



ELSEVIER

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

Charging strategies for economic operations of electric vehicles in commercial applications



Maximilian Schücking^a, Patrick Jochem^b, Wolf Fichtner^b, Olaf Wollersheim^a, Kevin Stella^{a,*}

^a Project Competence E, Karlsruhe Institute of Technology, Hermann-von-Helmholtz-Platz 1, D-76344 Eggenstein-Leopoldshafen, Germany

^b Institute for Industrial Production (IIP), Karlsruhe Institute of Technology, Hertzstraße 16, D-76187 Karlsruhe, Germany

ARTICLE INFO

Article history:

Received 24 October 2015

Accepted 28 November 2016

Keywords:

Battery electric vehicles

Charging strategies

DC fast charging

Key performance indicators

ABSTRACT

When substituting conventional with electric vehicles (EV) a high annual mileage is desirable from an environmental as well as an economic perspective. However, there are still significant technological limitations that need to be taken into consideration. This study presents and discusses five different charging strategies for two mobility applications executed during an early stage long-term field test from 2013 to 2015 in Germany, which main objective was to increase the utilization within the existing technological restrictions. During the field test seven EV drove more than 450,000 km. For four out of five presented charging strategies the inclusion of DC fast charging is indispensable. Based on the empirical evidence five key performance indicators (KPI) are developed. These indicators give recommendations to economically deploy EV in commercial fleets. The results demonstrate that the more predictable the underlying mobility demand and the more technical information is available the better the charging strategies can be defined. Furthermore, the results indicate that a prudent mix of conventional and DC fast charging allows a high annual mileage while at the same time limiting avoidable harmful effects on the battery.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

The electrification seems to be a very promising way to cut future CO₂ emissions from road transport (Creutzig et al., 2015). This is especially true if the underlying electricity demand of electric vehicles (EV) is generated by carbon-free energy resources (such as wind or solar energy) (Ensslen et al., 2017; Jochem et al., 2015; Sohnen et al., 2015). Furthermore, EV show potential to reduce the oil dependency of western societies and decrease local emissions in urban areas, i.e. noise and local air pollutants such as SO_x, particle matters, CO and NO_x (Jochem et al., 2016). Concerning both aspects, a high life-time mileage is desirable to fully utilize the EV emission saving potential (Stella et al., 2015).

However, EV are still a new technology and therefore face some hurdles that are currently limiting their market success considerably (Ensslen et al., 2014). Two of those hurdles are the limited range of current vehicles (about 150 km) and their purchase prices that are considerably higher than the ones of their internal combustion engine driven counterparts (ICEV) (Dumortier et al., 2015). In commercial transport both limitations are easier to overcome than for private passenger car applications (Ketelaer et al., 2014). This is mainly due to the fact that for many applications trips are more predictable, single trips above the maximum range are more easily replaced by conventional cars, and the high purchase price of EV can be

* Corresponding author.

E-mail addresses: maximilian.schuecking@partner.kit.edu (M. Schücking), patrick.jochem@kit.edu (P. Jochem), wolf.fichtner@kit.edu (W. Fichtner), olaf.wollersheim@solarwatt.net (O. Wollersheim), kevin.stella@de.bosch.com (K. Stella).

negated by the higher annual mileage of commercial cars due to the lower variable costs of EV operation compared to ICEV (Bickert et al., 2015; Gnann et al., 2012; Plötz et al., 2015; Sierzchula, 2014).

Therefore, for environmental as well as economic motives the aim of this study is to increase the number of trips and hence the annual mileage of EV in commercial fleets. One essential part is the development of specific charging strategies that allow a high operating grade. These include the usage of fast charging infrastructure in order to show an economic advantageous application of current EV compared to conventional vehicles in an empirical field test (a detailed description of the research aim can be found in Section 2.4). The field test with several cross-border commuters from Alsace (France) to Karlsruhe (Germany) lasted from early 2013 till the end of 2015. The research project behind was comprised of two different user groups: the first were fixed car-pooling commuter groups that travelled on average 75 km one-way from their homes in France to work in Germany; the second were employees on business trips during the day between two plant sites around 70 km apart, one in Germany and one in France. The EV were equipped with data loggers tracking battery as well as GPS data to allow a detailed technological and economic analysis.

The article is structured as follows: the second section provides an overview of the existing literature focusing on charging strategies, economic reasons as well as limitations of fast charging. It illustrates the gap in the literature and states the underlying research aim. The third section introduces the research project RheinMobil and the method by explaining the research design, setting and data collection. The fourth section is divided into five subsections; each describes and analyzes a different charging strategy that was implemented for the two mobility applications. The fifth section discusses the presented strategies in reference to the literature and introduces key performance indicators (KPI) for comparison. It also includes a small Total Cost of Ownership (TCO) analysis as well as a discussion of the technological implications. The last section concludes by summarizing the results, outlining the limitations and suggesting topics for future research.

2. Literature review

There are two main perspectives in the literature on the impacts of charging EV. One comprehensive focus deals with the impact on the electricity system (1) and the second focus considers the impact on the vehicle and the battery (2). There are several dimensions for focus (1). Some studies take a macroscopic point of view by looking at the impact on the electricity load and the resulting implications on the power plant portfolio and electricity grid (Babrowski et al., 2014; Camus et al., 2011; Dharmakeerthi et al., 2014; Hadley and Tsvetkova, 2009; Hahn et al., 2013; Harris and Webber, 2014; Jansen et al., 2010), another emphasis is on additional emissions caused by electricity generation based on the timely distribution of charging (Bickert et al., 2015; Donateo et al., 2015; Ensslen et al., 2017; Jochem et al., 2015; Khoo et al., 2014; Muneer et al., 2015; Rangaraju et al., 2015; Sohnen et al., 2015; Thompson et al., 2011), still others aim on maximizing the input from (local) renewable energies (Atia and Yamada, 2015; Kier and Weber, 2015; Pantoš, 2011; Škugor and Deur, 2015; Wu et al., 2016). These topics are sometimes connected to different charging technologies such as controlled charging or even vehicle-to-grid (V2G) systems, providing virtual energy storage for grid services in the local electricity system (Bishop et al., 2016; Kristoffersen et al., 2011; Tomić and Kempton, 2007). The second focus (2) is on vehicles and their batteries. Previous studies investigate the development of an optimized charging strategy from an EV perspective considering factors such as the state of health (SOH) of the battery, cost optimized charging, including V2G, and parking time (Bashash et al., 2011; Neubauer et al., 2012). Other studies go even more into battery-related technical details by evaluating the charging and discharging behavior of the battery packs or even of individual cells (Kim et al., 2014; Onda et al., 2006; Rahimian et al., 2011).

2.1. Charging strategies for EV

The understanding of the term charging strategy presented in this study differs from the one commonly used in the literature. In previous studies “charging strategy” is mostly applied in terms of timing the charging event (from an electricity grid perspective). Three options are mainly discussed: instant charging (uncontrolled charging), controlled charging (load and time), and V2G. The idea of controlled charging mainly focuses on avoiding load peaks and improving the electricity market efficiency by offering load shift potentials (flexibilization of electricity demand/demand response) (Axsen et al., 2011; Babrowski et al., 2014; Kang and Recker, 2009). Some studies analyze the real charging behavior of EV users in the context of timing, distribution, and type of charging (Khoo et al., 2014; Sun et al., 2015a, 2015b). Other “charging strategies” focus on sustaining a high SOH of the battery (Lunz et al., 2012). Our perspective starts from a mobility application that is focused on increasing the annual mileage of EV in order to replace mileage of ICEV. Therefore, not only the time and power of charging, but also the location is highly relevant.

Currently, many authors assume that charging takes place at home, at work or at other public electric vehicle supply equipment (EVSE) (Axsen et al., 2011; Neubauer et al., 2012; Speidel and Bräunl, 2014). The configuration of the EVSE varies between locations and countries depending on charging power, grid connections, and other technological standards (Azadfar et al., 2015). Previous research suggests that for first-time EV users, home charging is most convenient and most probable – especially for households in rural areas, in suburbs or for people with access to city parking garages. However, charging at work or in public is also seen as realistic. Consequently recharging at work or public places leads to less demand for charging at home (Kang and Recker, 2009; Neubauer et al., 2012).

Download English Version:

<https://daneshyari.com/en/article/5119979>

Download Persian Version:

<https://daneshyari.com/article/5119979>

[Daneshyari.com](https://daneshyari.com)