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EV Fast-Charging Stations: a Boost for Power System Stability?

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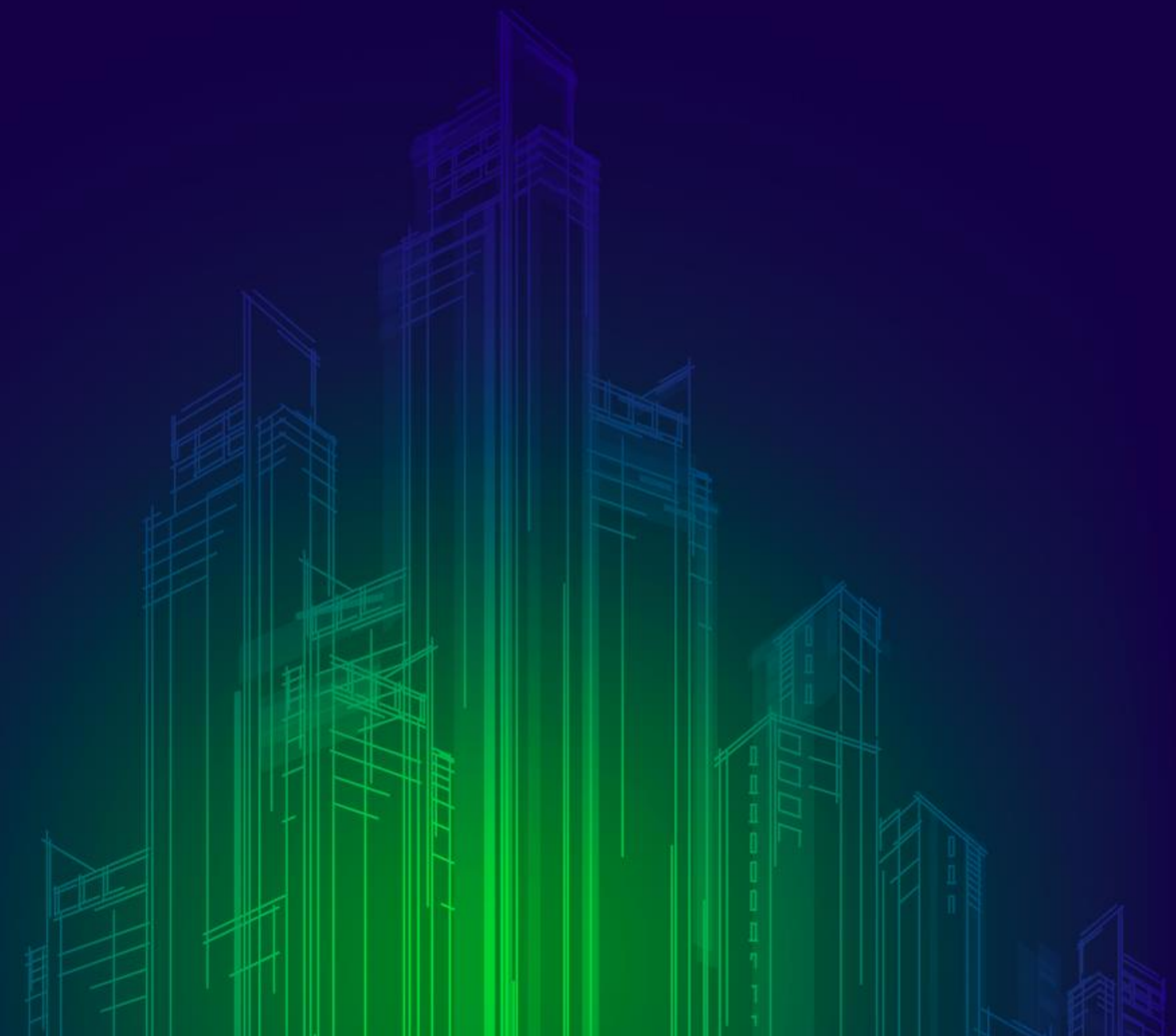


INDICE

Electric Vehicle Ultra-Fast Charging

The missing link to EV widespread adoption

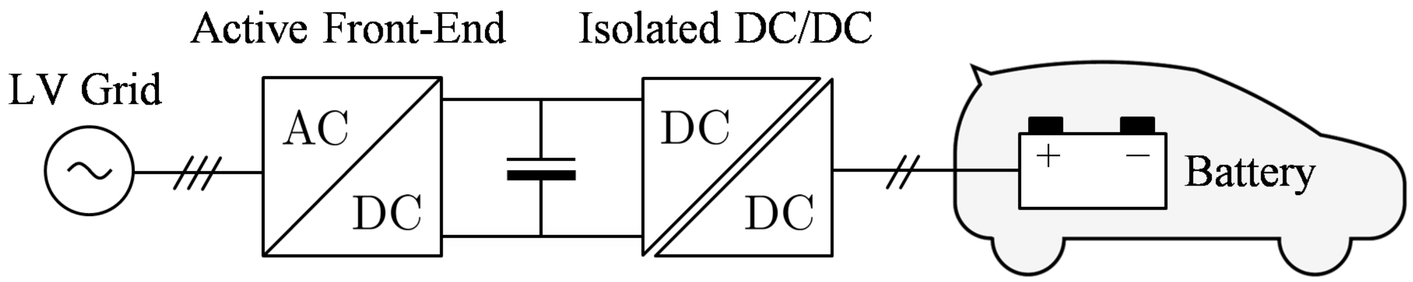
? What is **Ultra-Fast**?

≈ 400 km of range in 10 minutes

1000 V
350/500 A

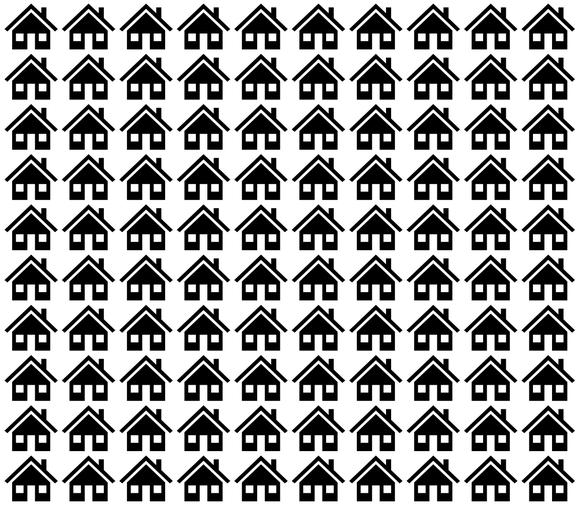
350/500 kW

- *Li-ion batteries ⇒ bottleneck for EV driving range and cost*
- *Ultra-fast charging as a key solution for reducing average battery pack size (cost) and range anxiety*
- *Thousands of DC charging stations are being installed worldwide, but…*



…without considering the impact on the grid!

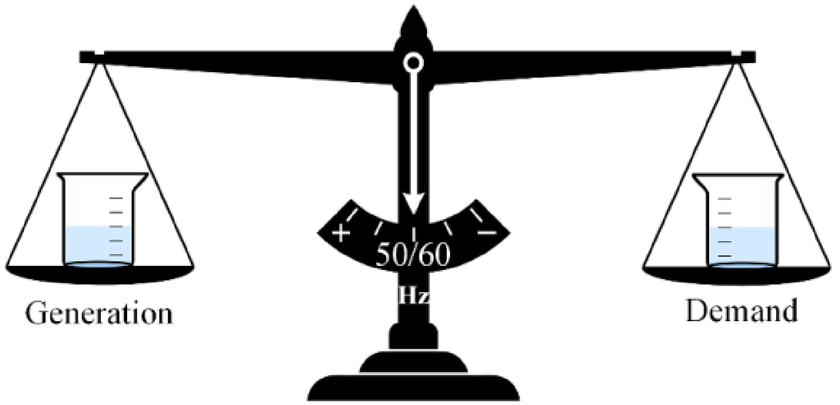
≈ 100 European households!



What does the Grid Need?

*The key aspects of **power quality***

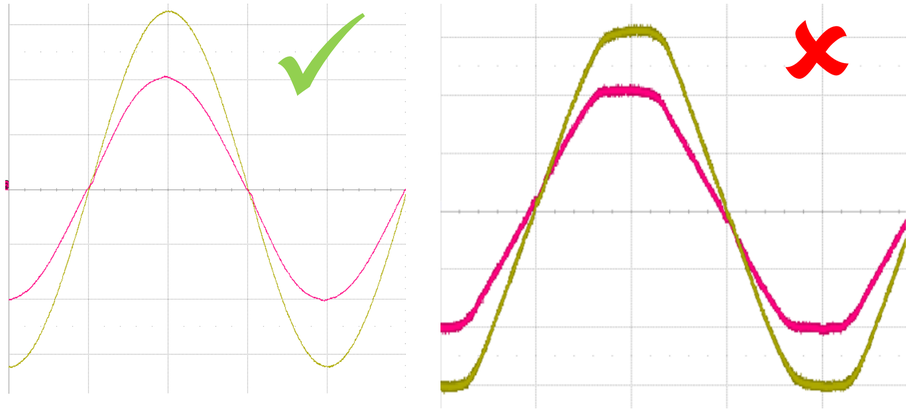
1. *Stable frequency (e.g. 50 Hz)*



Source: J. Fang et al., "On the Inertia of Future More-Electronics Power Systems," in *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 7, no. 4, pp. 2130-2146, Dec. 2019.

2. *Stable voltage (e.g. 230 V)*

3. *Low harmonic distortion*

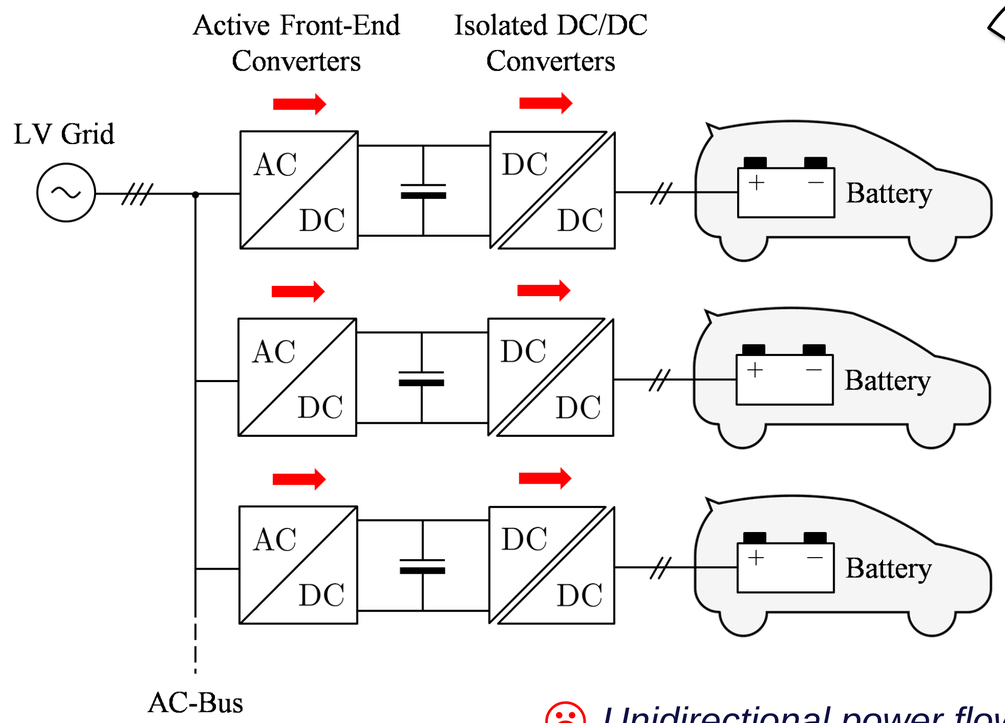


4. *High short circuit currents, to trigger protections*

The EV Charging Opportunity

*Challenges and opportunities of future **multi-MW** charging stations*

Industry Standard



☹ *Unidirectional power flow*

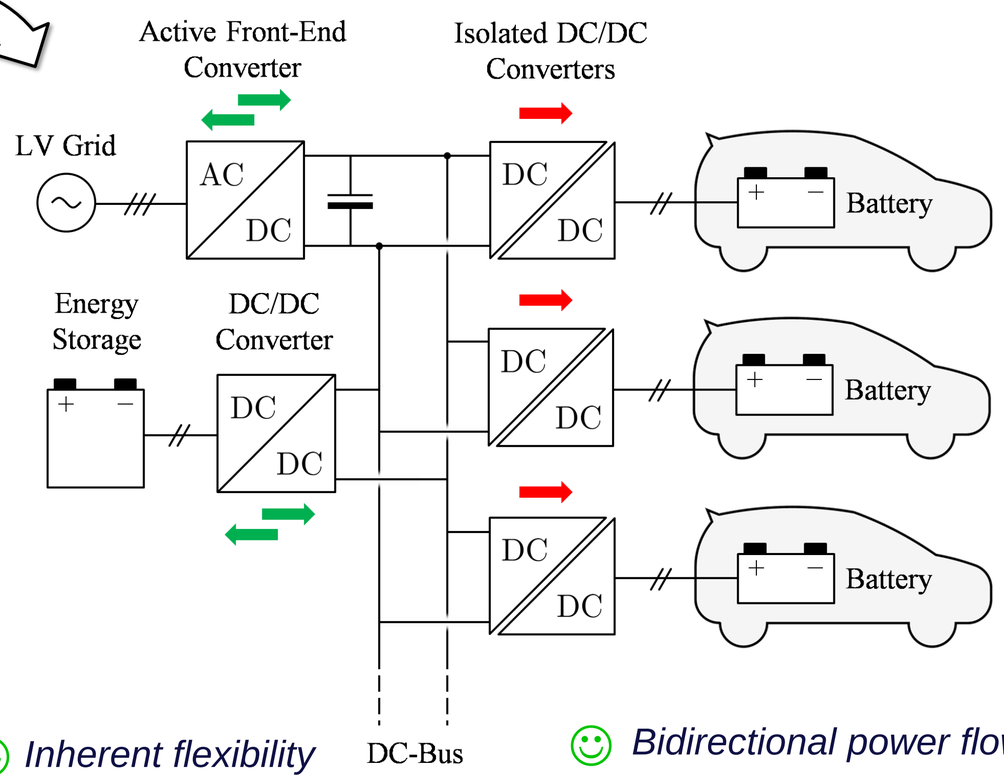
☹ *No flexibility*

☹ *Utility transformer overload*

☹ *High peak demand charges*

☺ *Lowest cost of investment*

Next Generation



☺ *Inherent flexibility*

☺ *Bidirectional power flow*

☺ *Peak load shaving*

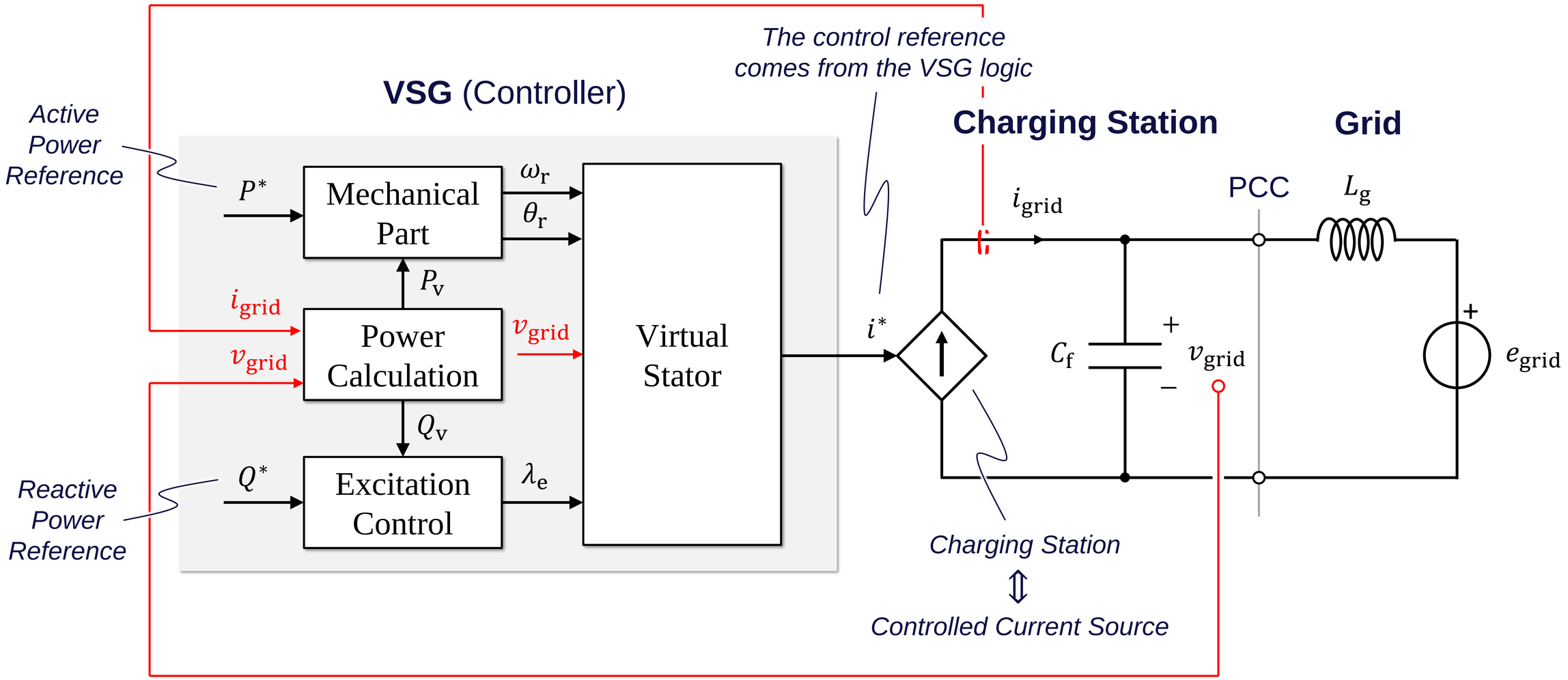
☺ *Grid ancillary services?*

☹ *Highest cost of investment*

☺ *Lowest cost of operation*

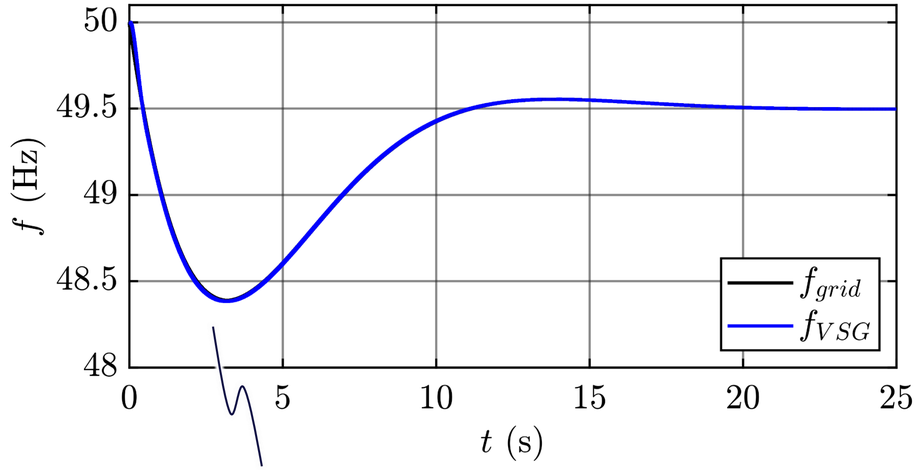
The Virtual Synchronous Generator (VSG)

Controller for grid-side converter



VSG: Ancillary Services

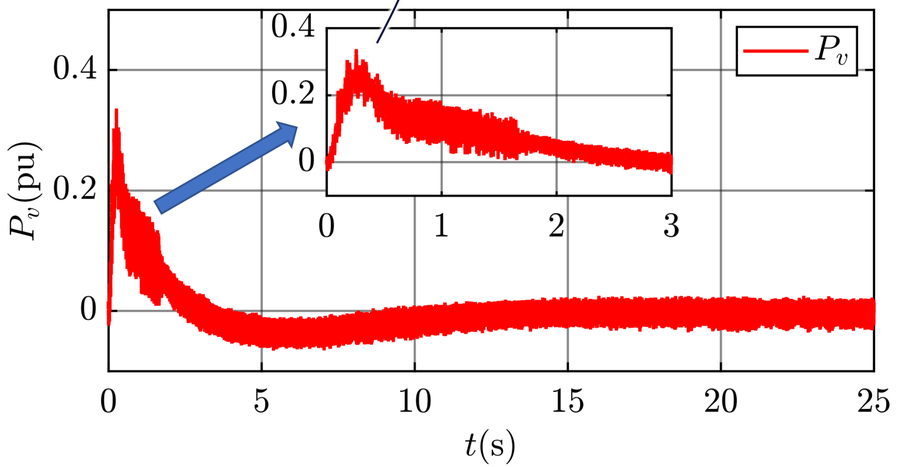
① *Frequency regulation through **active power (P)** injection*



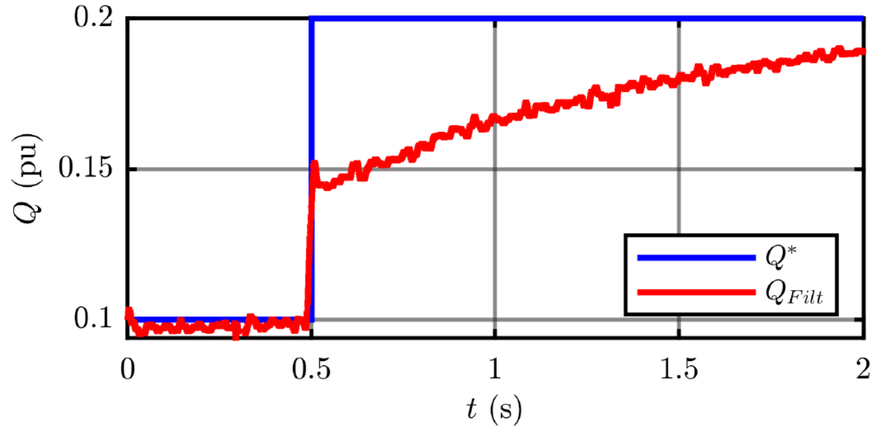
Disconnection of a major generator (severe grid frequency drop)

Active power injection (virtual inertia)

$$\boldsymbol{P} \propto -\frac{\mathrm{d}f}{\mathrm{d}t}$$



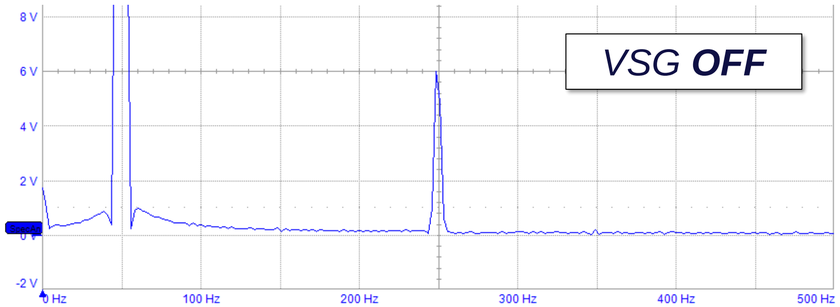
② *Voltage regulation through **reactive power (Q)** support*

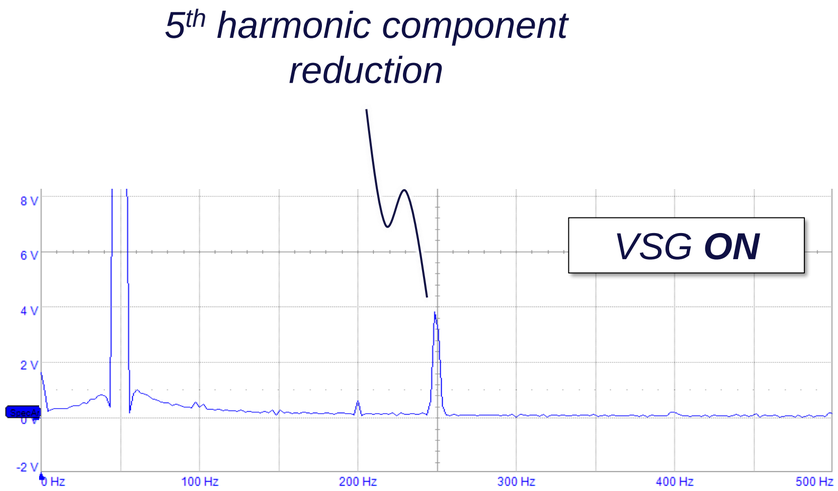


Response to a reactive power reference step

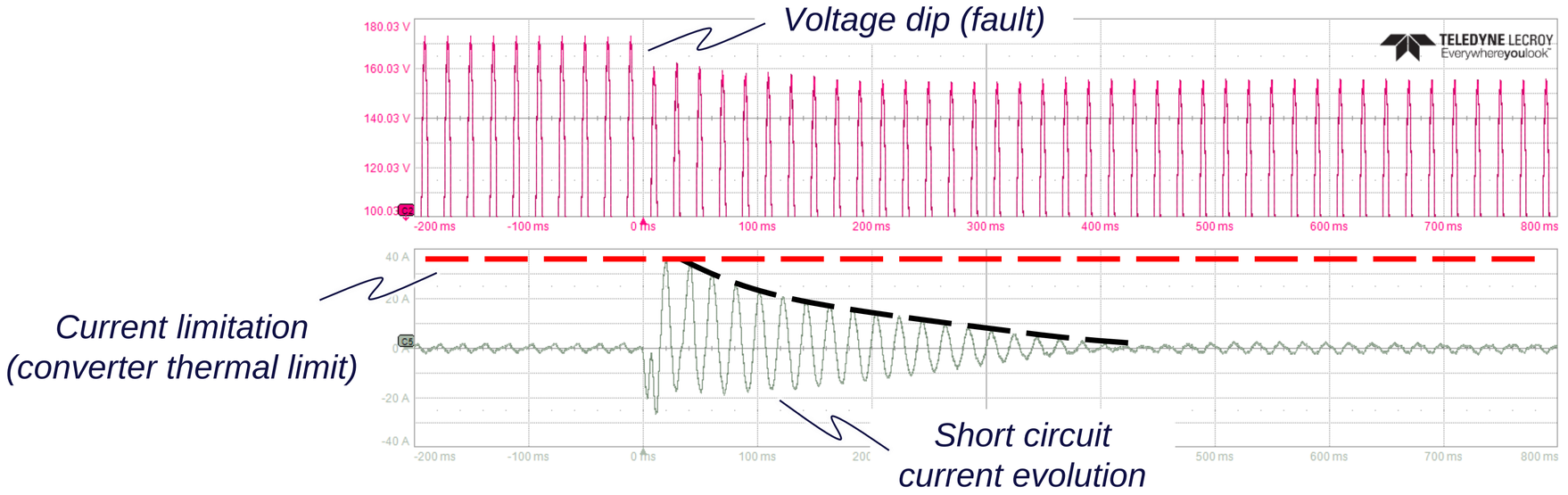
VSG: Ancillary Services

3 Harmonic compensation





4 Short circuit current injection during grid faults, to trigger protection relays



Conclusions

- *Conventional EV fast charging stations cause a heavy **strain on the utility**, meanwhile generating high peak power **demand charges** for the station operator*
- *Next-generation charging stations with **integrated energy storage** can support the grid and reduce peak power demand at the same time*
- *The **Virtual Synchronous Generator** (**VSG**) is a robust, effective and straightforward way (i.e. software add-on) to control future charging stations, as it directly provides:*
  - *Frequency regulation (active power injection), by virtual inertia*
  - *Voltage regulation (reactive power support)*
  - *Harmonic compensation*
  - *Short circuit current injection (to trigger protection relays)*

  ⇒ ***Power quality***
- *The provision of **ancillary services** can translate in extra revenue for the charging station operator*

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