EV flexibility for the Electric System: The FCR case
Outline

1. Context & Objective
2. Mathematical formulation
3. Some results & perspectives
Context & Objectives
1. Context & Objectives

French Transportation Facts:
- Transportation represents 30% of the total final energy consumption
- Gas represents 98% of its energy source
- Road transportation represents 90% of it

Basic Transition to EV might:
- Stress the electricity production
- Stress the transportation network
- Stress the distribution network

Unless...
1. Context & Objectives

The charging schedule is integrated with the electric grid/production

Smart Charging is a first level integration of EV charging. It allows to reduce the stress by shifting the power usage in time and avoid consuming at the peak demand.

Vehicle to Grid (V2G) makes possible the EV to discharge the battery on the power grid. This allows to also reduce the global peak demand by reinjecting power to the grid.

V2G allows a seamless integration of the EV with the electric system.

In this work, we want to explore a tight integration of EV charging with the electric system.
1. Frequency Containment Reserve

It is mandatory to keep the AC frequency really close to 50Hz (in Europe)
• Main electric production units (Thermal & Hydraulic) require that (for ☠ reasons)
• The frequency reflects the balance between consumption and production
• Every day, we reserve some production capacities to dynamically adjust the production to maintain the frequency between acceptable values
• This is the Frequency Containment Reserve

In this work, we developed a method to optimize an EV fleet charging schedule while:
• Dynamically adjusting the charging power according the frequency
• Taking into account TSO requirements

This is the tightest integration with the electric system
Mathematical model
Hypothesis:
- Assuming the FCR capacity is already defined
- The time arrival and departure of each EV in the fleet is given
- The SoC at time of arrival is also given

The problem is to construct a charging schedule for each EV that minimizes the overall charging cost while
- fully charging the evs at the end of the charging session
- preserving enough power and energy capacity for the FCR
2. Some notations

\[ \delta t = \text{timestep duration} \]
\[ p_{ev,t} = \text{charging power (> 0 means charging, < 0 means discharging)} \]
\[ batt_{ev,t} = \text{state of charge of the battery} \]
\[ capacity_{ev} = \text{battery max capacity} \]
\[ c_t = \text{electricity cost} \]
\[ \rho = \text{battery efficiency} \]
\[ FCR_{ev,t} = \text{power reserved for FCR service} \]
\[ \delta t_{FCR} = \text{requested duration at full FCR activation} \]
\[ demand_t = \text{FCR demand} \]
\[ t_{0, ev}, t_{F, ev} = \text{begining and ending of the charging session} \]
2. Basic V2G Smart Charging

\[
\text{min} \quad \sum_{ev,t} c_t p_{ev,t}
\]

s.t.

flow: \quad \text{batt}_{ev,t} = \text{batt}_{ev,t-1} + (\rho \text{p}^+_{ev,t} - \text{p}^-_{ev,t}) \delta t

capacity: \quad \text{batt}_{ev,t} \in [0, \text{capacity}_{ev}]

pmax: \quad \text{p}_{ev,t} \in [-p_{max}, p_{max}]

SoC_0: \quad \text{batt}_{ev,t_0, ev} = \text{SoC}_{ev}

SoC_F: \quad \text{batt}_{ev,t_{F, ev}} = \text{capacity}_{ev}

transaction: \quad \text{p}_{ev,t} = 0 \forall t \notin [t_{0, ev}, t_{F, ev}]
2. FCR requirements

\[\begin{align*}
\min & \sum_{ev,t} c_t p_{ev,t} \\
\text{s.t.} & \\
FCR : & FCR_{ev,t} \geq 0 \\
powercapacity : & p_{ev,t} + FCR_{ev,t} \leq p_{max} \\
& p_{ev,t} - FCR_{ev,t} \geq -p_{max} \\
batterycapacity : & battev_{t} + \rho(p_{ev,t} + FCR_{ev,t})\delta t_{FCR} \leq capacity_{ev} \\
& battev_{t} - (p_{ev,t} - FCR_{ev,t})\delta t_{FCR} \geq capacity_{ev} \\
demandsatisfaction : & \sum_{ev} FCR_{ev,t} = demand_t
\end{align*}\]
2. Basic Idea

Source: Vandael 2013
Some results & perspectives
3. Simulations:

![Graph showing overall fleet power and fleet power with FCR activation over time.]
3. Simulations

Overall fleet power with FCR activation

FCR demand
FCR capacity

Overall fleet power with FCR activation
3. Conclusions

We were able to integrate smart charging and FCR service
While guarantying the quality of service for the user AND the TSO

Next: ...
New services for the electric system to fully integrate V2G and electric system
In order to reach the same level of services as a regular power plant
This (and much more) already exists...
4. Dreev: Smart Charging for Flexibility Markets

- EV flexibility aggregator for services to the electric system
- V2G and V1G
- Development in France, UK, Italy, Belgium, Germany
4. Dreev: Smart Charging for Flexibility Markets

What if your EV could earn you money?

Discover our offers
Thank you for your attention