Evaluation of Four Possible Load Shifting Strategies for Electric Vehicles Utilizing Autoregressive Moving Average Methods for Electricity Price Forecasting

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Abstract. This paper quantifies and compares monetary saving effects that can be achieved by applying different instances of a load shifting system to battery charging of electric vehicles. Along this line, we evaluate four possible load shifting strategies including two methods for predicting energy prices. The proposed strategies refer to a demand side management where electricity customers actively respond to a fluctuation of market prices within 24-hour cycles. We find that forecasting strategies outperform fixed charging times only by a relatively small margin.

Key words: Load Shifting, Load Shifting Strategies, Electricity Price Forecasting, Autoregressive Moving Average Methods

1 Evaluation of Load Shifting Strategies

German policy makers have formulated ambitious targets to accelerate the adoption of electric vehicles: Until the year 2020, more than one million electric vehicles should be registered within the country [1]. While critics argue that these goals are too aggressive and not fully realistic, there nevertheless appears to be some agreement that electric vehicles will be the future of individual road transport and sooner or later overtake convectional cars in numbers. Along this development, systems for battery charging will considerably gain importance. The development goes hand in hand with the fast adoption of renewable electricity sources and the creation of a fluid electricity market in order to handle the partly stochastic electricity supply by rewarding demand flexibility on the side of the consumers.

In this research in progress paper, we aim at optimizing the charging cost of electric vehicles under the assumption that tariffs are available that follow the spot market price for electricity (plus some fixed and/or relative margin for the retailer, the grid operator, etc.). In order to achieve high validity of the results, we use hourly intraday electricity prices from the EEX PHELIX stock market index for Germany and Austria that are available online from the energy exchange. Moreover, we use the specification of an electric vehicle that is commercially available (a BMW i3 with a 125 kW synchronous motor, a usable battery capacity of 18.8 kWh, and a norm-cycle consumption of 12.9 kWh per 100 km) as a model car in order to quantify possible savings. The charging profile introduces an exemplary car owner who uses the car from 07:00 AM to 07:00 PM. The remaining time period can be exploited for a load shifting strategy [2].

The first strategy under observation is rather simplistic and primarily serves as reference scenario. Here, the charging process starts at constant power whenever the test user arrives at home. This strategy is referred to as forward scheduling. The second strategy takes advantage of an inherent characteristic of 24-hour electricity prices, namely the fact that energy prices regularly achieve a daily minimum between after midnight and before early morning, as historic price curves reveal. The car is charged in such a way that the battery is full just in time at 07:00 AM. This strategy is named backward scheduling. The third strategy uses an exponential smoothing technique in order to determine and exploit the possibly cheapest time windows in accordance to the prediction. This strategy substitutes for the forecast of strategy two. The fourth strategy is the most advanced approach as it aims at dynamically determining and exploiting time windows of low energy prices by predicting electricity prices using an autoregressive-moving-average (ARMA) model [3]. We use the Akaike Information Criterion (AIC) as a means for selecting the best model, considering manual data adjustments and seasonality presumptions.

Subsequently, the most promising predictive strategy is selected by comparing the mean absolute deviation (MAD) of predicted values versus actual values. Finally, the financial saving potential is exemplary estimated by comparing both the second and the best of strategies three or four with strategy one.

The study illustrates that basic time series forecasting methods for electricity prices can be used to improve the exploitation of low price time windows on the electricity market. Therefore, owners of electric vehicles, with short loading times in particular, profit from the application of a demand side management of battery charging. The possible savings due to an active reaction to market fluctuations can be approximated, leading to a hands-on recommendation for e-car owners.

The preliminary findings, as illustrated in Fig. 1, reveal that the forecast strategies three and four outperform strategies one and two in terms of low price time window exploitation on a sample day. It shows that the simple approaches in strategies one and two fall short in comparison to strategies three and four.

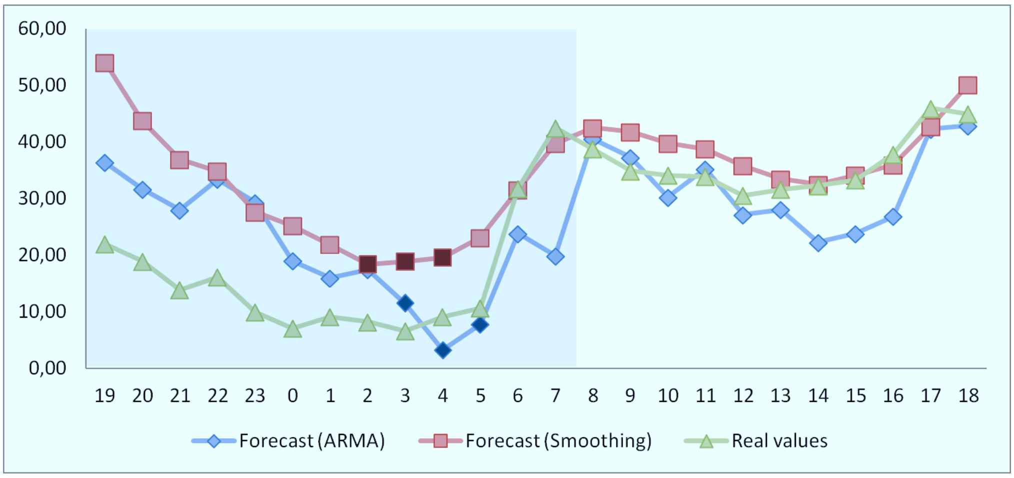

Fig. 1. Forecast 03.11.2013-04.11.2013

For the sample day, overall savings for strategy three amount to 56.3% compared to strategy one and 53.6% compared to strategy two. The application of strategy four saves 51.9% compared to strategy one and 48.9% compared to strategy two.

2 Conclusion and Outlook

Strategies that use forecasting of electricity prices help to reduce the cost of charging electric vehicles. Not surprisingly, these strategies outperform approaches that utilize simple static charging times that are defined according to historic price curves. However, the earnings appear to be rather small – even if one assumes that perfectly accurate price forecasts were available. The reason for the small effect size is the largely self-similar profile of daily electricity prices that allow for defining fixed but reasonably accurate time windows of low prices in combination with the relatively long charging times of the batteries. Nevertheless, one can assume that forecasting strategies will become more attractive if the volatility of electricity prices increases along the growing share of electricity from stochastic energy sources such as wind and solar. On the other hand, forecasting in combination with large loads may reduce the price variability on the spot market, which might reduce the overall effect size. Future work should thus consider more complex models that take the feedback effect into account in order to obtain a more precise picture of the benefits of charging strategies.

References

1. German Federal Government: Nationaler Entwicklungsplan Elektromobilität der Bundesregierung. Berlin (2009)
2. Prüggler, N.: Economic potential of demand response at household level—Are Central-European market conditions sufficient? Energy Policy (60), pp. 487–498 (2013)
3. Contreras, J., Espinola, R., Nogales, F. J., Conejo, A. J.: ARIMA models to predict next-day electricity prices. IEEE Transactions on Power Systems, vol. 18(3), pp. 1014-1020 (2003)