Paris Session 2022

cigre
For power system expertise

Tutorial

Electric Vehicles as Distributed Energy Resource (DER) Systems
Part 2

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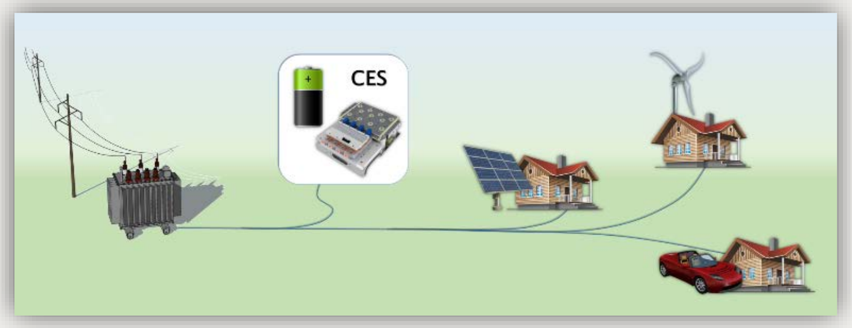
Tutorial - Part 2

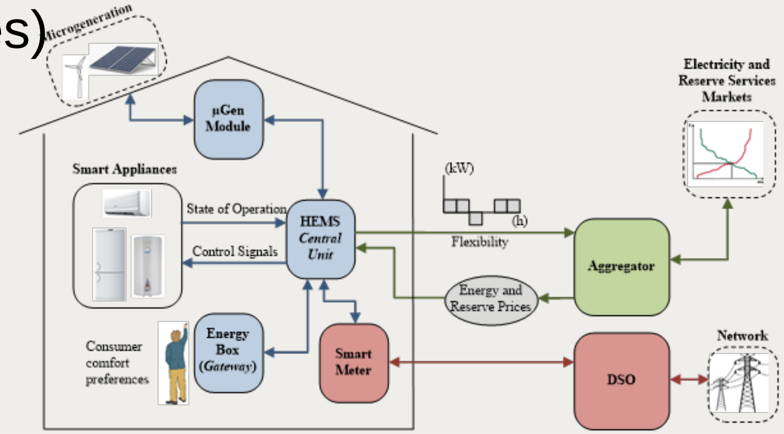
EV Control Charging
Provision of AncillaryServices to DSO & TSO

Types of DER

- Distributed generation (solar PV, wind power, mini-hydro plants, CHP)
- Stationary storage units
- **Electric vehicles batteries**



- Load with demand response capability (Smart Homes)

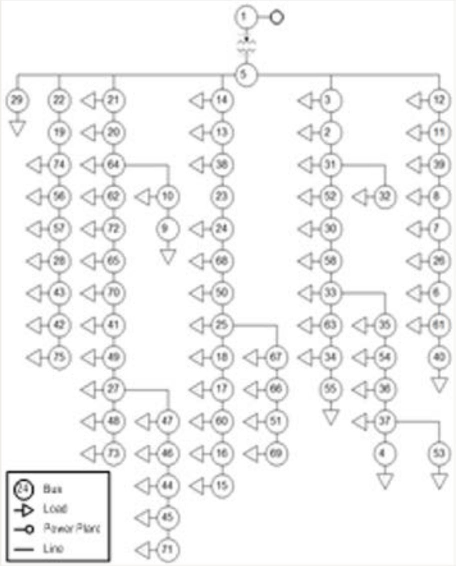


Main approaches to control EV charging

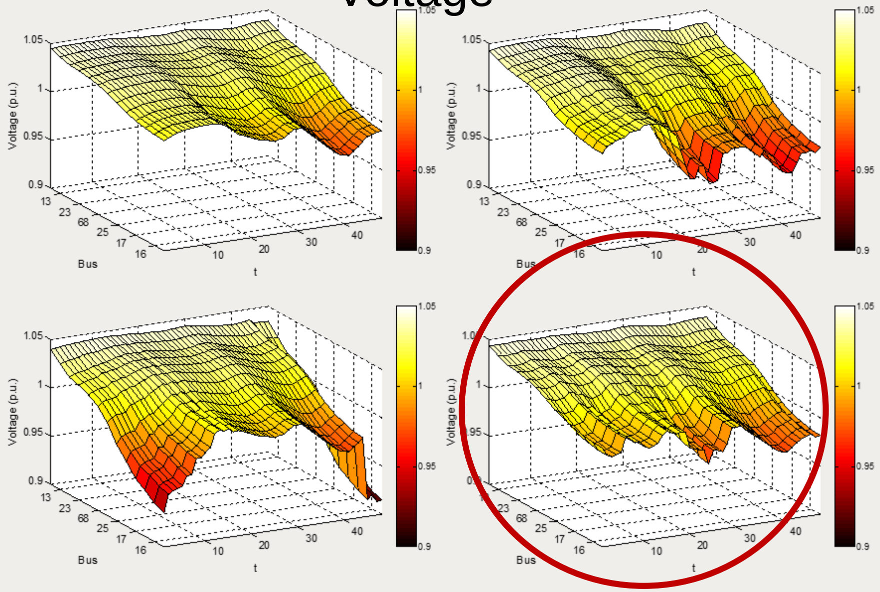
- Uncontrolled / Dumb charging
  - Charging starts automatically when EVs plug-in and lasts until its battery is fully charged or charge is interrupted by the EV owner
- Time-of-use tariff / “multiple tariff”
  - EV are responding to price signals / Tariffs
- Controlled Charging / Smart Charging / V1G
  - EV active charging management developed by Aggregators or DSO
- Vehicle-to-Grid (V2G)
  - Aggregators control the power that EVs inject into the grid
- Vehicle-for-Grid (V4G)
  - Voltage support provided by EV power converters (reactive power control)

Grid impacts of different EV charging approaches

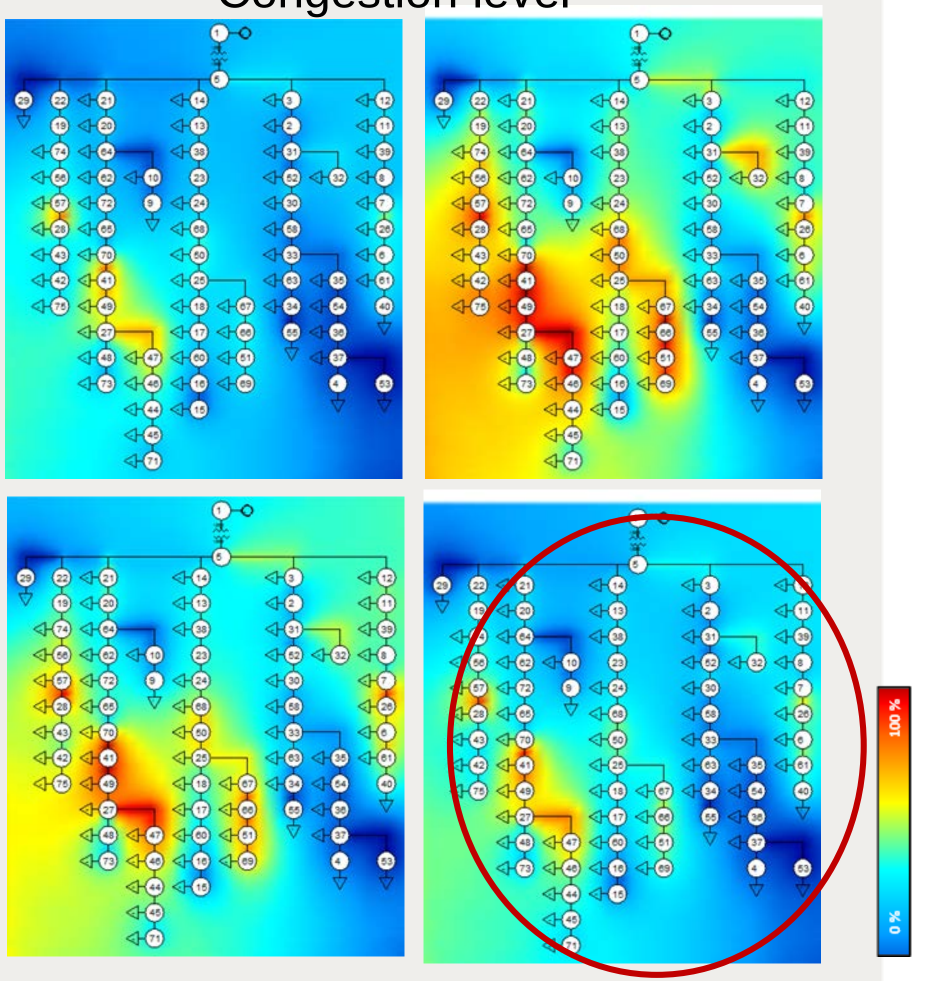
Impacts on LV network

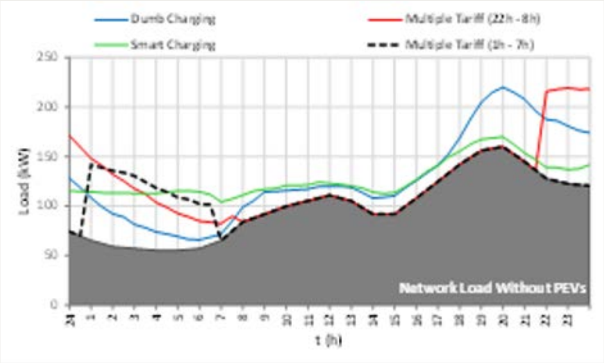


Voltage



Congestion level





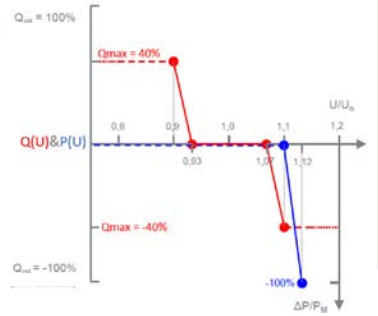
No Evs	Dumb charging
ToU Tariffs	Smart Charging

Controlled charging provokes less impacts on the grid

Enabling Smart Charging and V2G / V4G

- The adoption of Smart charging and V2G will allow:
  - To control bus voltage and branch congestion levels dealing with conventional load changes and local renewable generation (avoiding curtailment of renewable sources)

- V2G & V4G control strategies
  - **Dispatching EVs in the four P-Q quadrants is highly effective at supporting voltage** in distribution feeders. EV power converters (in V2G) can operate in any of the P-Q quadrants with slight modifications to the charger, providing or consuming reactive power locally, and without a large impact on batteries life cycles. EV converter set points can obtained:
    - Distribution OPF, where P, Q from the EV converters are control variables
    - Via **smart power chargers** capable to adapt their reactive power via a local droop control mode.
  - Voltage regulation strategies similar to the ones used to control power generated by PV facilities should be adopted for EV charging when there is poor voltage performance.
  - → Regulators should encourage new designs for charging equipment to be capable of providing reactive power support.



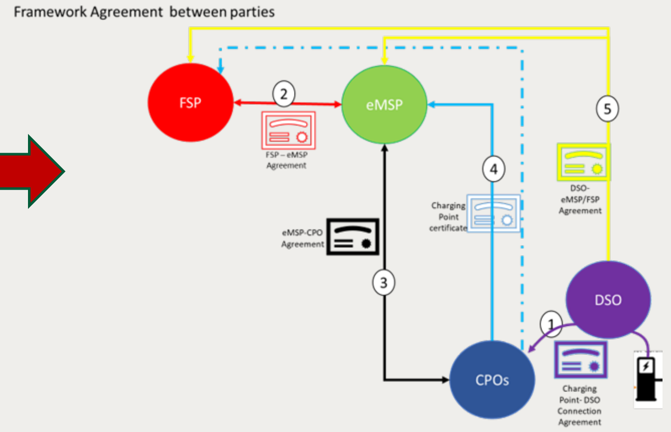
Enabling Smart Charging and V2G

- The adoption of Smart charging and V2G / V4G requires the adoption of communication standards between the EV and the charging infrastructures:
  - For control of charging in AC up to 22 kW in mode 3, IEC 61851 can provide the necessary support, using the integrated pilot wire;
  - For DC charging in mode 4 using CHAdeMO (Japan) and CCS (Europe), ISO 15118 provides the required support. For V2G the ISO 15118-20 is the adopted standard.

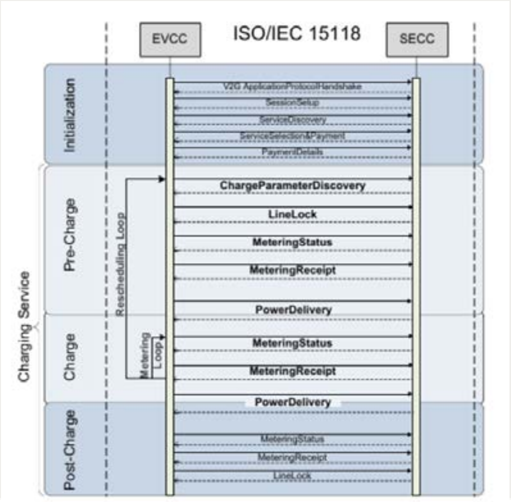
- The ISO 15118 standard opens the possibility for energy companies, DSO and solution providers to exploit the flexibility provided by electric vehicles.

- Data transmission between CPO, FSP, and DSO must be interoperable.

Data exchanges must be standardized



Activation of V2G Service According to ISO15118-20



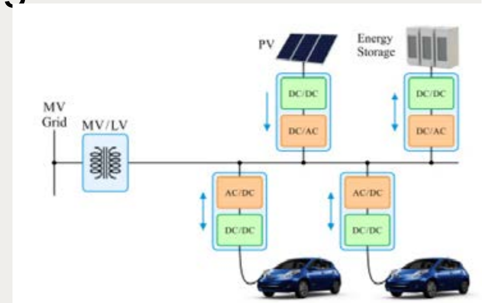
Fast Charging: A challange for future planning and operation of Distribution grids

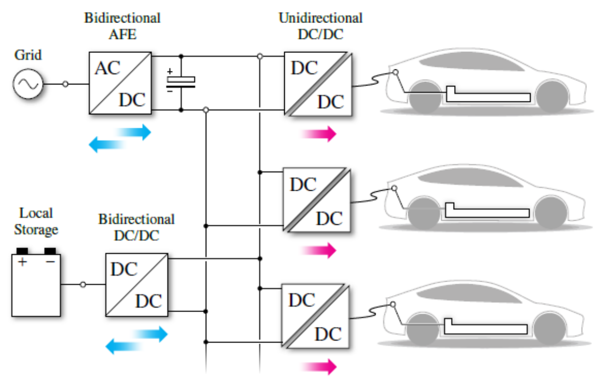
- Fast EV charging units can have charging capacity between 50 and 350 kW.

- Charging stations can present a total charging capacity between 500 kW and 10 MW. Future charging stations in motorways can range up to 50 MW!

- This provokes large impacts in grid operation: large voltage drops, branch overloads, power quality…

- The design of these charging stations requires local storage units (ultra capacitors and batteries) and local renewable generation to support the charging duties;



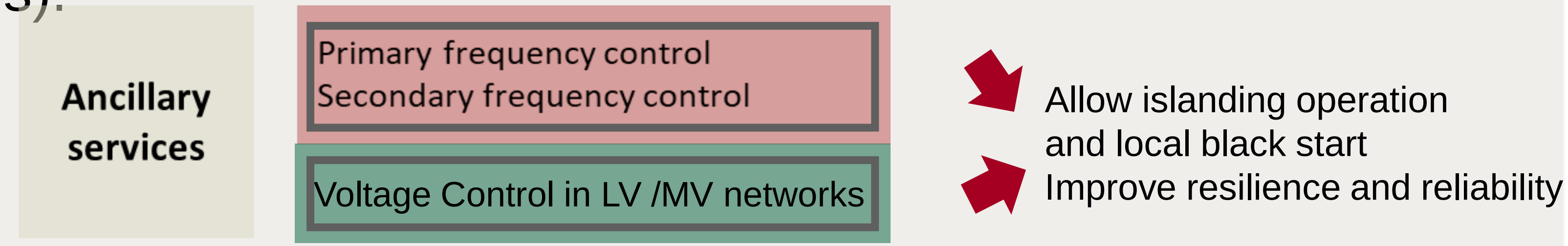


- Charging stations need to be supplied via a HV distribution infrastructure with a meshed structure. In motorways with a charging station in every 50 km the load of this infrastructure will be considerable and will require an almost dedicated supply grid.

Provision of Ancillary Services to DSO and TSO

- EV can be regarded as a very flexible resource:
  - Controllable loads – when using Smart charging strategies
  - Distributed storage units – when operated in Vehicle to grid (V2G) mode

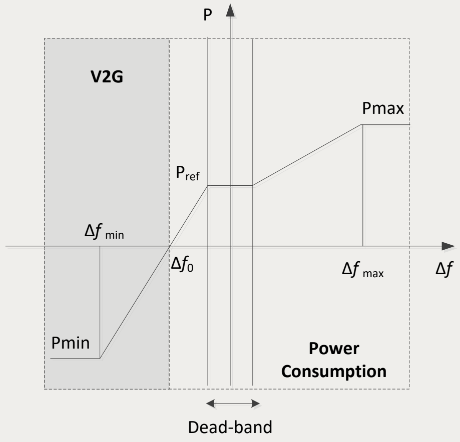
- EV can provide a set of ancillary services to the grids (microgrids, distribution grids and transmission grids):

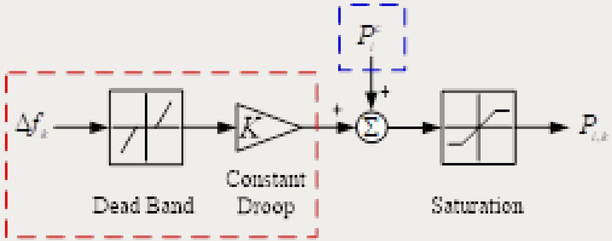


- If EV are integrated into energy community projects they can optimize the load balance, generation, and storage of an energy community . This requires smart chargers - both in applications considering V2G where the EV acts as additional storage provider for the community.

EV participating in Power Frequency Control

- EV can participate in primary frequency control, using a local control approach
  - The EV change their power output when the frequency becomes out of a defined dead band:
    - **Increase power consumption:** when there is an increase in the systems frequency.
    - **Reduction on power consumption:** for frequencies below the dead-band minimum.
    - **EV injects power (V2G): f**or frequencies bellow f_0.

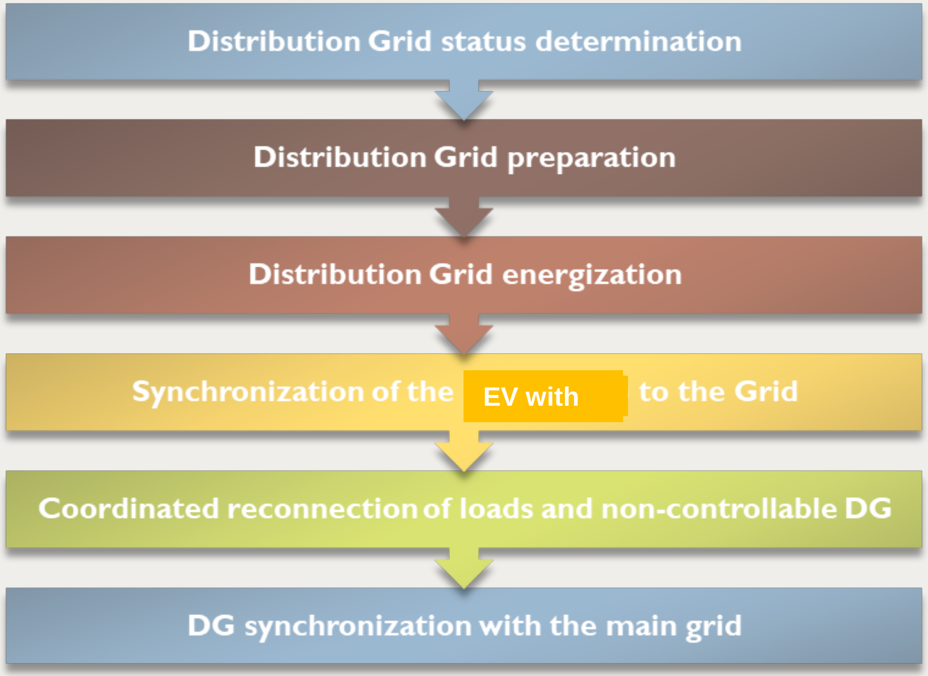


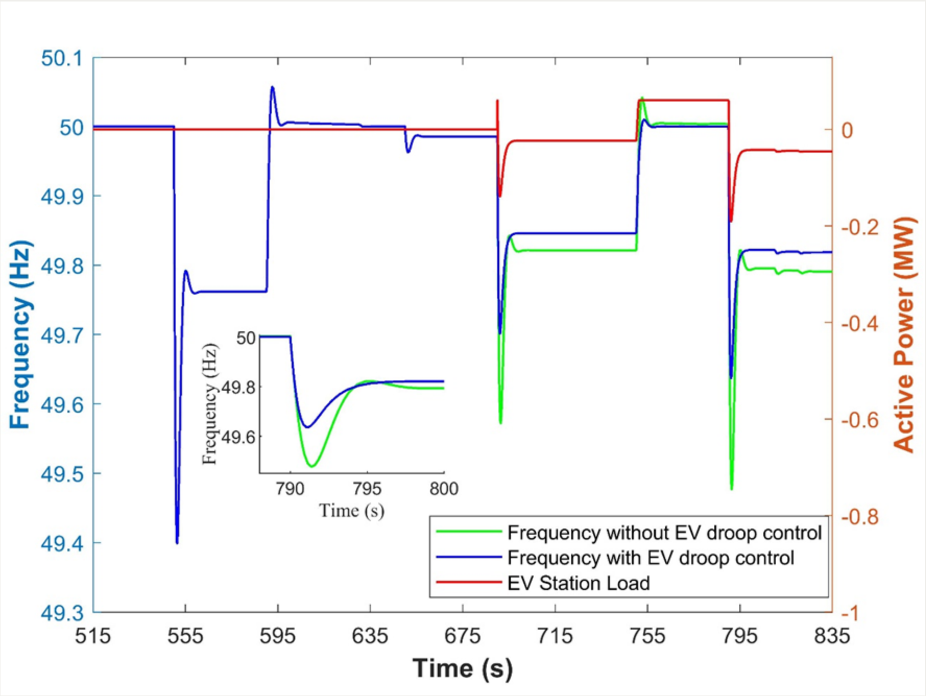


Communication links bring additional delays in the control loops leading to instabilities for islanded operation

EV participating in black start

- EV support black start and system restoration in distribution grids

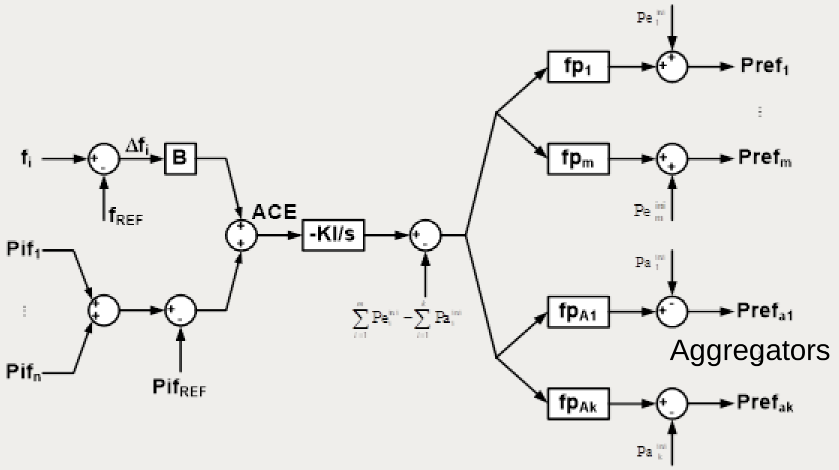


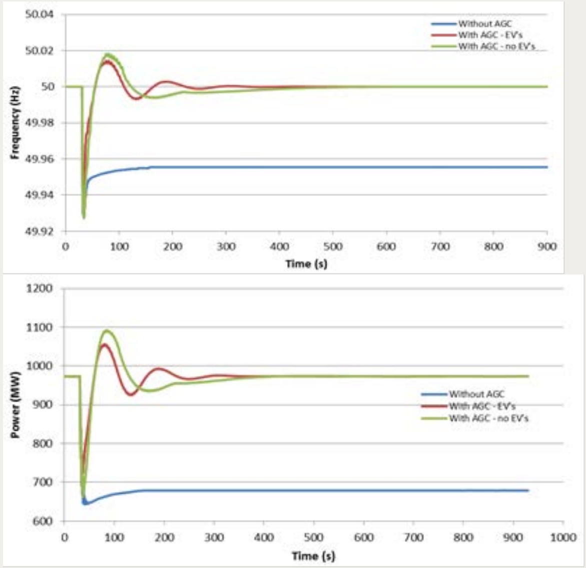


Through the frequency support during islanding operation, EV batteries participation will lead to smaller frequency excursions.

EV participating in Power Frequency Control

- EVs can also participate in secondary frequency control, requiring an aggregator to serve as interface between EVs and the AGC
  - The AGC sends set points to the EV aggregators that afterwards will distribute these point through the connected EVs,





  - The frequency down-regulation service can be provided by increasing the charging power of EVs, and the up-regulation can be realized by discharging or decreasing the charging power → management of EV up and down reserves.

Projects exploiting the provision of EV ancillary services

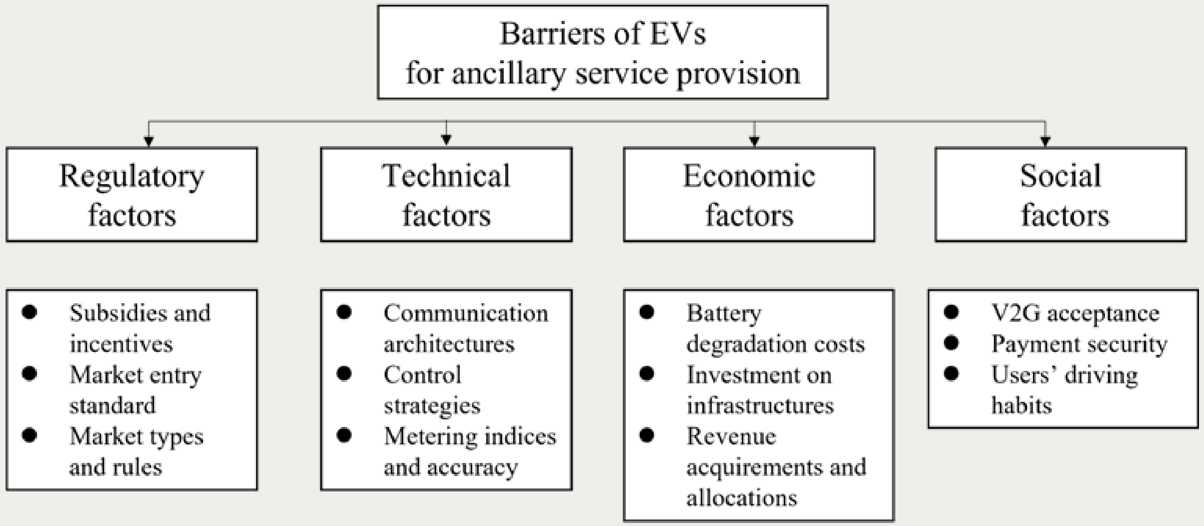
EV TSO service provision and market-specific features

Project Name	Parker	Smart Solar Charging	Invent	Re-dispatch	KEPCO	M-TECH LABO
Service	Frequency containment	Frequency response	Frequency response	TSO constraint management	Time-shifting for energy users	Peak shaving
When to act	Pre-fault	Pre-fault	Continuous response to signal	Pre-fault	Peak	Scheduled
Triggering action	Grid frequency	Forecast on USEF platform	Grid frequency (AGC signal)	TSO control signal	Market signals	Forecast
Response speed	< 10 seconds	Within minutes/hours	< 4 seconds	seconds ~ 2 minutes	< 10 seconds	N/A
Duration of service	Up to 30 mins	Minutes-hours	Continuous	Hours	1 – 4 hours	3 hours (1 pm-4 pm)
Status	Proven	Researched	Tested	Tested	Tested	Tested

There are still some problems remaining to be solved. The current hardware remains immature, including high costs of bidirectional chargers, significant energy losses during power conversion, and some marginal degradation cost of batteries. In addition, these pilot projects show that novel business models are urgently needed to bridge the heavily regulated energy system and decentralized EVs.

Barriers for EV to provide ancillary services

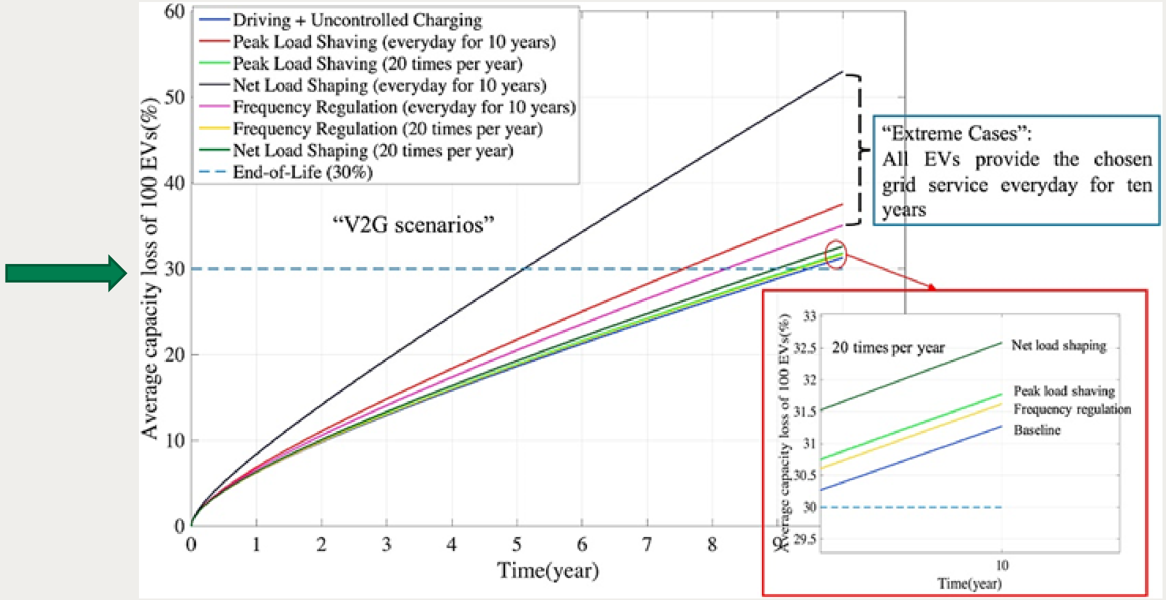
Most important ancillary services require the adoption of the V2G concept → Several barriers can then be identified



Examples of specific barriers: minimum bid limits, overwhelming communications and control task, reliability, delay, and security of communications, high technical requests for metering systems (bidirectionality for P, Q), battery degradation costs, investment costs in hardware and communication infrastructures …

Battery degradation costs

- V1G operation does not causes any degradation to the battery
- If V2G is used for peak load shaving and frequency regulation on a daily basis, the degradation is dependet on the depth of usage (amplitude of the control participation)



No relevant degradation exists

Extra costs to the V2G operation due to battery degradation need to be recognized
Public policies should advocate V2G publicly, and guide EV users to participate in ancillary service market