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Impact of V2G service provision on batteries

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A battery model was developed to analyze the degradation in the battery of an electric vehicle (EV) due to the provision of vehicle-to-grid (V2G) services. The model was coded in a python script so that simulations of an EV, that regularly performed V2G services, could be performed. The insights gained from these simulations assisted in the techno-economic analysis of a case study, wherein a company installs V2G chargers at its premises to profit from its employees' EVs by either providing ancillary services to the grid or by peak shaving. Three types of V2G services were simulated and the results showed that two of them had a reasonable payback period for the company, under the given conditions.

CSEM was asked to carry out a study under the frame of the InterReg RegEnergy project, where Planair S.A., Greenmotion S.A., and Groupe Renault are analyzing the integration of PVs and EVs at the Y-Parc technological park in Yverdon-les-Bains. The primary objective of the V2G study was to analyze the impact of V2G service provision on the Li-ion battery of an EV. In pursuit of this objective (i) an extensive literature review on V2G installations in Europe and the effect of V2G service provision on batteries was performed, (ii) a model to compute the amount of degradation a battery underwent, based on its usage profile, was developed, and (iii) this model was used to perform a techno- economic analysis of degradation in the battery of an EV that provided various V2G services.

The battery model developed consisted of two parts, (i) a battery dynamics model and (ii) a battery degradation model. The dynamics model includes the voltage, internal resistance and the state of charge (SoC) change during charging and discharging phases. It was based on a simple equivalent circuit model consisting of a voltage source (which varied as a function of the SoC) and a variable resistor (which varied with the SoC and temperature). The degradation model described the calendar and cycle aging that the battery would undergo during its lifetime, thus accounting for the state of health (SoH) decrease. It was based on a semi-empirical stress factor model. The calendar aging was modelled to be dependent upon the storage SoC and temperature while cycle aging was dependent on the current rate (C-rate), temperature, average SoC and depth of discharge (DoD) during cycling. The state of resistance (SoR) increase was also modelled in a similar fashion with it being dependent on the C- rate, average SoC and DoD during cycling. The decrease in SoH and increase in SoR accounted for the capacity fade and power fade in the battery, respectively.

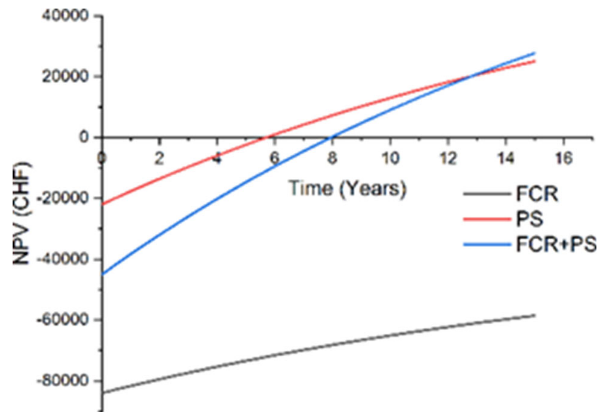

Figure 1: Illustration of the output of the degradation model.

The parameters for the model were derived using data from experiments performed on Li-ion NMC cells within the energy system lab at CSEM in Neuchâtel and the Energy Storage Research Center (ESReC) in Biel/Bienne. These experiments included Galvanostatic Intermittent Titration Technique (GITT) tests to obtain the relation between the open circuit voltage (OCV) and SoC, and Electrochemical Impedance Spectroscopy (EIS) measurements to derive a relation between the resistance of a cell, its temperature, and SoC. The parameters for the degradation model were obtained by performing battery aging experiments at different temperatures, DoDs and C-rates.

The above model was coded in a python script which takes the battery usage profile, number of days to be simulated, battery size, etc. as inputs and output the battery degradation over the simulated period. An example of the output is shown in Figure 1.

The model developed was used for a techno-economic analysis for a case study described as follows: A company planned to install V2G chargers at its premises so that it can use the employees' EVs to provide V2G services such as frequency containment reserve (FCR) or perform peak shaving (PS) to earn revenue or save costs, respectively. The challenge was to compute the degradation in the battery due to the V2G provision and, thereby, decide upon the amount of compensation to be given to the employees that will incentivize them to participate in this program. Finally, an evaluation of whether this was a profitable venture had to be carried out. Three scenarios were simulated wherein: (i) only FCR was provided [FCR] (ii) only PS was performed [PS] and (iii) FCR was provided simultaneously together with PS [FCR+PS]. The techno-economic analysis of the scenarios showed that considering a 12 kW charger costing CHF 1000, the FCR scenario was not profitable. However, the cost of the charger dropped to lesser than CHF 300, this scenario may become more interesting. On the other side, the PS and FCR+PS scenarios are more profitable after a payback period of 6 and 8 years, respectively, as shown in Figure 2.

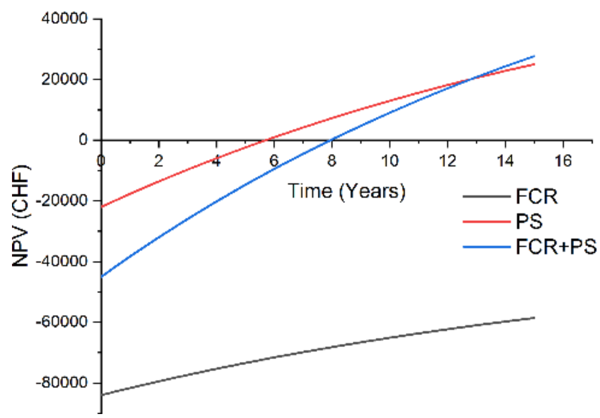

Figure 2: NPV evaluation for the 3 simulated scenarios.

CSEM and RegEnergy partners are now in discussion on how to best profit from the project results in the light of the Y-Parc V2G implementation plans. On CSEM side, next steps will be to: (i) publish the developed simulation model, and (ii) to improve it in the frame of the IEA annex 32 initiative, in which CSEM aims at developing an open-source tool to estimate the degradation impact on Li-ion batteries from different applications.