

INTEGRATING E-TRUCKS INTO ELECTRICITY MARKETS BY OPTIMIZED CHARGING

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Overview

Two most recent developments led to a groundbreaking change in the market perspective of drivetrains in freight transportation (Link et al., 2024): The improvements of the battery technology and charging technology led to the situation that almost every truck trip in Europe can be undertaken by a battery electric truck because the mandatory rest time of truck drivers for 45 minutes after 4.5 hours of driving can be used to recharge the battery for the next allowed driving time. Together with the speed limit of 80 km/h (50 mph) the maximum mileage between the breaks becomes 360 km (225 miles). Current e-Trucks offer the required range (e.g. Daimler eActros, MAN eTGX) and charging power of up to 1 MW are completely compliant with this regulation. This, together with a significantly lower total cost of ownership for e-Trucks compared to conventional diesel trucks, may lead to a fast market uptake for e-Trucks, soon. However, the charging solution for their company ground is often unclear and logistics companies are hesitant to invest.

Consequently, the idea of this paper is to estimate the potential profits logistics companies can expect if they connect their e-Trucks during dwell times to the charging unit and allow a third party (i.e. an aggregator) scheduling the charging and discharging process optimally according to forecasted electricity prices on different wholesale electricity markets (i.e. day-ahead, intraday and balancing (aFRR) markets) in Germany. By utilizing charging infrastructure and optimizing charging and discharging during empirical based dwell times at depots, potential revenues for e-truck owners are compared to a "zero intelligence" charging approach. The analysis evaluates the impact of key parameters, such as different charger power levels and final desired state of charge (SOC) on potential revenue. For each month in 2023, a sample day was randomly selected, and the corresponding spot market and balancing market prices were extracted. Using empirical data from the German truck fleet (Wermuth et al. 2012), a random set of charger powers from a constant list, a random matrix of hypothetical hourly energy call for aFRR energy market and a developed mathematical model, maximum revenue from all trucks participating in the vehicle-to-grid (V2G) market lead to revenues of up to € 70 per truck and night for the month of October 2023 in average. This easily compensate the costs for smart charging infrastructure. Hence, new businessmodels might be developed from these results.

Methods

A mathematical optimization model was developed using Python and Gurobi to maximize the profit of e-trucks participating in electricity markets. The study utilized empirical truck data from the KiD-2010 survey (Wermuth et al. 2012), including truck arrival and departure times, parking hours, and charging power levels, along with 2023 prices for all three considered electricity markets (eex.com). Six scenarios were evaluated, each varying key parameters like bidirectional charging, final state of charge, and charger power levels. The optimized V2G profits were compared to a "zero intelligence" baseline, revealing the financial benefits of controlled charging strategies for e-truck operators.

Results

The e-truck owners can make on average a profit from € 10 up to € 70 per night allowing V2G use (cf. *Figure 1*). This profit will decrease if only unidirectional chargers or lower charger powers are used (68% and 18% respectively), or in fewer number of markets participated (28%). However higher charger powers lead to more profit (10%).

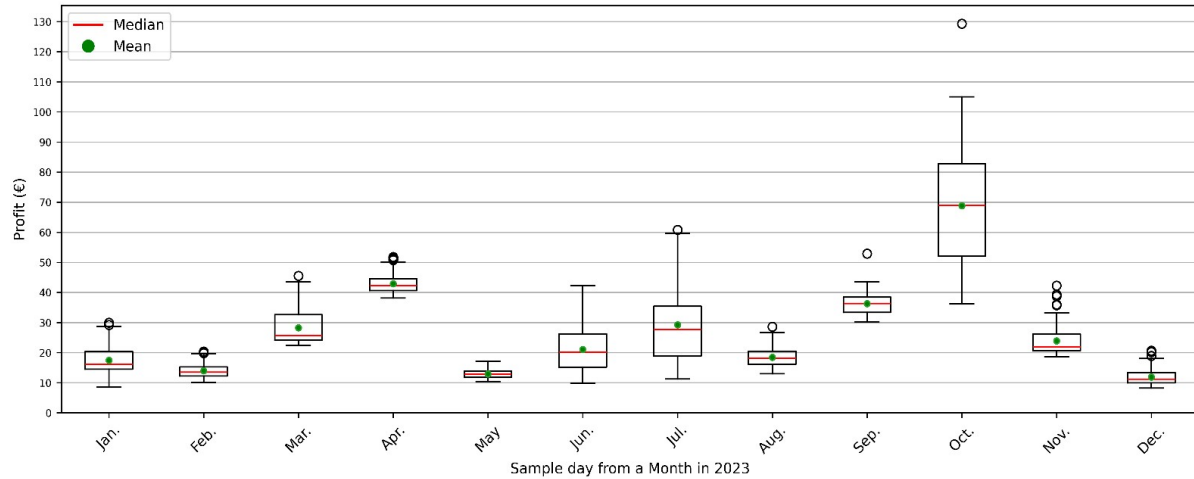


Figure 1: Average profits per truck per overnight dwell time

Conclusions

Recent developments in battery and charging technologies lead to a groundbreaking change in the truck market. Together with European regulation almost all trips are suitable to eTrucks – if sufficient charging stations are available (which is not yet the case). This research identified significant revenue potentials for German logistic operators of eTrucks if providing their charging flexibilities to wholesale electricity markets. Especially bidirectional charging might lead to an overcompensation of charging costs. Business cases of new aggregators might play an important role since an increase in the participating truck fleet decreases risk for commitments to the market.

References

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