Participation of vehicle-to-grid fleets into the primary frequency control market

Neil Piton, Prof. Jean-Yves Le Boudec, Prof. Marc Petit from CentraleSupelec
Mail: neil.piton@epfl.ch

Abstract
Parties of the Paris Agreement “recognize that […] sustainable patterns of consumption and production […] play an important role in addressing climate change”. Worldwide, transportation sector is responsible for 23% of the total greenhouse gases emissions [1]. Bearing it in mind, car manufacturers are developing full electric vehicle solutions in order to avoid use of fossil fuel for transportation. Electric vehicles should be included in the operation of the electric grids for system wide and local grid services. This article highlights the possibility and the profitability of V2G fleets to perform primary frequency control under some assumptions, with two case studies: a company fleet from CEA-Grenoble and a car sharing fleet from a “ecomobility” company named Clem’.

Company Fleet case study: theory and results
A fleet of 20 Twizy (Renault), used by the company during the day and in charging mode from 8PM to 5AM. Vehicles have bidirectional capabilities. Frequency control is performed during the charging process. Each half hour the fleet estimates the needed power operating point (POP) to charge the vehicles from the state of charge (SOC):

\[
P_{\text{charge}} = \min \left( \frac{SOC_{\text{max}}(t + t_{\text{max}}) - SOC(t)}{t_{\text{max}}} \right) P_{EYSE}
\]

\[
P_{\text{discharge}} = \min \left( \frac{SOC(t) - SOC_{\text{min}}(t + t_{\text{max}})}{t_{\text{max}}} \right) P_{EYSE}
\]

\[
POP = \frac{P_{\text{charge}} + P_{\text{discharge}}}{2}
\]

Available power for primary frequency control is computed from the previous POP calculation. Converters efficiency induces asymmetrical calculation in function of the sign of POP:

\[
P_{\text{bid}} = \begin{cases} P_{EYSE} - \eta \cdot |POP| & \text{if } POP \geq 0 \\ P_{EYSE} - |POP| / \eta & \text{if } POP < 0 \end{cases}
\]

An aggregator collects the calculated \( P_{\text{bid}} \) of all the vehicles and sums them to obtain a total \( P_{\text{bid, total}} \) for the entire fleet, available during one hour until the next clearing period, at the grid connection point. Then, within the same period, the aggregator performs frequency measurements to estimate the regulation power \( P_{\text{reg}} \) the fleet has to adopt by applying a factor \( \frac{1}{f_{\text{max}} - f_{\text{min}}} \) to \( P_{\text{bid, total}} \) if the frequency droop is less than 200mHz (otherwise all the reserve has to be set). For the dispatching program, the aggregator communicates the factor \( \frac{1}{f_{\text{max}} - f_{\text{min}}} \) to be applied to all the vehicles, i.e. the dispatch is uniform.

Simulated revenues from frequency containment reserve: 145.5€ by vehicle and by year, and 122.7€ by subtracting electricity losses from converters efficiency (efficiency set to a constant for simplicity reasons).

Car Sharing case study: theory ans results
Car sharing introduces a more complex component, since demand is not as predictable as in the company fleet case. Solution to provide frequency reserve with car sharing fleets would be to consider an aggregation of a larger number of vehicles to avoid lacking contracted reserve.

Real data on Renault ZOE, bidirectional capabilities considered since unidirectional capabilities constraint frequency reserve participation. For each time step, aggregator verifies if there is any customer who wants to reserve a car for the future. A car is assigned only if its SOC is sufficient to provide the consumption for the reservation period (calculation is made thanks to a mean consumption in kWh/1/2h).

If \( SOC < \beta \cdot SOC_{\text{max}} \), with \( \beta \in [0,1] \) a chosen parameter, the battery needs to be charged:

\[
P_{\text{ch}} = \min \left( \frac{SOC_{\text{max}} - SOC(t)}{t_{\text{max}}} \right) \eta \cdot P_{EYSE}
\]

\[
P_{\text{POP}} = \text{quantification of} \left( \frac{P_{\text{ch}}}{2} \right)
\]

\[
P_{\text{bid}} = \min \left( \frac{1}{\eta} \cdot |POP| \right) P_{EYSE} - \frac{1}{\eta} \cdot |POP|
\]

Otherwise, when \( SOC \geq \beta \cdot SOC_{\text{max}} \), we compute powers as in the company fleet case study, i.e. the operating power will fluctuate between the lower limit \( \beta \cdot SOC_{\text{max}} \) and the upper limit \( SOC_{\text{max}} \) in red on the figure below.

Simulated revenues from frequency containment reserve: 1679,6€ by vehicle and by year, and 725,2€ by subtracting electricity losses from converters efficiency (\( \beta = 0,7 \)).

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References