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Transportation Research Procedia 19 (2016) 241 – 257

Transportation Research Procedia

www.elsevier.com/locate/procedia

International Scientific Conference on Mobility and Transport Transforming Urban Mobility, mobil.TUM 2016, 6-7 June 2016, Munich, Germany

Fleet Disposition Modeling to Maximize Utilization of Battery Electric Vehicles in Companies with On-Site Energy Generation

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Abstract

Various intelligent fleet disposition algorithms can be used to allocate mobility requests to a fleet of electric vehicles. However, none of these incorporate the issue of on-site energy generation at the company running the mixed fleets. This work presents an approach to distribute trips to a mixed fleet of conventional internal combustion engine vehicles and battery electric vehicles in coordination with a decentralized energy management, such that economic and ecologic target parameters are maximized. This includes a detailed charging schedule. A new algorithm based on a mixed integer linear program was developed that incorporates variable charging infrastructures, the mobility profile of a company and different vehicle classes, to produce an optimized usage schedule for the company. As main findings, the new developed model is capable of analyzing the financial and ecological potential of substituting individual ICEVs with BEVs and provides a customized recommendation for the optimal fleet composition, depending on the number of trips and the specification of the vehicles.

Peer-review under responsibility of the organizing committee of mobil.TUM 2016.

Keywords: Battery electric vehicle, fleet disposition, trip allocation, charging management, corporate mobility, utilization, operating cost

1. Introduction

The goal of the federal government to achieve 1 million registered battery electric vehicles (BEVs) by 2020 (Nationale Plattform Elektromobilität, 2010) can only be reached by addressing all consumers in the vehicle market.

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Peer-review under responsibility of the organizing committee of mobil.TUM 2016.
doi:10.1016/j.trpro.2016.12.084

Vehicle owners can be divided into private persons and corporate institutions. Company vehicles constitute close to 4.5 million cars, representing 10% of all registrations (Kraftfahrtbundesamt, 2015). Results of current research programs as the BMWI sponsored "Information and communication technology (ICT) for Electric Mobility II" demonstrate (Hacker et al., 2015): electrical powertrains can be applied to light trucks, buses and transport vehicles including service and delivery fleets. Commercial users in contrast to private owners exhibit features particularly suited for the application of electric vehicles: routing is more predictable, yearly mileage is higher and investment decision is based on TCO (Total Cost of Ownership) approach rather than purchase price (Hacker et. al., 2015). Furthermore, several analyses on the mobility behavior of commercial companies show that the region of operation is mostly limited to a radius of 50 – 100 km, often focused on the inner region of a city (Vogel, 2015). The integration of BEVs into commercial fleets allows reduction of local air pollution as well as noise exposure. In summary, commercial use of vehicles reveals a high potential for the application of BEVs.

TCO analyses have shown that BEVs require high mileages in order to overcompensate higher purchase prices with lower operating costs (Hacker et. al., 2015). At the same time, low range and lengthy charging periods restrict usability for long distance trips. The key to maximize utilization and avoid rejection of trips is to integrate BEVs into a shared fleet with multiple users. Trips can be freely assigned to any of the vehicles in the fleet, allowing BEVs to be preferred wherever feasible while simultaneously ensuring maximum coverage of all trips. A fleet disposition model to allocate each trip to a corresponding vehicle is required to ensure both feasibility as well as maximization of BEV benefits. The idea of this paper is to integrate on-site energy generation into the disposition model as well as including limited quantity and power of charging stations.

The model assigns trips depending on the actual minimization target: overall cost or overall emissions. In case of ecological optimization the simulation prefers recharging mainly with regenerative energy sources while at the same time maximizing the mileage of BEVs, aiming at a reduced carbon footprint. Optimizing overall costs can lead to preference of ICEVs, depending on the corresponding cost per kilometer. Likewise, recharging will be scheduled to periods of cheap energy availability, e.g., during nighttime. In general, the disposition model is capable of determining a detailed charging schedule for every BEV.

2. Related Work

Commercial fleet management tools are recommended for fleet sizes greater than 5 to 7 to ease administration of accounting, monitoring vehicle conditions and adhering to maintenance requirements (Grausam et. al, 2015). Some fleet management tools offer fleet disposition plug-ins in addition. However, only few solutions support range and charging restrictions of BEVs. The "comm.fleet" software assigns trips according to cost per kilometer, CO_2 emissions or overall utilization. In addition, it provides various options for users to specify their vehicle demand, e.g., features and number of seats (Community4you, 2015). "fleetster" specializes on corporate car sharing and offers a web and app based reservation interface which is independent of the fleet manager (Next Generation Mobility, 2015). Allocation of trips can either be chosen by the user or is determined automatically by cost comparison. However, both solutions focus on real time functionality, i.e. each user is appointed a vehicle immediately during the reservation process. Reservations scheduled earlier or later are not taken into account. Therefore, only local optima can be determined.

Research on global optimization of fleet disposition has been conducted with different aims. In general, static and dynamic scheduling has to be distinguished. Static approaches assume all trips are known at the beginning of the day and do not exhibit any changes. Dynamic methods focus on flexibility regarding unforeseen events such as break-downs or accidents and tolerate obligatory loss in optimality.

2.1. Static scheduling

Sassi and Oulamara (2014) examined the application of BEVs in fleets comprising up to 120 vehicles. The Electric Vehicle Scheduling and Charging Problem (EVSCP) proposed is defined as follows: for a given number of trips, BEVs, ICEVs and charging infrastructures a disposition schedule shall be deduced such that the kilometers driven by BEVs is maximized. This optimization problem can be classified as a variant of Fixed Interval Scheduling (FIS) with the additional constraint of limited energy of each BEV (Kovalyov et al., 2007).