Institution of Electrical Engineering and Automation | Lund University, Faculty of Engineering |
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Master Thesis: Battery Profit Optimization
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Battery Profit Optimization

Popular science summary by *Ebba Helfer*

An electric vehicle battery's life can be divided into a 1st and 2nd life. After a few years of usage, the vehicle battery is no longer suitable for the vehicle application, due to degradation, but that does not mean that the battery itself is useless. At that point in time, the battery can be removed from the vehicle, and begin its 2nd life, connected to the grid.

The battery's two lives

In the future, a market full of 2nd life batteries will be formed, as a consequence of the electrification of the vehicle fleet. Simultaneously as the 2nd life market is growing, Svenska Kraftnät, who is responsible for maintaining the grid frequency at 50 Hz in Sweden, are fearing difficulties in maintaining the grid frequency at the desired level. This has lead to increased investments in the balancing markets, where large and small scale energy suppliers can trade so called ancillary services.

The battery's life is limited by either the cycling or the calendar life. The calendar life can, in a simplified manner, be viewed as a number of days during which the battery can store and provide energy. In contrast, the cycle life is defined as a number of cycles the battery can perform before reaching end of life (EoL) and this number varies with the depth of the cycles, meaning that the deeper cycles a battery performs, the fewer cycles can be performed. When a battery is in a commercial vehicle, it is usually cycled deeply, as there is a profit loss if the vehicle stands still for too long, during e.g. charging. However, when the battery instead is connected to the grid, there is a possibility to cycle the battery more shallow, as the state of charge (SoC) can more easily be controlled by an implemented algorithm.

As the battery´s life can be divided into two, and the battery earnings differ per calendar day for the different applications, the question arises when to remove the battery from the vehicle application, and instead connect it to the grid, in order to profit maximize. When the battery has reached its EoL in the vehicle, it can be taken out and several battery packs can be connected together, forming a battery energy storage system (BESS). In turn, this BESS can trade on both energy and power markets, entailing significant revenue, whilst providing Svenska Kraftnät with ancillary services and thus contributing to a more stable grid.

This market opportunity was investigated in the thesis by implementing an analytical tool, which mimics the potential battery ecosystem, in MATLAB.

First, a battery degradation model was implemented which, with the help of the pre-existing rainflow algorithm, calculated battery degradation based on a charging cycle. Secondly, a trading algorithm, which traded on the balancing markets and the day-ahead market was implemented, considering a set of rules formulated by Svenska Kraftnät. Lastly, a sensitivity analysis in the form of a parameter sweep was conducted to investigate how different battery characteristics and market climate affect the total earnings, expected battery life time and degradation.

Results

In general, the results show that the earlier the batteries are removed from the vehicle, the higher total earnings are reached until EoL. This extends to the preference of cycling the batteries deeper in the 1st life, so that a lower state of health (SoH) is reached earlier, in terms of calendar days.

For the simulations performed, the total earnings until EoL vary between 1.10 to 4.55 million euros, with the highest earnings rewarded to the battery with the best characteristics, and vice versa. An average earnings case is presented in the figure below, together with its expected life time. For almost all cases, the highest earnings are achieved for the trade size/extreme price combination which has a life time limited by the cycle life, and not the calendar life. Additionally, several of the results show a clear optimal combination regarding how to design a trading algorithm in order to profit maximize.