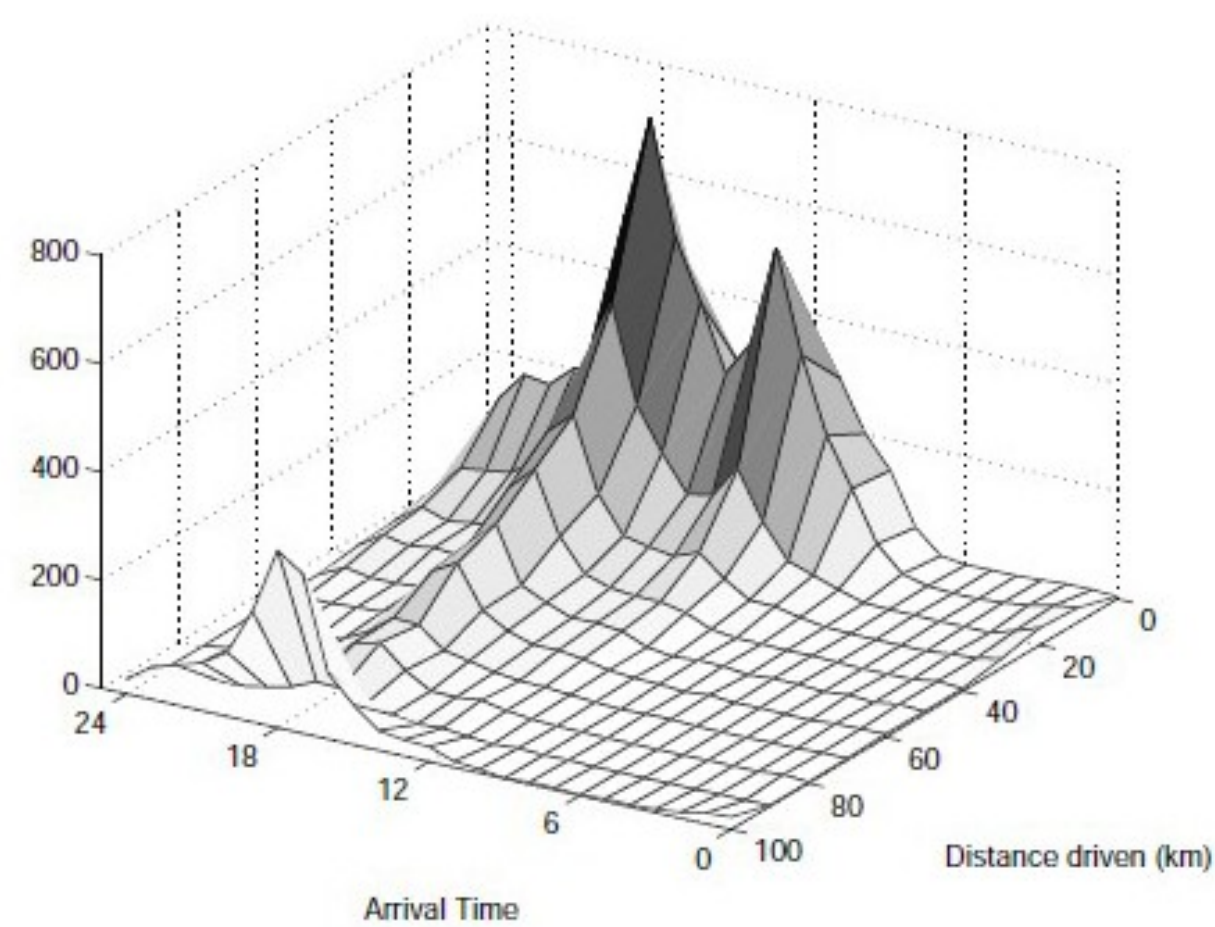
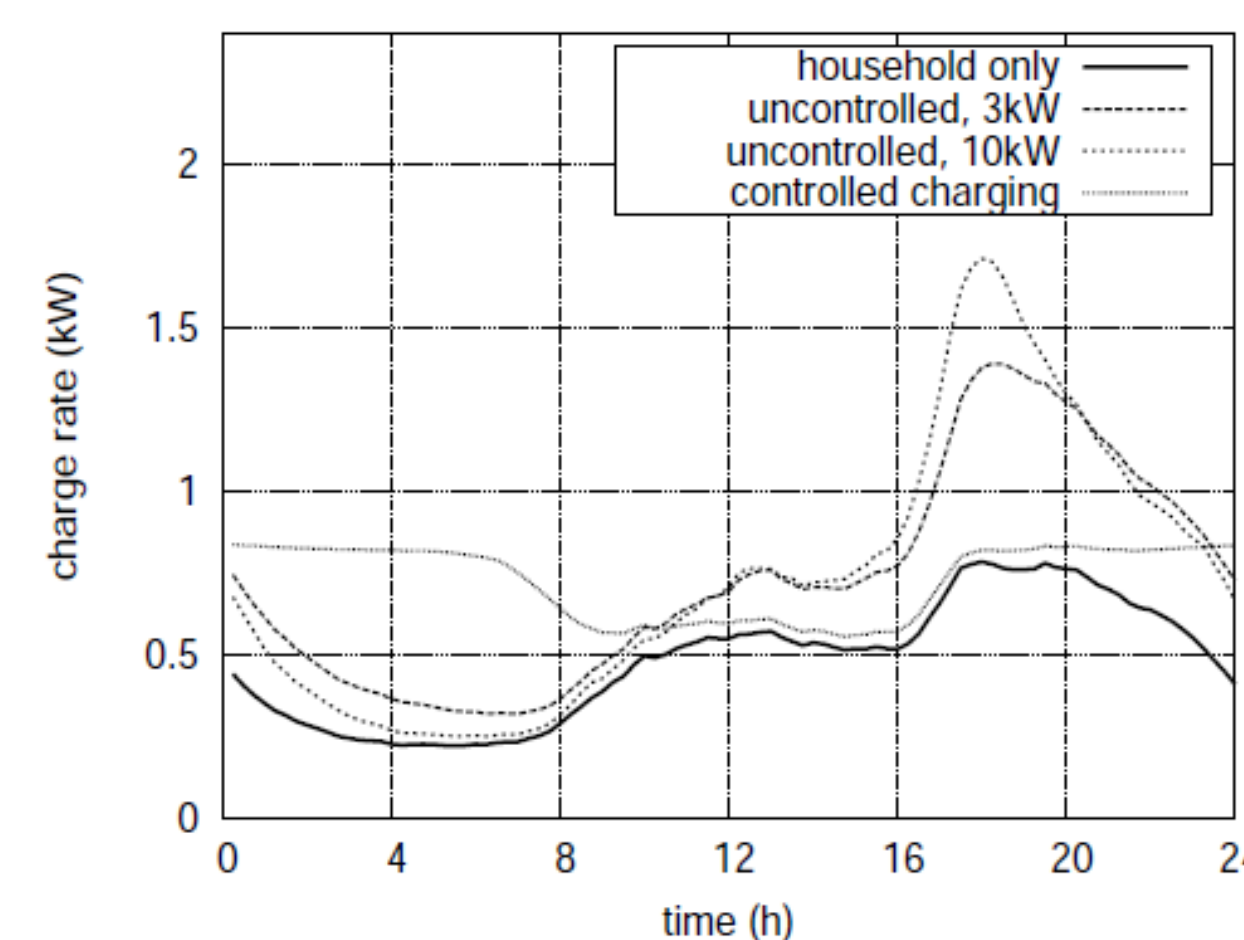


Potential Cost Savings of Controlled Electric Vehicle Charging

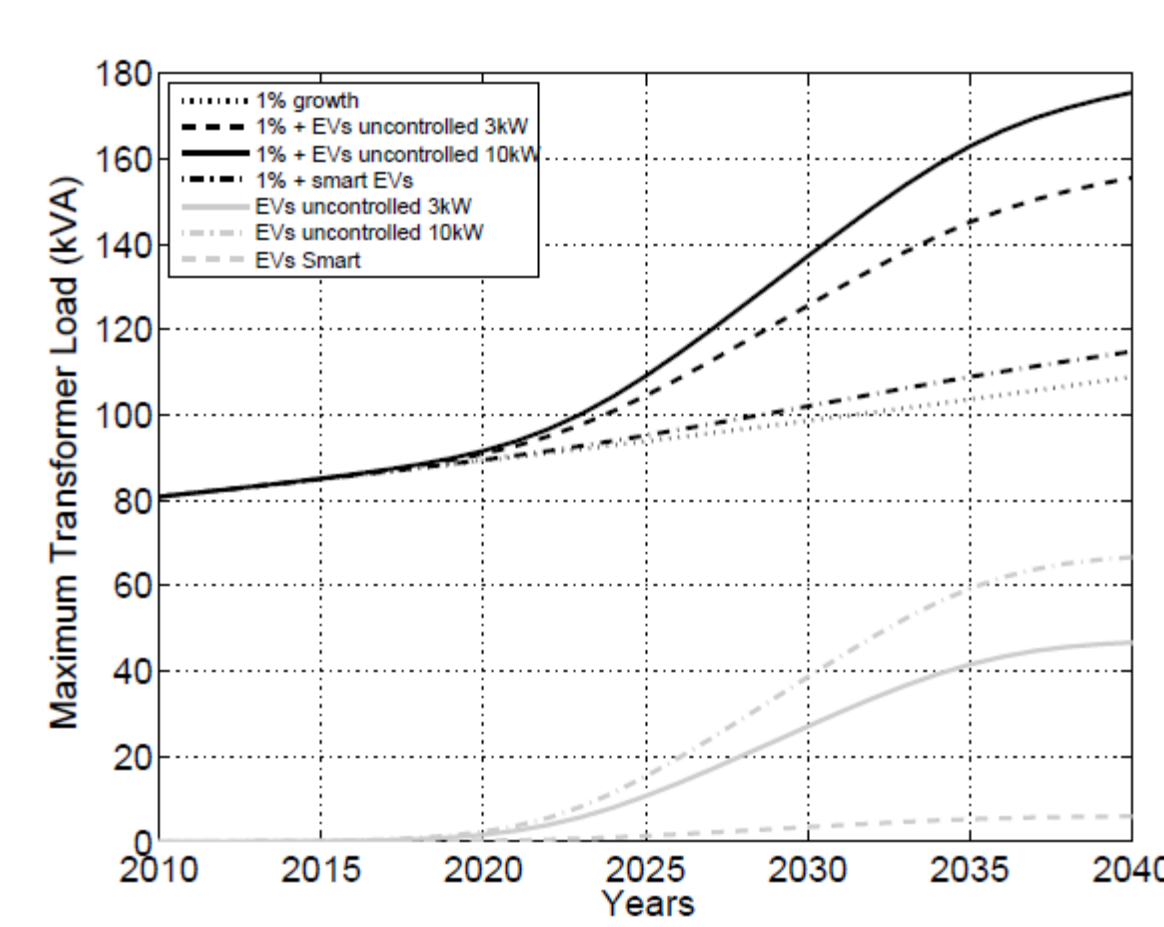
R.A.Verzijlbergh, M.O.W. Grond, Z.Lukszo, J.G. Sloopweg, M.D.Ilić



Driving patterns: distribution of daily driving distance and home arrival time.



Aggregated household load for households with one EV.



Evolution of aggregated peak load per household for 75% EV penetration.

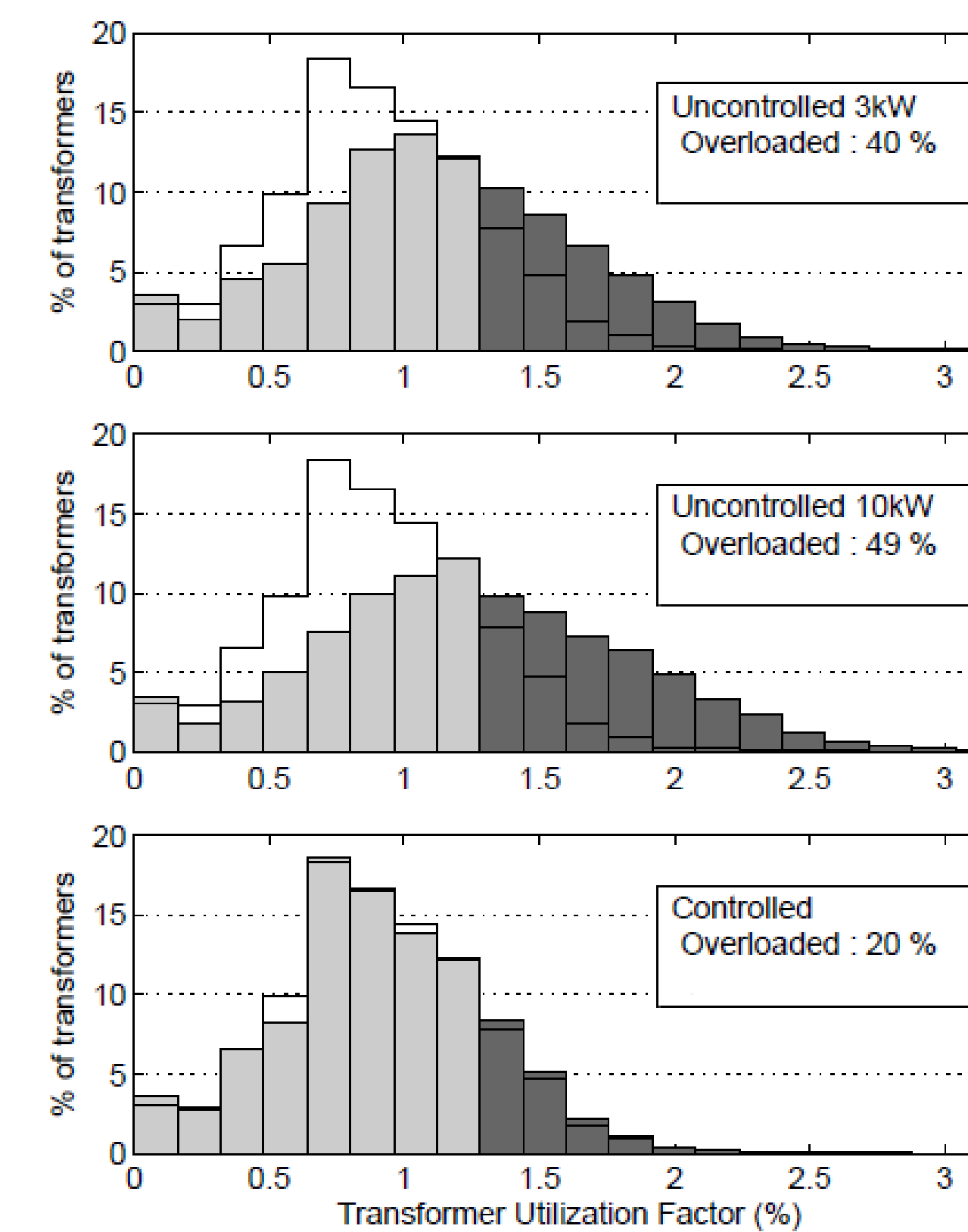
Charge Profiles

Aggregated profiles of electric vehicle charging are derived with the use of car driving patterns. From a dataset derived from interviews with roughly 18000 car drivers, we have used daily driving distances, home departure times and home arrival times to construct various charge scenarios.

In the uncontrolled charging scenario, a car driver comes home, plugs in the EV and starts charging with a constant power (either 3kW or 10kW) until

the battery is full. The controlled charging scenarios takes into account at what time the car has to be full for the next home departure. It will charge the battery when the 'normal' household load is minimum, normally during the night.

The effect of applying charge control is immediately clear when adding the EV load to the household or system load. In the uncontrolled charging scenario the peak increases, but less pronounced than sometimes suggested.



Histograms of MV/LV-transformer loading factors in three different EV charging scenarios

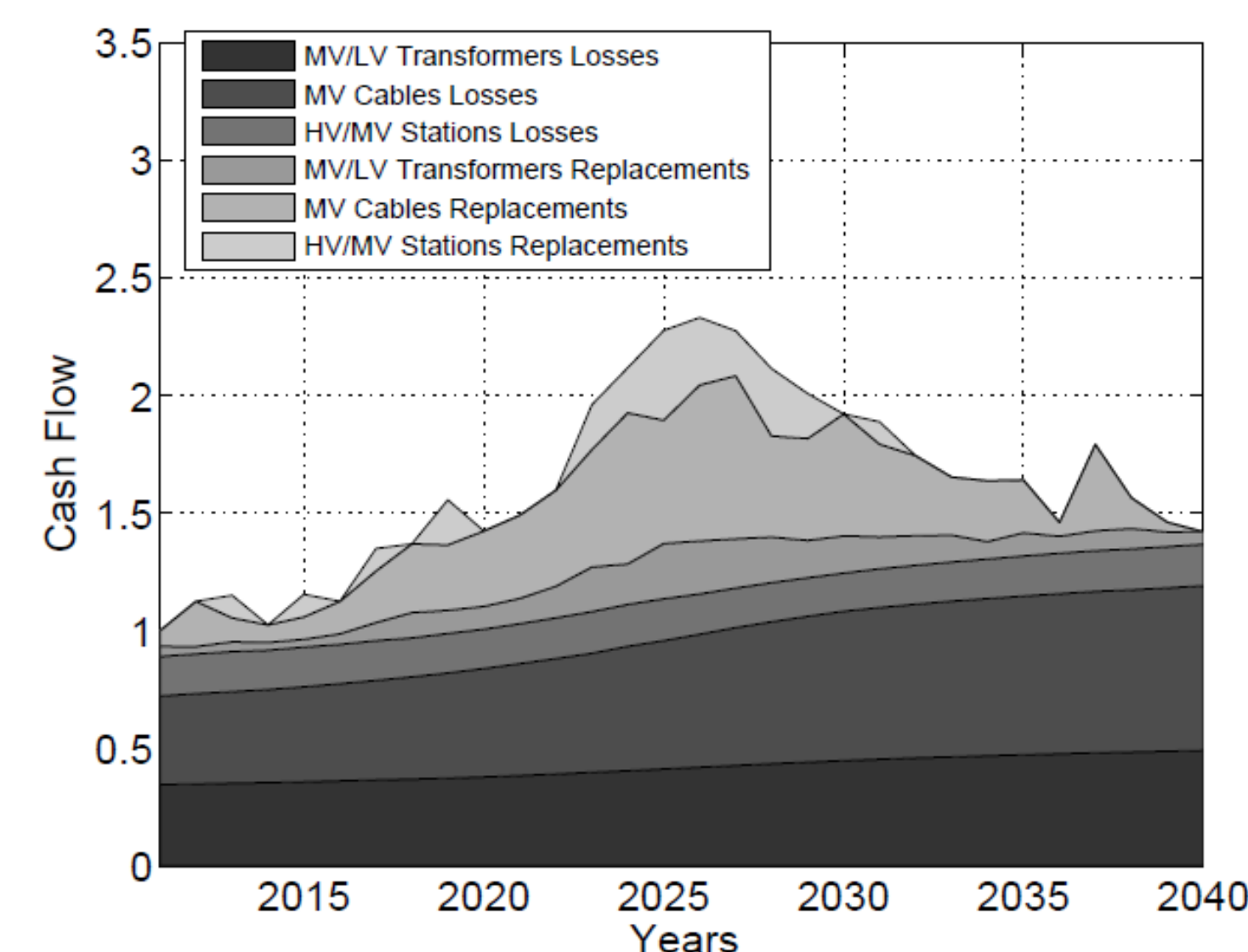
Grid asset impacts

To study the impact of EV charging on distribution grid assets, a large number of distribution networks in the Netherlands have been analyzed. The EV load profile has been added to measured load profiles on LV cables, MV/LV transformers and MV-cables, which have been adjusted to account for 30 years of 1% electricity consumption growth. The resulting loading factors (1 denoting a grid asset loaded at nominal capacity) can hence be interpreted as the loading factor that would result from 30 years of electricity growth plus the extra load caused by EVs.

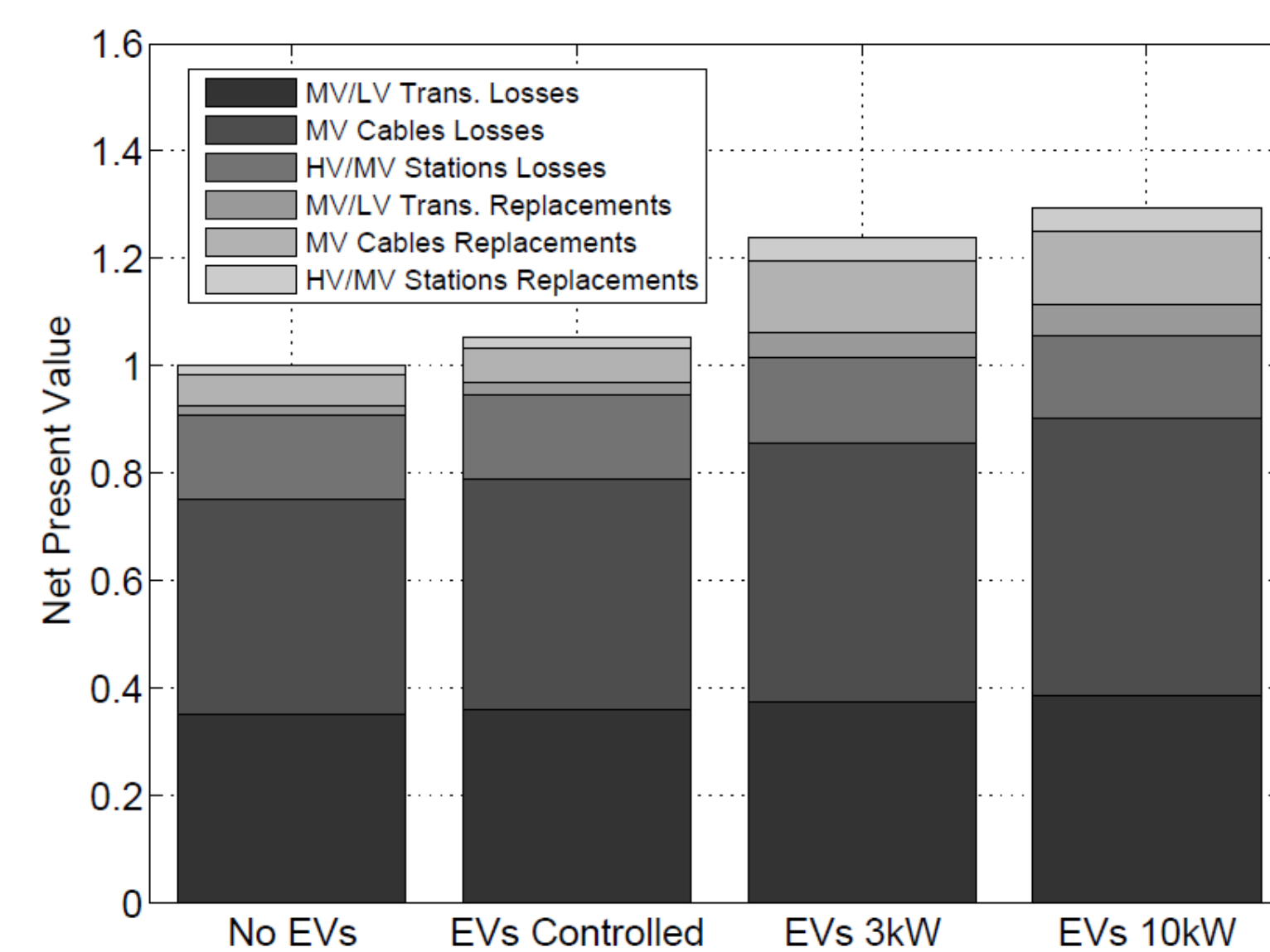
In the controlled charging scenario there will practically no extra overloaded grid assets. These results give an indication of the possible value of smart charging for distribution system operators.

Percentages of overloaded grid assets in different EV charging scenarios

Property	Threshold Value	1% Growth only	Uncontrolled 3kW	Uncontrolled 10kW	Controlled
MV/LV Transformers	1.16	18%	40%	49%	20%
MV Distribution Cables	0.6	6%	13%	15%	7%
MV Transmission Cables	0.68	22%	42%	46%	25%
HV/MV substations	varies	35%	61%	66%	42%



Pattern of investments needed for replacements and yearly energy loss costs.



NPV of the different cost types in the four different scenarios.

Cost calculations

EV charging is expected to have significant costs due to the fact that grid assets have to be replaced by heavier types to avoid overloading. Next to this, increasing costs for energy losses are expected. This study is the first to quantify these costs.

Based on the future network load profiles and the resulting expected number of overloaded network components presented above, we have calculated the costs for replacements and energy losses. The figures to the left show how the costs occur over time (top) and what the differences in NPV between the scenarios are and how they are distributed over various cost components.

The largest cost impacts is expected on the MV-cable level, since these replacements are generally very costly. Energy losses increase only moderately, due to the fact that heavier network components usually have lower losses.

The total difference in NPV between the controlled and uncontrolled is approximately 20%. This difference is roughly for 60% due to replacements and for 40% due to energy losses. Also, a fraction of the costs lie beyond the 2040 horizon.

Conclusions

- First study to quantify cost savings due to electric vehicle charging based on future load profiles and expected network impacts.
- Controlled charging leads to significant reduction of replacement of grid assets. Effect on energy losses is more moderate.
- Cost saving potential up to 25% possible. Largest impact in replacement on MV-cables.
- Results suggest that controlled charging of EVs is a cost-beneficial way to accommodate large number of EVs.

Comparison of NPV between different EV charging scenarios. The cost savings due to controlled charging are roughly 20% compared to uncontrolled EV charging

Scenario	Total	Replacements	Energy Loss
No EVs (absolute)	265M €	25M €	240M €
No EVs	100 %	100 %	100 %
EVs controlled	105 %	113 %	104 %
EVs uncontr. 3 kW	124 %	240 %	112 %
EVs uncontr. 10 kW	129 %	257 %	116 %

References

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