HOW TO AGGREGATE THE LOAD SHIFTING POTENTIAL OF ELECTRIC VEHICLES FOR ENERGY MODELS

Patrick Jochem, Karlsruhe Institute of Technology (KIT) and German Aerospace Center (DLR), Curiestr. 4, 70563 Stuttgart, Germany, +49 711 6862687, jochem@kit.edu, www.dlr.de/ve
Sabrina Ried, Sebastian Soldner, Thomas Dengiz and Axel Ensslen,
Chair of Energy Economics, Institute for Industrial Production, KIT,
+49 721 608-44670, sabrina.ried@kit.edu, sebastian.soldner@student.kit.edu, thomas.dengiz@kit.edu

Overview

It is already widely acknowledged in the literature that the additional load by an increasing market share of electric vehicles is not only a burden to engery systems, but rather a benefit – if their charging processes are controlled. At least, the current user patterns with ideling times of more than 23 hours a day, a daily energy demand of only 8 kWh and an available energy stoarage capacity of about 50 kWh illustrates the potential of electric vehicles dealing as an electricity storage in the energy system [1]. The resulting flexibilities are already comprehensively analysed and published (e.g. [2,3]). However, the question on how to consider this flexibility in energy system models comes up. Among other influencing parameters, the vehicles are not always available, i.e. they are mobile or not connected to a charging point, and the charging rate (i.e. realised charging power) differs significantly between charging stations and vehicles. Consequently, each flexibility is different (cf. Figure 1) and depends on to the required energy demand for accomplishing the next trip (SoC required for the next trip), the plug-in time and maximal charging rate, as well as the current available additional battery capacity (i.e. the Depth of Discharge (DoD) available), which is important when excess electricity is in the system. The exact mathematical aggregation of these heterogeneous polygons seems challenging.

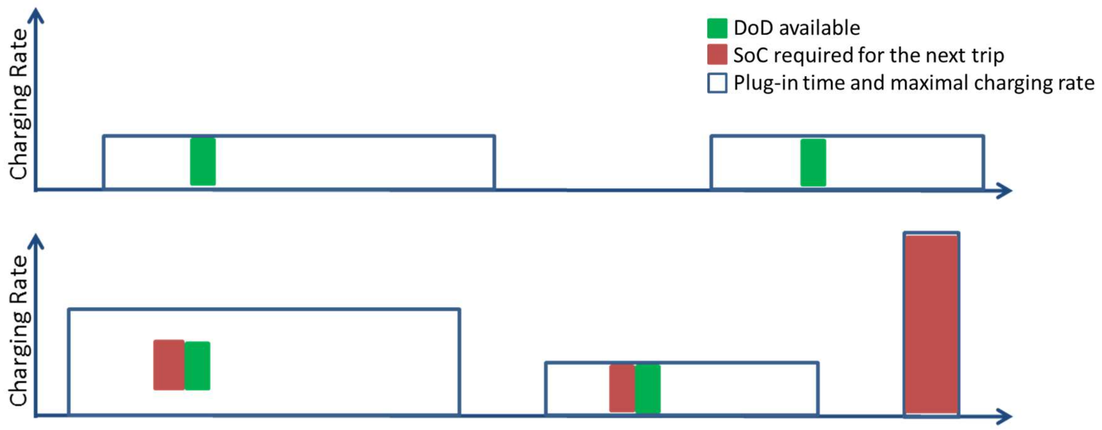

Fig. 1: Example load flexibilities from two electric vehicles

In the following, we give a short overview of different approaches how these flexibilities are aggregated (i.e. approximated) in current energy sytem models and give insights on the feasibility of an exact mathematical approach, which was recently applied by Barot [4] in the energy context.

Methods and Data

Our contribution is twofold: First, we give a literature review on current aggregation approaches of load shift potentials by electric vehicles in energy system models. Most energy systems with a (super)national context are using fictious national storage where an average charging rate and nonavailabilities are considered. This approach often overestimates the load flexibility but seems sufficient on the (super)national level. On more disaggregated levels, e.g. NUTS3, this simplification may significantly overestimate the load shift potential and is, hence, insufficient for a detailed analysis.

Second, we give an introduction into the approach by Barot [4] and give insights of first experiences when applying this approach to a comprehensive set of load flexibilities from electric vehicles. It provides a mathematically sound demonstration of summing different convex, multi-dimensional polytopes. This method corresponds to the Minkowski sum [7]. Barot [4] shows that this approach is able to cope with heterogeneous charging patterns of electric vehicles and thus is able to model the resulting aggregated load flexibility exactly.

Results

While on the decentralized level (like neighborhoods), each vehicle can be considered individually in energy system models (cf. [5]) national energy systems usually refrain from considering single vehicles due to comprehensive computatioal efforts, but a fictious aggregate. These aggregates usually overestimate the load shift potential because single limitations cannot be considered adequately and they are not mathematically exact (e.g. [6]). Therefore, an exact formulation improves the consideration of electric vehices in energy system models substantially – especially for decantralised systems and in studies on storage technologies.

Our first experiences with this approach, however, indicate that calculating the Minkowski sum is only viable for low-dimensional polytopes and, therefore, a low number of considered time-steps. The latter has a significant impact on the model complexity, what we will show in our contribution. Consequently, mathematical approximation methods need to be applied before integrating this approach in energy systems [8]. Our approach and results are further explained and illustrate in [9].

Conclusions

Current aggregation methods for considering load flexibilities by electric vehicles in energy system models do not consider these heterogeneous load shifting potentials adequately – especially if decentralised energy systems with storages are under investigation. The Minkoswki-based approach provided by Barot [4] for aggregating tese flexibilities is mathematically a comprehensive approach. It seems that the approach is still limited to small electric vehicle fleets and in particular short time horizons of about 10 time steps because of computational limitations. In our contribution, we illustrate these current limitations and may provide first suggestions on which approximation methods can be applied for integrating this approach into energy system models.

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