THE IMPACT OF CHARGING INFRASTRUCTURE ON THE LOAD SHIFT POTENTIAL OF ELECTRIC VEHICLES

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Overview

To attain the climate targets, it is necessary to transform the whole energy system. Renewable energy sources (RES) can help to decrease the greenhouse gas emissions in the electricity sector. In the transport sector, plug-in electric vehicles (PEVs) can be a means to reduce greenhouse gas emissions if powered by electricity RES. However, in a significant number, they risk to cause additional load peaks that have to be balanced to ensure a stable electricity system. Ideally, electricity demand of PEVs and electricity generation of RES are coordinated e.g. by demand response. However, for this purpose, a sufficient charging infrastructure is needed. While most studies focus on domestic charging facilities [1] or include additional charging at work [2] for private passenger cars, this paper also considers commercial PEVs and the use of public charging stations. The aim is to assess to what extent additional charging facilities can contribute to PEV market penetration in Germany and if these new charging options as well as new load shift potentials may help to avoid new peaks in the residual load[1]. The analysis shows that mainly domestic charging and charging at work increase the diffusion of private electric vehicles while public charging points with low power rates only have a marginal effect. However, charging infrastructure at work also enables vehicle charging during hours with high RES feed-in. Hence, its construction facilitates peak shaving and the integration of RES.

Methods

In our analysis, we combine two existing models: The agent-based simulation model for PEV market diffusion, ALADIN (ALternative Automobiles Diffusion and INfrastructure), simulates the driving of conventional vehicles with PEVs. This allows to determine their ability to substitute conventional vehicles and, thus, to derive the PEV market diffusion [3]. For this purpose, approx. 300,000 driving profiles of conventional vehicles are analyzed. The share of PEVs on all driving profiles is equal to the market share of PEVs in one year which diffuse into the vehicle stock over time. This permits the simulation of the charging point usage (distinguished by accessibility) paired with the market diffusion of PEVs.

The resulting charging profiles and number of PEVs serve as an input for the model eLOAD (energy LOad curve ADjustment). In this study, eLOAD is used to determine the least-cost scheduling of PEV-charging depending on an hourly price signal. It thereby simulates the potential contribution of demand response to residual load smoothing [4]. The methodological approach consists of two parts. At first, eLOAD aims to estimate the long-term evolution of national electricity system load curves, which is driven by structural changes on the demand side and the introduction of new appliances (such as PEVs). In a second step, eLOAD optimizes the national demand response deployment to adjust the overall net load. With respect to PEVs, eLOAD considers technical (battery storage size) and organizational constraints (driving and parking cycles, charging capacity) when determining the least-cost charging.

In the present modeling exercise, we consider three scenarios to assess the impact of different charging infrastructures (domestic, at work and in public) on the contribution of electric vehicles to residual load smoothing and the integration of RES. In scenario S1, only domestic charging is permitted (commercial vehicles charge at commercial charging points respectively). In scenario S2, additional charging at work for private users is allowed and completed by public charging infrastructure in S3. For simplification, all charging options are considered to permit charging with 3.7 kW.

Results

The results of the model simulations for Germany in 2030 are shown in Table 1. They indicate that additional charging infrastructure at work (and, to a very limited extent, in public) enhance the diffusion of private electric vehicles. In contrast to the private cars, the number of commercial PEVs is independent of the additional charging options because these vehicles tend to not charge in public according to the simulation. This is even clearer when the commercial PEV stock is regarded which remains at 1.2 million PEVs in all three scenarios (cf. Table 1). Public charging points do not increase the number of PEVs, even when these charging points are subsidized by large.

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[1] The residual load equals the system load minus the generation of fluctuating renewable energies.

Table 1 German PEV stock in different scenarios in 2030 (in million)

	S1	S2	S3
Private PEV stock	3.4	4.1	4.1
Commercial PEV stock	1.2	1.2	1.2
Total PEV stock	**4.6**	**5.3**	**5.3**

As the PEV stock and the charging options differ especially in scenario S1 compared to S2 and S3, the load curves vary too. Considering demand response, Figure 1 compares the load curve of uncontrolled charging (black line) and optimized charging (red line) in S1. Charging of electric vehicles in summer time is primarily shifted into midday hours due to substantial PV-based power generation and a correspondingly low level of the net load and low electricity prices. In the winter season, vehicle charging is partially shifted into night time hours, especially at days with low solar generation. Furthermore, Figure 1 shows the optimized load curves for S2 and S3. Charging options at work in S2 imply that an additional load peak occurs in the morning hours when people arrive (green line). If public charging points are added in S3, the electricity demand remains almost the same (dotted black line).

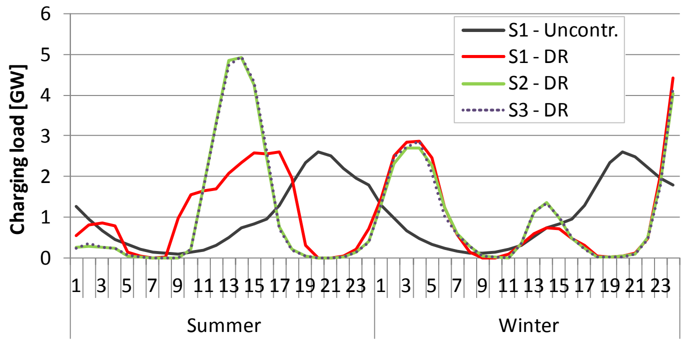

Figure 1 Electricity demand of PEVs an a Tuesday in summer and winter, with uncontrolled charging (uncontr.) or Demand Response (DR)

In total, the deployment of load shifting can facilitate peak shaving in Germany by about 2 GW or 3.3% compared to a scenario without load shifting. Thus, the surplus of electricity by RES can be reduced by 19% which means that 1.1 TWh of RES surplus is used for charging. In contrast, uncontrolled charging of PEVs at work, at home and in public (S3) raises electric load by more than 2 GW, in particular at current peak hours (at 10am and 7pm).

Conclusions

The results show that additional charging options at work promote the diffusion of private PEVs, but public charging points do not increase the number of PEVs significantly, even when these charging points are largely subsidized. The additional charging infrastructure enables vehicle charging during hours when solar or wind electricity generation is at the maximum and thus, facilitates peak shaving and the integration of RES. However, other flexibility options like storage or demand units (e.g. heat pumps) may compete with PEVs for low electricity prices during hours with high RES feed-in. Therfore, the effects of the competition among flexible technologies will also be evaluated in the paper.

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References

[1] D. Dallinger, G. Schubert, M. Wietschel (2013): *Integration of intermittent renewable power supply using grid-connected vehicles - A 2030 case study for California and Germany*. Applied Energy, 104(0):666–682.

[2] S. Babrowski, H. Heinrichs, P. Jochem and W. Fichtner (2014): *Load shift potential of electric vehicles in Europe*. Journal of Power Sources, 255(0):283 – 293.

[3] T. Gnann (2015): *Market diffusion of plug-in electric vehicles and their charging infrastructure*, Dissertation, KIT Karlsruhe.

[4] T. Boßmann (2015): *The contribution of electricity consumers to peak shaving and the integration of renewable energy sources by means of demand response*, Dissertation, KIT Karlsruhe.