ELECTRIC VEHICLES SMART CHARGING: REPRESENTATIVE LOAD PROFILES BASED ON RESIDENTIAL TIME-VARYING ELECTRICITY TARIFFS AND HOUSEHOLD CHARACTERISTICS

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Overview

Operating decisions of private actors are having an ever increasing influence on the energy system [1, 2]. This work models the relation between electricity tariffs and electric vehicle charging profiles of residential customers. An optimisation model that captures the economic rationality of time-varying tariffs and user-centric charging decisions is proposed and applied in a case study for Germany. The model results are then combined with specific household characteristics (e.g. income level, number of inhabitants, educational level) to generate household specific electric vehicle (EV) load profiles. This individual consideration of household specific load patterns from EVs allows to conisder this heterogenic behaviour in decentralised energy systems in greater detail, e.g. for electrotechnical considerations or local market interactions. To illustrate the effects on the charging profiles, different tariff components, e.g. energy and/or demand charges, and different dynamic tariffs are modelled including taxes and levies (e.g. wind compensation mechanisms).

Methods

To analyse the influence of optimised charging under consideration of dynamic tariffs and derive characteristic load profiles for different household types, the VencoPy framework is used [3]. VencoPy calculates boundary conditions for the charging behaviour and of possible vehicle-to-grid potentials based on mobility data and techno-economic assumptions. This allows to investigate the increased demand for electricity due to the electrification of passenger road transport. Figure 1 shows a schematic representation of the model building blocks.

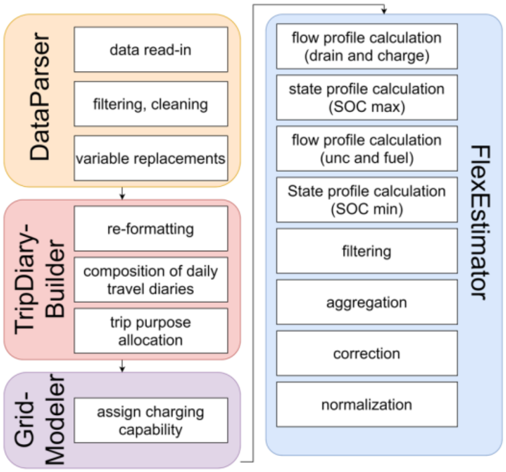

Figure 1: VencoPy framework workflow components.

Based on driving profiles of typical households and on technical data and assumptions about EV, boundaries for minimum and maximum states of charge (SoC) of the vehicle batteries are calculated. From this, hourly resolved demands for uncontrolled charging, as well as load shift potentials for controlled charging can be derived for different electric vehicle fleets.

The VencoPy framework was used in different projects [3, 4, 5, 6]. Among others, it was applied to the German transport survey "Mobility in Germany" to investigate the influence of electric vehicles on the future load shifting potential and its impact on the German power system [4]. The framework was applied in a case study involving two recent German national travel surveys [7, 8] to exemplify the implications of different mobility patterns of motorised individual vehicles on load shifting potential of electric vehicle fleets [3]. Exemplary results of the framework include the distance travelled per hour, the connection availability, and the upper and lower limit for the battery SoC. Based on different decision methods, charging and discharging profiles can be calculated.

By additionally taking real-time prices into account in the charging control mechanism, each vehicle in the “Mobility in Germany” dataset [8] will be analysed singularly and its flexibility optimised. As the framework interface allows to directly access additional survey variables, such as household size, income, age and geographical region, the advantage of this approach is that it allows to link each vehicle profile to specific household types. A sensitivity analysis on different electricity tariffs and tariff components will be carried out in order to analyse how these parameters infuence the charging operation of the vehicles and how these affect the different household clusters.

Results

Electricity tariffs are a main economic driver for private consumer investments in distributed energy resources (DERs), such as photovoltaic (PV), EV and storage systems [9]. Utilities rate design and policy makers’ decisions around different tariff components (volumetric rates, demand charges, feed-in compensations, etc.) affect the economic viability of DER technologies, fostering or discouraging behind-the-meter investments [10].

The results provide representative EV load profiles based on household characteristics including the effects of electricity tariff structure on residential EV flexibility profiles [11]. Different groups of tariffs are identified and modelled, following variations in energy prices and in demand respectively. With a number of price-oriented and load-oriented ToU tariffs, the analysis is further carried out to explore the effects of different types of tariffs on various household clusters, showing that electricity tariffs have a significant impact on the resulting load.

Conclusions

By employing an optimisation routine, different EV charging profiles are obtained for different household types and ToU tariffs. The quantification of the influence of electricity tariffs proves whether these are effective to reshape EV load profiles for residential customers in order to avoid bottlenecks in the distribution grid. Even though both price-oriented and load-oriented ToU tariffs are suitable to decrease the electricity bill for end customers and peak demand, price-oriented ToU tariffs show their advantages in cost saving and load-oriented ToU tariffs are more effective in peak demand reduction. Finally, such characteristic charging profiles, representing decentralised user-centic decision provide a necessary tool for agggregators and useful starting point for comparisons with simplified system cost minimising strategies employed in energy systems models.

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