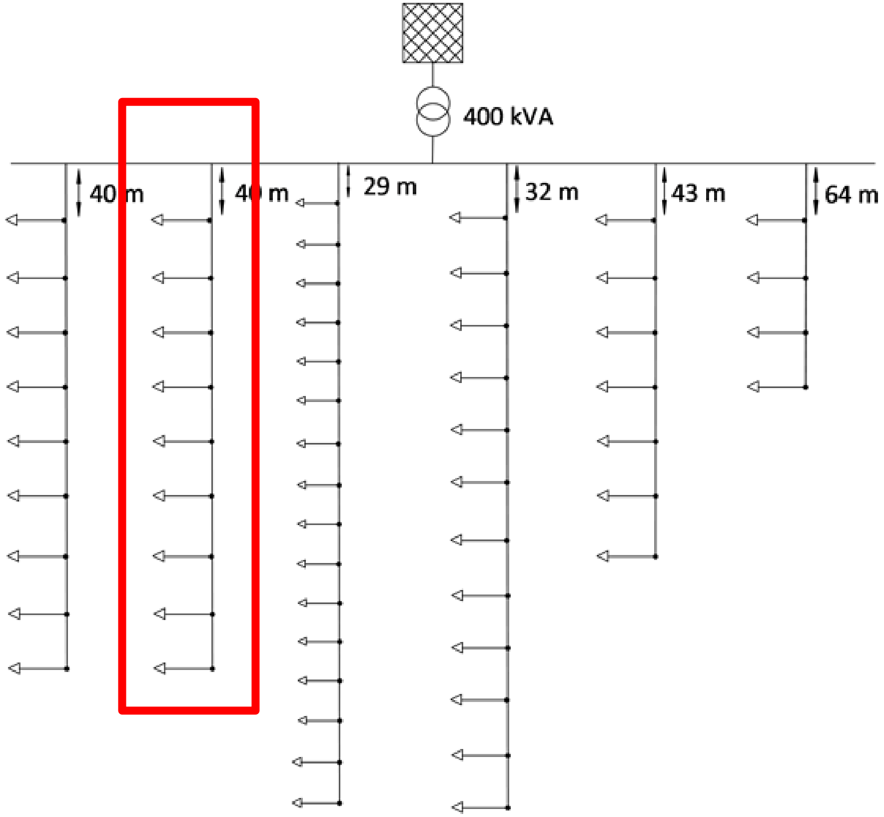


Concurrency factor for EV charging

1. Charging profile for each EV is created
   - Charging power (7.06 kW), energy capacity (15.7 kWh) and energy consumption (14.1 kWh/100 km)
   - Arrival time (randomly assigned)
   - Stored energy before charging (see Scenarios)
   - End time of the charging process is calculated
2. All individual charging profiles are added to the resulting profile P_{Res}
3. Maximum daily concurrency factor is determined as

$$\mathrm{c(n)} = \frac{\max(P_{Res})}{n * 7.06\ kW}$$

Scenarios

- Three different scenarios are used to describe the SoC before the charging process starts
  - Scenario 1: SoC randomly assigned
  - Scenario 2: SoC = 0%
  - Scenario 3: 40 km daily driving distance

Concurrency factor for EV charging

1. The maximum daily concurrency factor is calculated
2. Out of 365 maximum daily concurrency factors the maximum yearly concurrency factor is determined
3. As input data is assigned randomly, the maximum yearly concurrency factor is subject to statistical deviations
4. Therefore, the average of 1000 maximum yearly concurrency factors is used in the simulations

Concurrency factor for households

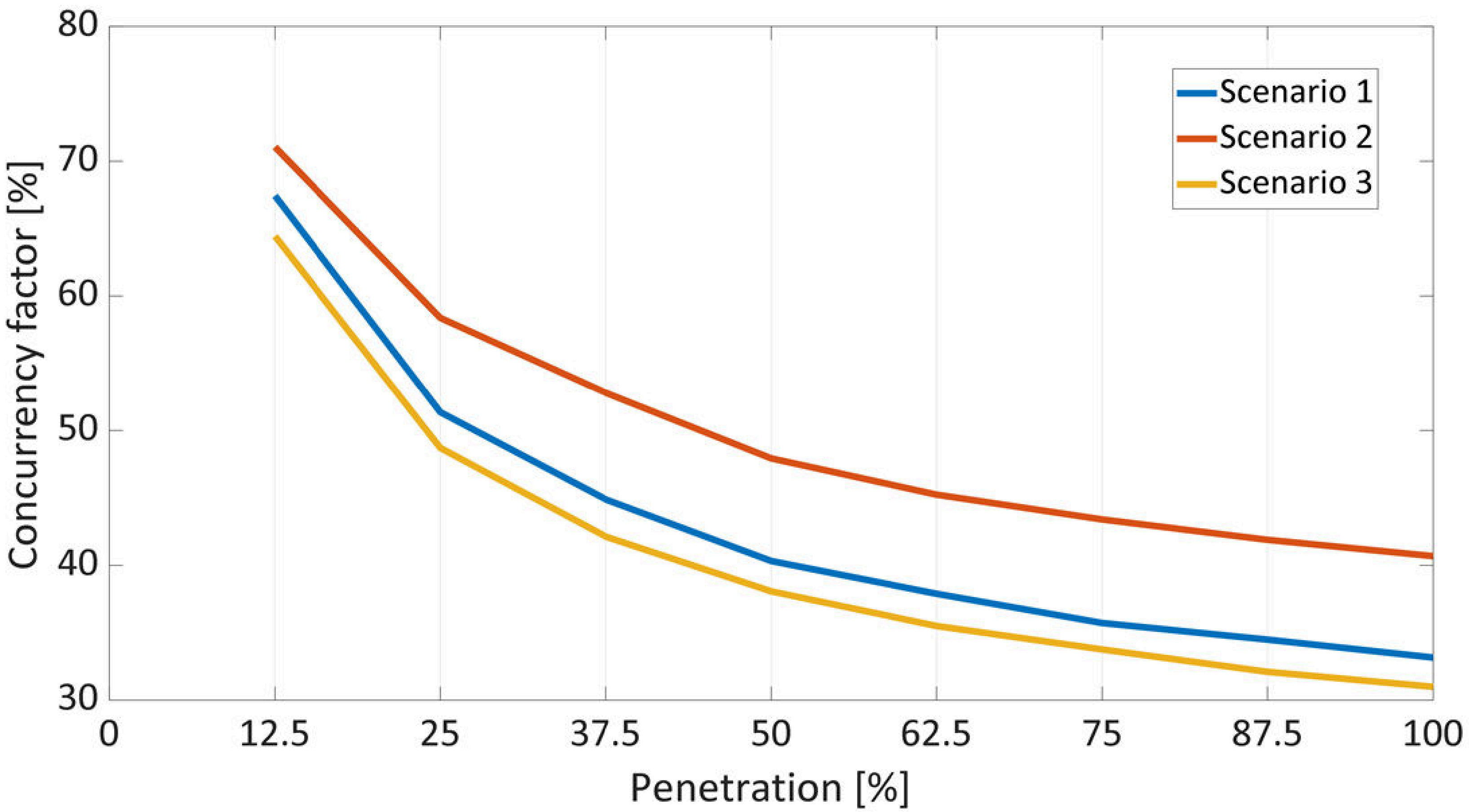
- Concurrency factors for households are already in use for grid planning processes

$$c_{HH}(n) = s + (1-s) \times n^{-3/4} \quad (s = 0.15)$$

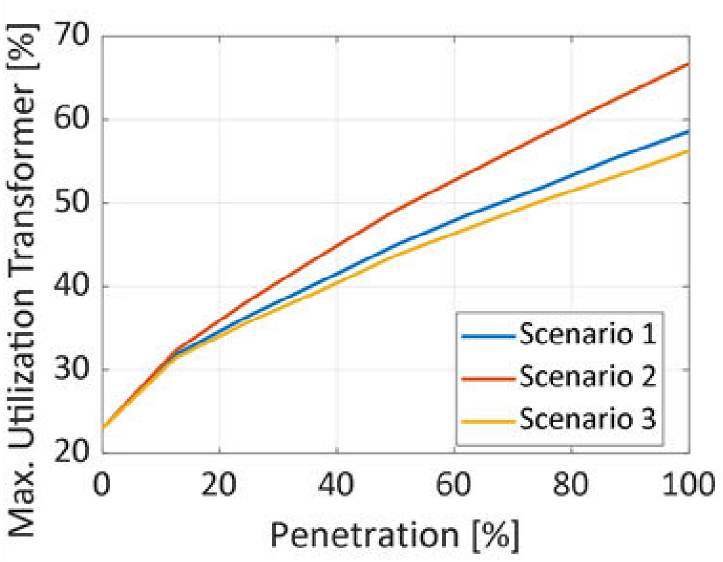
- The contribution of each load P(n) to the total high-load is calculated as follows

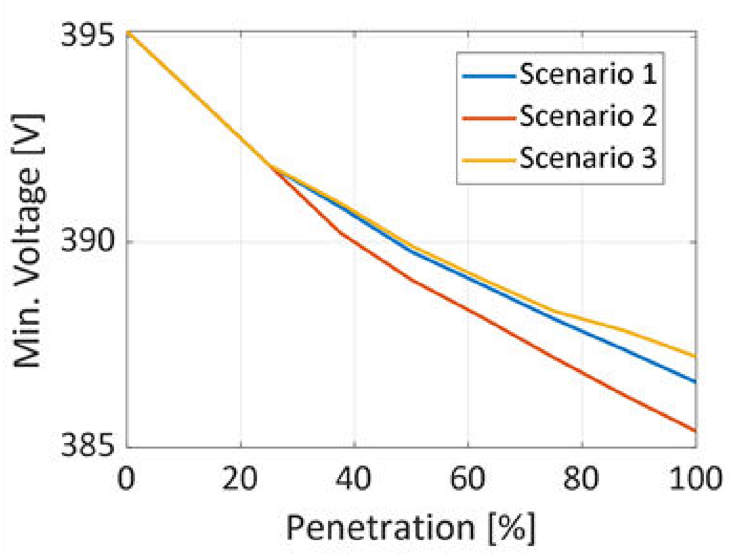
$$P(n) = P_{HH}(n) + P_{EV}(n)$$

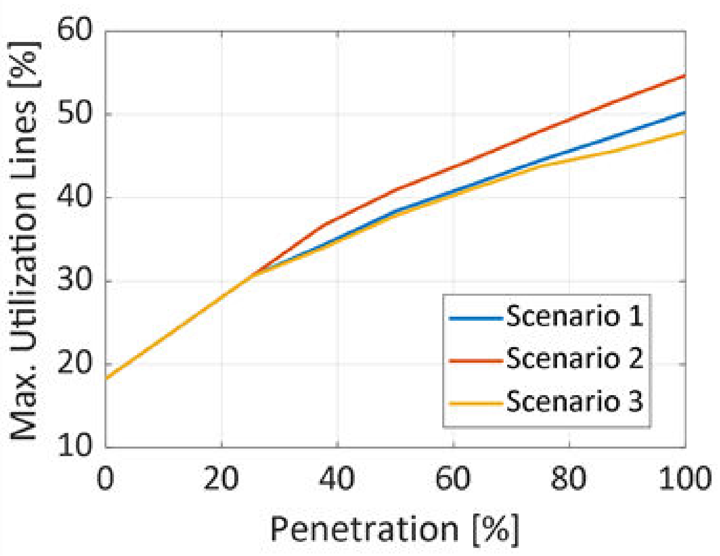
Concurrency factor for the whole rural grid



Results for the rural grid

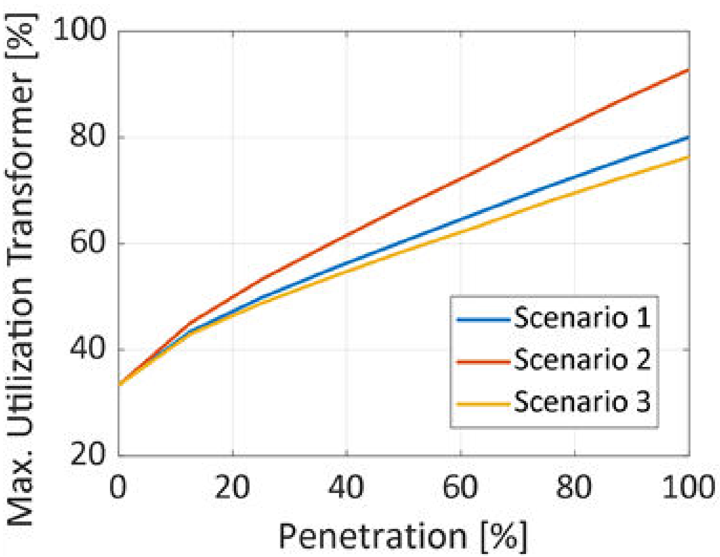


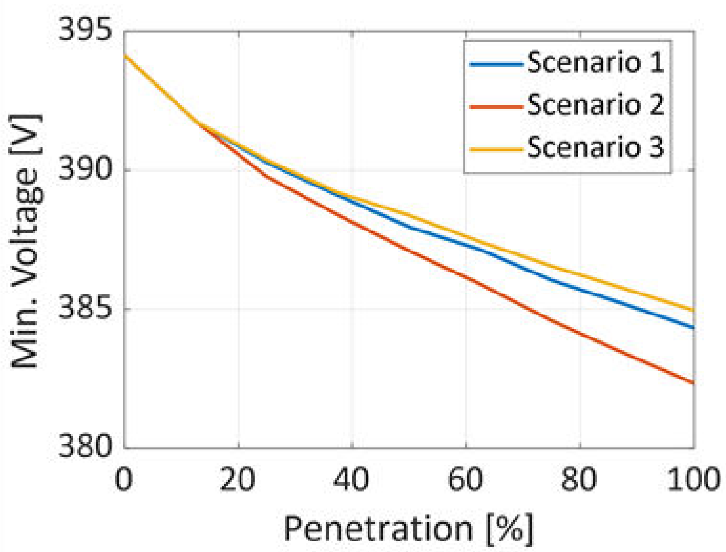


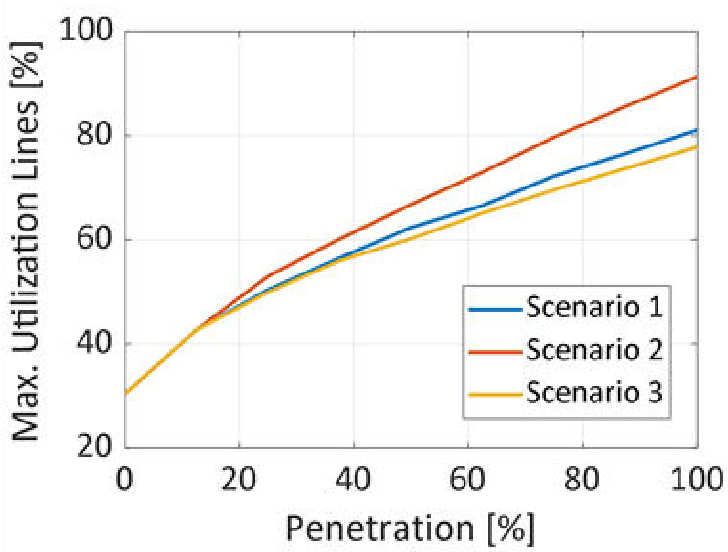


$\Rightarrow$ No violation of limits

Results for the suburban grid

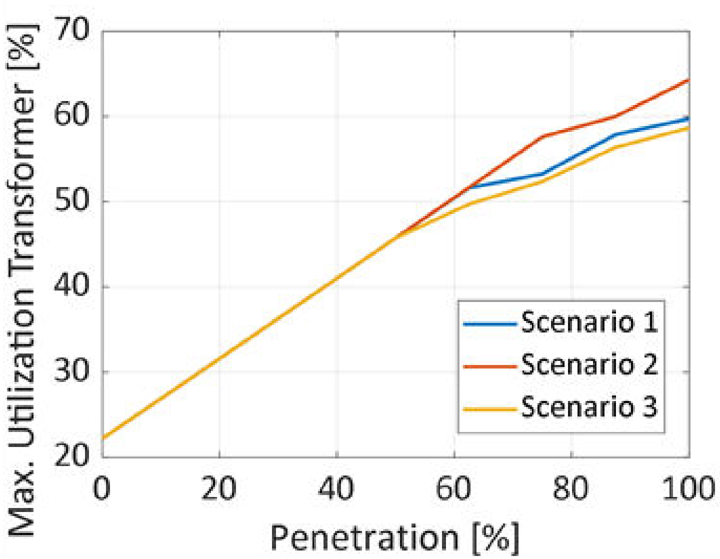


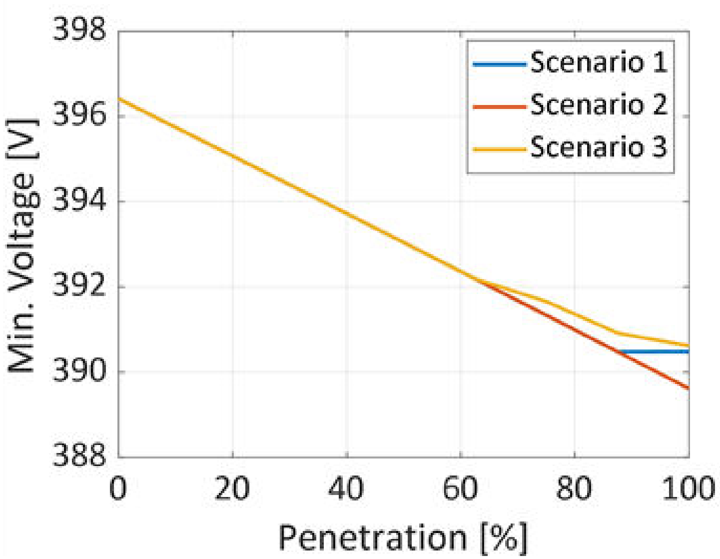


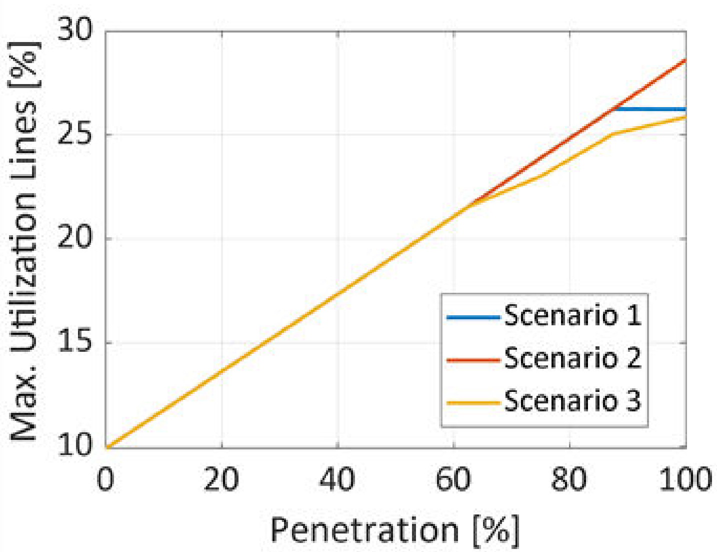


$\Rightarrow$ No violation of limits

Results for the campestral grid

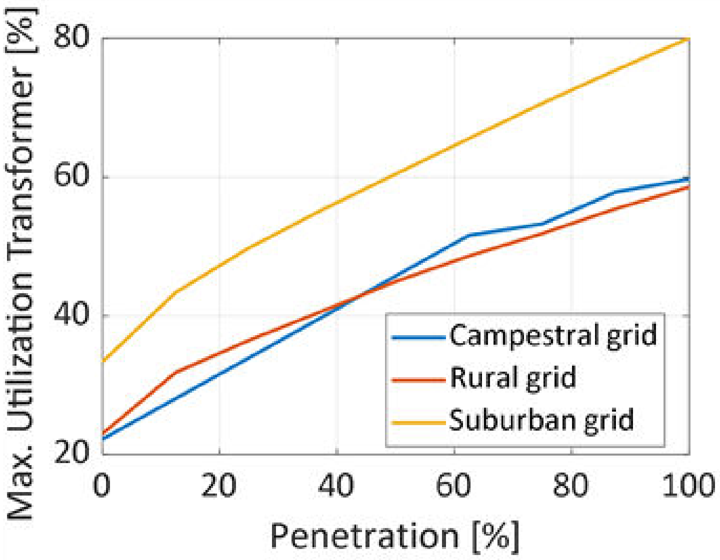


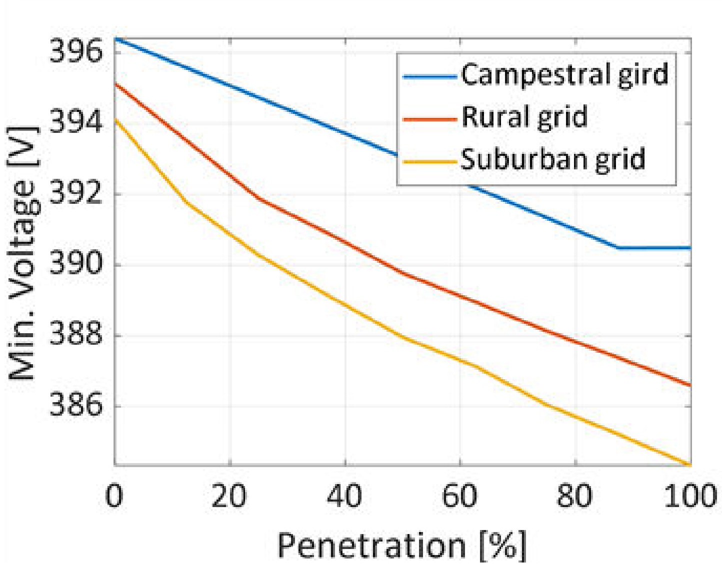


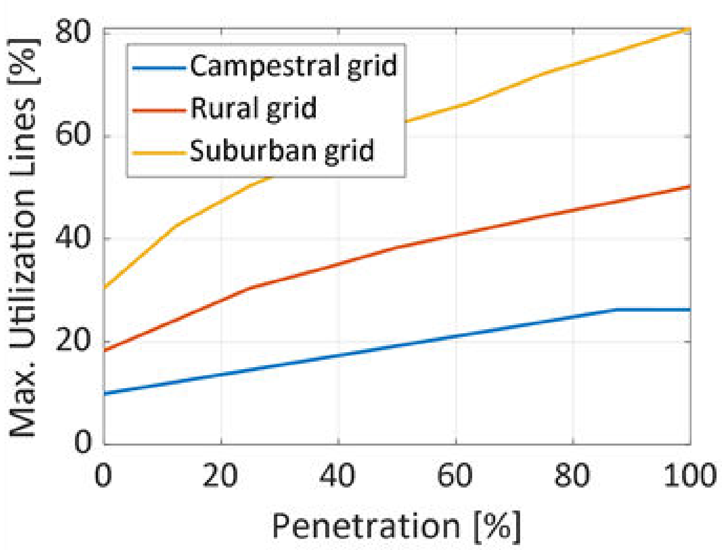


$\Rightarrow$ No violation of limits

Comparison of the different grids for Scenario 1







$\Rightarrow$ Highest stress for the suburban grid

Summary & Outlook

- Summary
  - No violation of limits for maximum 1 EV per grid connection point for current input data
  - Highest stress for the suburban grid

- Outlook
  - Higher penetration of EVs
  - Future development of charging power, energy capacity and energy consumption
  - Further low voltage grids & other voltage levels