Charging Electric Vehicles in the Hanover Region:
Toolbased Scenario Analyses

Bachelorarbeit

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1 Introduction

1.1 Topic and Motivation

In the present understanding of transportation, the car is an indispensable item. More than 45 million cars are licensed in the Federal Republic of Germany. Most likely these vehicles are powered by a combustion engine, a technology invented in the 19th century. In the discussion about future mobility the electric vehicles play a major role. This future technology offers the opportunity to reduce the dependence on oil, increases energy efficiency and minimises emissions (German Federal Government, 2009).

Already in 2007 the German government declared electro mobility as a key component for climate protection. The National Electromobility Development Plan followed in 2009 to speed up the development of battery electric vehicles and their establishment in the German market (German Federal Government, 2009). The declared objective by the German Government is to become the lead market and major provider of electric mobility solutions. Tax incentives in the form of 10-year tax exemptions were introduced in May 2011. On the 12th June of 2015 the legal basis for special privileges of electric vehicles entered into force (BMJV, 2015).

The most recent event in terms of electro mobility is the introduction of purchase incentives in the amount of 4,000€ per battery electric vehicle and 3,000€ per plug-in hybrid (German Federal Government, 2016). These incentives in May 2016 can be seen as a commitment to electro mobility by the German government. The objective is to put one million electric vehicles on the road by 2020 and six million vehicles by 2030 (BMUB, 2016). According to the National Electromobility Development Plan most urban traffic should be able to do without fossil fuels by 2050.

The electro mobility can be seen as an important component of the national transformation of energy systems towards sustainability. Electric vehicles could be the link between renewable energy sources and the transportation sector (German Federal Government, 2016). Therefore, the German Government underlines the importance of electric vehicles properly integrated in electricity and transportation networks.

1.2 Problem explanation and Research question

Regarding to the previously mentioned statement of the German Government, the integration of electric vehicles into electricity and transportation networks, is unknown territory. In 2016, the number of battery electric vehicles amounts 25,502 in Germany (Kraftfahrt-Bundesamt, 2016a). Therefore, the energy suppliers cannot have any kind of experience with a large number of electric vehicles and their power demand.

Especially the fact that an electric vehicle has a power demand comparable to a household, underlines the relevance of this topic. This thesis considers the integration of electric vehicles in the Hanover Region. In the following thesis the Hanover Region is simplified to its population, travel demand and electricity demand. The large scale integration of electric vehicles also involves new challenges in terms of demand side management in the Hanover Region.
The research question is defined in the following:

How does the integration of EVs affect the electricity demand in the Hanover Region and which requirements have to be met for a successful integration of electric vehicles?

2 Methodology

2.1 Approach

First of all, this thesis introduces technological backgrounds of electric vehicles, charging technologies, smart grids & demand side management. These basics are essential to understand further actions in this thesis. The technical background is followed by the literature review. This review analyses concepts introduced by papers, dealing with the integration of EVs in the grid or considering the impact of EVs on existing energy distribution systems in general. The next step is the design of a tool, modelling the impact of EVs on the power demand in the Hanover Region. Therefore, the model is split in parts to reduce complexity. For instance, the charging of a single electric vehicle and the demand side management are explained separately. The design model is followed by the implementation in Matlab R2016a. In the next step the scenarios are described and the impact of charging EVs in the Hanover Region is discussed. Moreover, the limitations of the designed tool and this thesis in general are discussed. Finally, this thesis closes with a conclusion and an outlook.

2.2 Design Science Research by Hevner (2004 & 2007)

In the following the method "Design Science Research" will be applied on the development of the model, explained in chapter 4. The article "Design Science in Information Systems Research" (Hevner *et al.*, 2004) and the article "A Three Cycle View of Design Science Research" (Hevner, 2007) convey the guidelines for the science research of this thesis. In general, these guidelines are made for design science in Information Systems research (Hevner *et al.*, 2004, p.83) to add scientific value to a research. Figure 1 shows the three cycle view of design science research applied on this thesis topic.

impact on the existing power demand. Furthermore, a 30 m^2 PV system in the first year of operation located in the Hanover Region supplies more electricity than an EV would need. The problem of the oversized PV system can be fixed by using adjusted input data.

The simulation tool cannot calculate the first day of the simulation correctly. The system starts with the situation that every car is fully charged at the first time step. Therefore, the calculated values especially for the power demand are below the usually values. After the initial phase of one day the simulation is working correctly.
Another minor defect is the decreasing level of power demand at the end of the charging time slot by executing the “valley filling” strategy. The DSM provides enough power to charge the EVs scheduled at last (short time to charge fully). These EVs have a limited charging power and are not capable to use the provided power. But to charge all EVs properly the DSM has a reserve, which causes the decrease of power demand at the end of the charging time slot. To achieve a perfect “valley filling” with constant power demand, the reserve has to be reduced and the available charging power has to be increased. But this operation mode might lead to EVs “running out” of battery (insufficient supply), in case of long-term simulations. Another possible solution could be to reduce the charging power below the 3.7 kW (mode 1) to achieve an adjustment of charging power that every EV can charge the whole charging time slot (midnight to 6:00 am). Charging in 6 hours by using a charging power below mode 1 won’t work to charge a standard EV completely. But according to scenario 3 a standard EV needs only 7,31 kWh for the daily charge (based on 39 km per day), which can also be achieved by using a charging power below mode 1. To achieve a stable long-term simulation, the DSM keeps the previously explained method.

8 Conclusion and Outlook

Based on existing literature a tool has been designed to analyse the impact of EVs on the electricity demand in the Hanover Region. This thesis combines the basics of electric vehicles, agent based modelling, travel demand and demand side management to design a Matlab tool. This simulation tool allows the user to model a variety of scenarios and provides data for detailed scenario analyses.

The research question, how the integration of EVs affect the electricity demand in the Hannover Region, can be answered in parts by this thesis. This thesis describes the negative aspects of uncontrolled charging and shows how to reduce these effects by introducing DSM and a coordinated charging strategy executed by a centralised control unit (requirements). Furthermore, shifting peak loads can be successfully done without neglecting the supply of EVs. This thesis shows the effects of EVs on the CO_2 balance of passenger vehicles and shows the potential of EVs to offer balancing power. With

the integration of PV systems, the reduction of CO_2 emissions related to electric passenger vehicles can be expanded.
This thesis can be the basis to anticipate the development of operating costs and energy prices in case of a large-scale integration of electric vehicles. Therefore, this model is meant to be implemented in the energy system simulator LESSI. The energy simulator could use this tool to predict the additional demand for EV charging. As a result, findings about the feasibility of EV integration, from the point of view of the energy supply side, can be gained.

The next challenge for this model is the integration in the energy system simulator LESSI. As a standalone tool the number of statements about a successful EV integration is limited. But as a part of an energy simulator the entire scope of EV integration in the Hanover Region can be examined.

The realisation of concepts presented in this thesis requires to solve a variety of challenges which need to be overcome in future. The market penetration of EVs assumed in the simulations has to be achieved in the future. The grid in the Hanover Region has to be developed to a Smart Grid and a charging infrastructure has to be build up. Furthermore, the success of demand side management will depend on the cooperation of EV owners too. In final words, the e-mobility have to face technical, political, social and legal challenges, the designed simulation tool never had.