The impact of different strategies for charging electric vehicles within a vehicle fleet

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Overview

To reduce the dependency on fossil fuels and to slow down climate change, the replacement of combustion engine based vehicles by plug-in hybrid vehicles (PHEVs) and electric vehicles (EVs) will be required [1]. With multiple electric vehicles, restrictions of the power grid have to be considered carefully. This requires adequate charging strategies which control the electric current flow.

This paper focuses on intelligent charging strategies for electric vehicles in a corporate vehicle fleet. The electric vehicles will impact the electricity demand of the enterprises and may consequently affect the contractual load. This has to be taken into account together with vehicle usage profiles and individual preferences in deriving optimal charging strategies.

Existing studies on optimal charging mostly focus on technical restrictions like [1], [2] or on cost minimization in a system context or with respect to wholesale prices [3], [4].

Methods

From a business perspective, avoiding an increase in the peak load is a key requirement. This is at least true in Germany where retail tariffs for medium and large customers include an important capacity charge based on actual peak demand. Therefore it is important to control the electric current flow. In order to reach this, different charging strategies are investigated with respect to the resulting cost efficiency. The reference charging strategy (basic model) is immediate charging. The electric vehicles will be charged when they arrive at the charging station only considering technical restrictions of the vehicle. A first improved strategy regards technical and contractual peak load restrictions and therefore the charging time will be shifted. The third charging strategy is a charging cost minimization strategy including technical and contractual constraints. The developed strategies are implemented as mixed integer optimization programs. Starting with the basic model, constrained charging maximization and various loading strategies like cost minimization, priority based charging and hybrid approaches are compared, including also an approximation of the non-linear charge curve of lithium ion batteries.

For the model we assume that the electricity costs, the conventional load of the company and the time interval of charging are known. For all strategies, we implement restrictions on the company peak load and the vehicle battery capacities as well as the maximal charging load. Furthermore various priorities are externally assigned to the different vehicles within a fleet.

As objective function either the maximization of the state of charge or cost minimization under charging constraints are considered. Moreover penalties based on priorities and on state of charge are investigated. Additionally, weighted combinations of several strategies are analyzed.

An extension of the approaches discussed so far considers the non-linear charge curve. A piecewise linear approximation of the convex charge curve is used as restriction for the maximum charging load.

Expected results

When all electric vehicles within the vehicle fleet will be charged at the same time the contractual load will be frequently exceeded. All developed specific charging strategies are capable to avoid that. When only the technical restrictions and the contractual peak-load are considered, the charging time of the electric vehicles is only slightly shifted. But still the vehicles will be fully charged as fast as possible. The cost minimization strategy shifts the charging time a lot. The vehicles will be charged at the lowest possible price. This will reduce charging costs by at least 20 %, yet requires additional information on the planned usage: The time of departure and the required minimum range have to be known.

Implications

The investigated charging strategies are a small part of relevant charging strategies for the future. Considering an individual enterprise it is important to limit its peak load and to minimize its energy costs. But for the whole system an as even as possible load distribution is preferable to minimize overall costs. Moreover, vehicle to grid (V2G) may contribute in the future to match load with available intermittent generation. Besides these advanced approaches, also the handling of limited and uncertain information (e.g. on future usage) is a key requirement for charging strategies in companies and households.

References

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