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Fragility of EV Grid-Impact Assessment to Modelling and Control Choices

Future developments and technological trends are by definition uncertain – this is especially true for the energy sector, which has seen several major paradigm shifts over the last decade alone. Electrification of the transport sector via electric vehicles (EVs) is a paradigm shift, whose impacts on the electric grid, i.e. loading of lines and transformers, are particularly difficult to evaluate as several modelling assumptions are made that introduce additional uncertainties.

As the energy sector has long investment cycles and, thus, requires robust long-term planning, such uncertainties need to be tamed.

An effective approach for reducing uncertainty is to explore many different, yet plausible future grid scenarios in a Monte-Carlo type fashion in order to quantitatively analyse sensitivities of underlying EV modelling assumptions.

The key idea is to leverage increasingly cheaper computation resources in order to reduce grid planning uncertainty and, ultimately, costly grid upgrades.

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Sensitivity Analysis 1 (Lucerne) – Fragility to modelling choices across all components of a low-voltage grid (60 simulations)

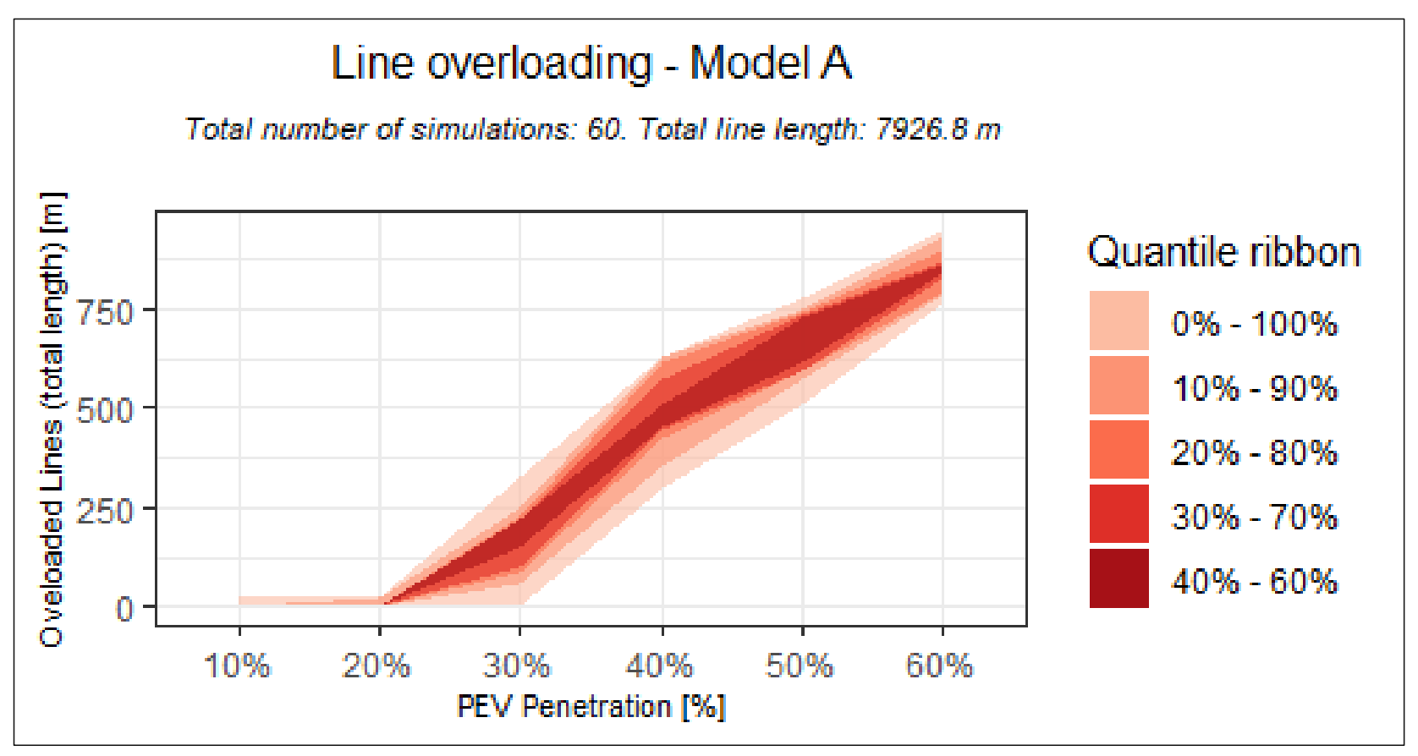
Modelling choices

EV modelling	Key Features
Model A (harsh)	11 kW, high charging coincidence
Model B (medium)	11 kW, low charging coincidence
Model C (mild)	3.7 kW, low charging coincidence

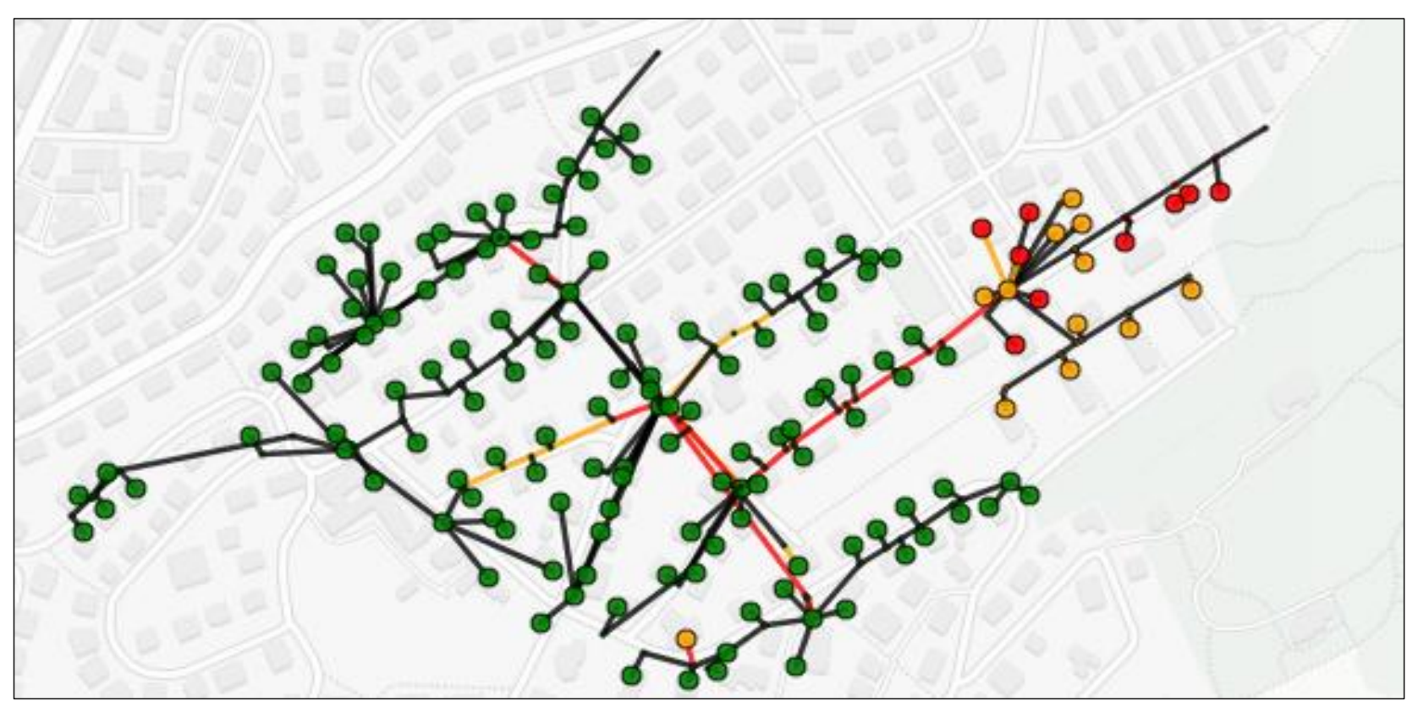
Legend

Color	Cases with violations
GREEN	0%
ORANGE	1% - 99%
RED	100%

Model A (harsh) – Heavy overload

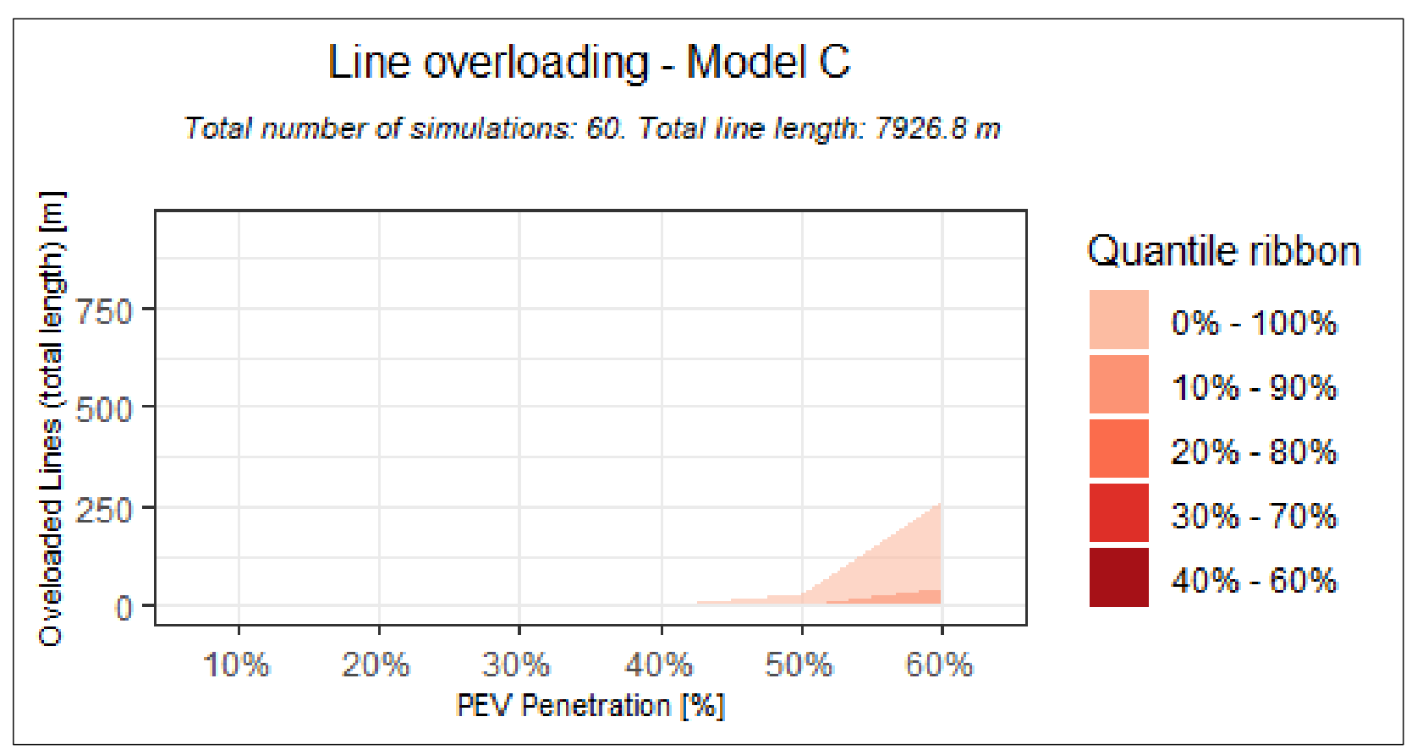


Model A: Total length of overloaded lines



Model A: summary, 60% EV penetration

Model C (mild) – No problem



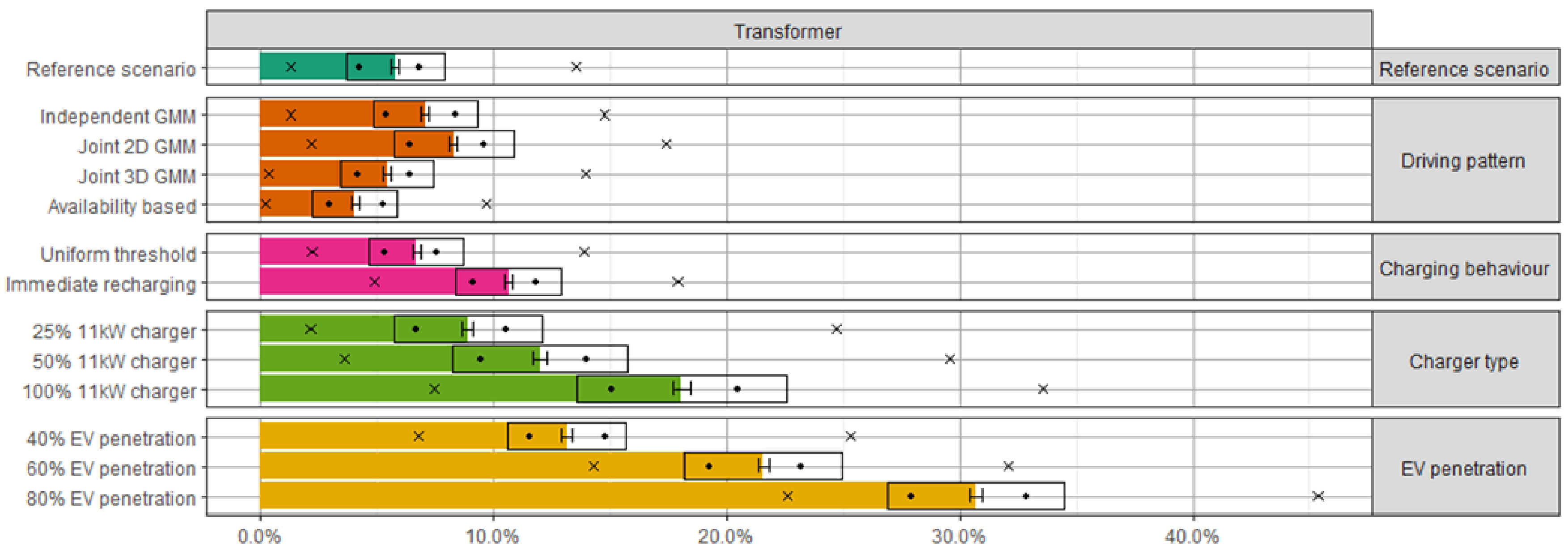
Model C: Total length of overloaded lines

Model C: summary, 60% EV penetration

Sensitivity Analysis 2 (Basel) – Fragility to modelling choices at the MV / LV transformer (5‘200 simulations)

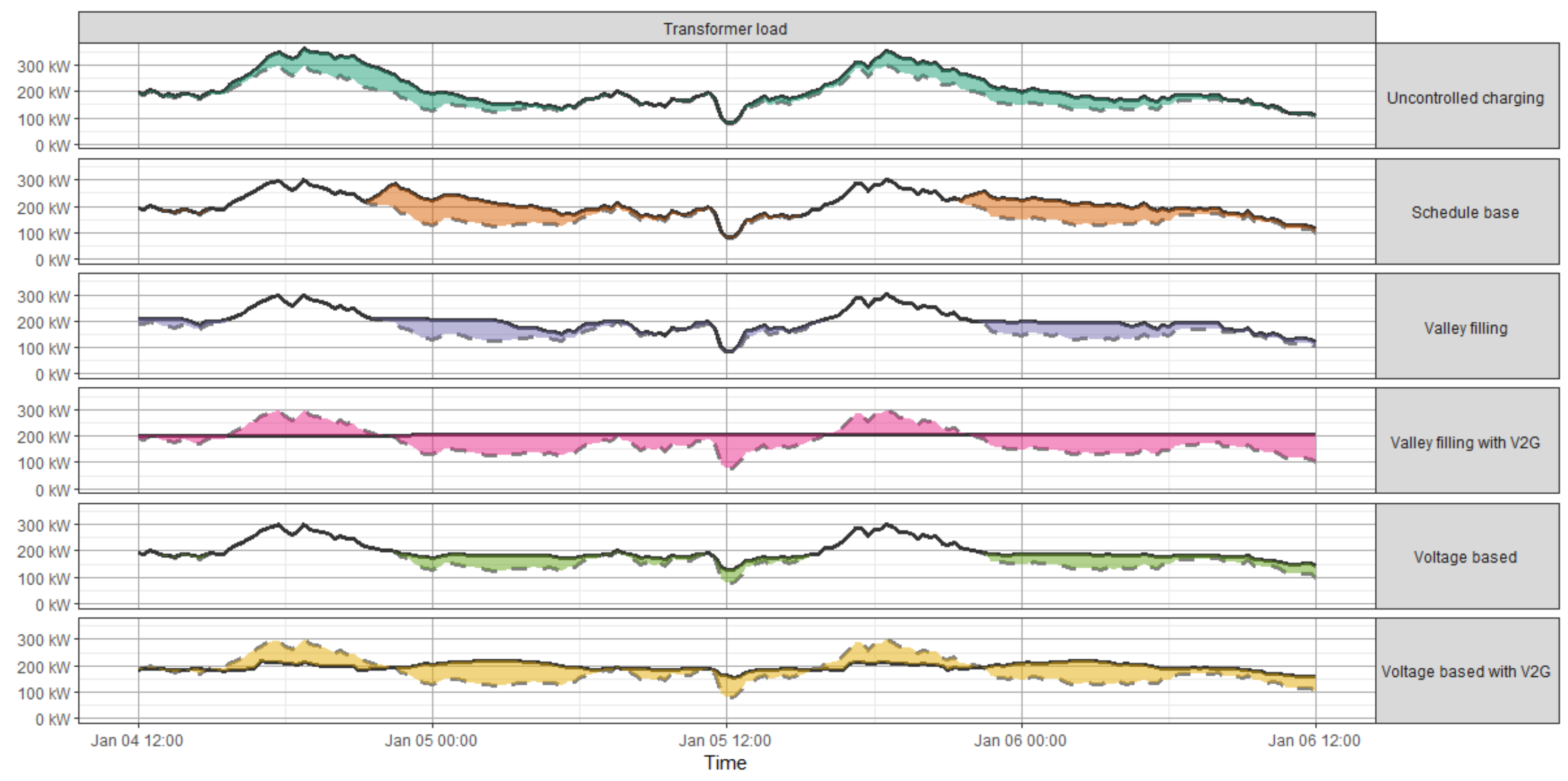
Modelling variable	Options (reference-scenario in bold)
Driving pattern	•**Direct measurements: Sampling of Mikrozensus Mobilität und Verkehr (MZMV) dataset** •Statistical model: independent Gaussian Mixture Model •Statistical model: joint 2D Gaussian Mixture Model •Statistical model: joint 3D Gaussian Mixture Model •Statistical model: availability-based
Charging behavior	•**Gaussian threshold** •Uniform threshold •Immediate recharging
Charger type	•**100% 3.7kW** •75% 3.7kW, 25% 11kW •50% 3.7kW, 50% 11kW •100% 11kW
EV penetration	•**20%** •40% •60% •80%

Reference-scenario: MZMV (Mikrozensus Mobilität und Verkehr) data set, 3.7 kW charger, 20% EV penetration, gaussian threshold for charging.



Transformer peak load increase with respect to the reference-scenario peak load

Sensitivities to control strategies at MV/LV transformer



- Schedule-based controls may induce new, possibly even higher power peaks.
- Voltage-based controls do not require coordination and are similar in effects to valley filling charging schemes.
- Vehicle-to-grid (V2G) operation has the potential of drastically flatten the net load.

Key findings and take-home messages

- Monte-Carlo type scenario-based analysis allows to assess the probability of grid problems to occur and where they are most likely to happen.
- Besides the rate of EV penetration, the highest sensitivity to grid impacts is observed for the modeling choice of the charging power (3.7 kW or 11 kW).
- Active EV charging control, i.e. in the form of load management schemes, is the most relevant lever for reducing grid impacts of electric vehicles.
- Simple, decentral EV charging schemes, i.e. voltage-based control, are similarly effective in reducing peak loading as central EV charging schemes that require extensive coordination and communication.
- Increasingly cheaper computation power is exploited to cover as many plausible grid scenarios as possible, thereby reducing planning uncertainty when deciding on potentially very costly physical grid reinforcements.
- The imminent uncertainty of future development trends can be significantly reduced in order to create tangible, implementable grid upgrade strategies.

References

- Toffanin D., Ulbig A. : Taming uncertainty in distribution grid planning – A scenario-based methodology for the analysis of the impact of electric vehicles. CIRED 2019 – paper n. 1955
- Stiasny J. : Sensitivity analysis of EV impact on distribution grids based on Monte-Carlo simulations. Master Thesis PSL-ETH. Publishing ongoing.
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