Generating electric vehicle load profiles from empirical data of three EV fleets in Southwest Germany

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Abstract

The increasing demand for electricity caused by a growing number of electric vehicles (EV) is a major challenge for future energy systems. For an integration of the electricity demand from EV, a comprehensive knowledge of its characteristics is essential. The analysis of charging behavior patterns of EV and resulting load profiles become important premises for this crucial task. Three electric mobility studies in Germany’s southwestern region (Get eReady, iZEUS, and CROME) deliver comprehensive data of EV use for this purpose. In this paper we analyze and discuss the mobility and charging characteristics of this data in detail. We derive empirical EV load profiles and show how they are affected by charging management as well as charging power. We present a model to simulate EV loads based on statistical characteristics of the conducted studies. The resulting charging load profiles show similar patterns as other EV studies. The developed simulation model and its results (see supplementary data available online) allow a realistic representation of EV demand in analyses of future energy systems.

1. Introduction

An increasing demand for energy, and electricity in particular, decreasing fossil energy source stocks and the necessity to act against climate change leads to a multitude of new policy objectives and measures. Supporting electric mobility is a major objective and leads to a shift from oil to electricity as an energy carrier particularly in the private transport sector. This will increase the impact of the transport sector on electricity systems. Yet, the current share of electric vehicles (EV) in Germany and most other countries is relatively low (below 1 % in January 2015 (EVI-IEA, 2016)). In consequence there is currently no demand for EV load forecasting by electricity suppliers (Linssen et al., 2009). However, various forecasts assume a rapidly increasing share of EV in the private transportation sector (e.g. Kieckhäfer et al. (2016)). In future, the energy system has to cope with this additional load. This adaptation requires precise forecasts of the load caused by electric mobility. Charging can only be controlled and regulated based on a good knowledge of future electric mobility pattern. This knowledge will enable the full potential of possible grid services (Habib et al., 2015) and market supporting measures (Drude et al., 2014). These measures are highly relevant in the context of energy transition and concomitant increase in renewable electricity generation (REG) as well as decentralized generation in general.

To address this need, this paper provides load profiles and a model for generating synthetic load profiles that are based on real EV mobility and charging data of three mobility studies with a total of about 30,000 recorded charging operations by more than 400 EV. To be able to fully understand the nature of the EV load we give detailed insights into characteristics of the underlying EV mobility data. As a consequence we give answers to the following research questions: (i) How can EV mobility and charging data be processed to create descriptive EV load profiles and what are the characteristics of these EV load profiles? (ii) How can EV load profiles be simulated using empirical charging data? (iii) What are the characteristics of these simulated EV load profiles?

The complete approach of this paper is shown in fig. 1. In a first step we give a literature overview of existing analyses of EV fleet studies, the subsequent performed simulation of EV load profiles and their applications (c.f. part 2). Following, the data basis from three field trials (c.f. part 3) and their statistical characteristics, filtering and preparation of these data sets (c.f. part 4) are addressed. Based on these data sets a subsequent empirical load profiles for various scenarios are derived (c.f. part 5). Moreover, the used methods and assumptions for the load profile generation are discussed. Subsequently, we present the simulation model that allows generating weekly or daily charging load profiles for a given number of EV based on the presented EV mobility data (c.f. part 6). The paper concludes by comparing the results with findings from other studies as well as validating and critically assessing the overall results of this paper (c.f. part 7).
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