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How electric vehicle charging can improve grid stability with FCR

Europe’s power system is synchronised around a physical “contract”: the grid frequency must stay close to 50 Hz. When total generation exceeds consumption, frequency rises and when consumption exceeds generation, frequency falls. Because the grid itself stores only negligible amounts of energy, this balance must be maintained continuously by increasing or decreasing generation and/or by adjusting controllable demand.

Frequency Containment Reserve (FCR) is the first automated layer that counteracts these deviations. Providers measure frequency locally and adjust their active power output (or consumption) proportionally. In continental Europe, a small deadband around 50 Hz (49.99–50.01 Hz) avoids unnecessary switching. Outside it, contracted FCR is automatically activated by each participant proportionally to the frequency deviation from the 50 Hz target.

This mechanism matters more than ever. With the decline of synchronous power plants, the kinetic energy stored in the rotating masses of generators and turbines (“inertia”) also declines. Lower inertia means frequency can change faster after variations in production or consumption, leaving less time for corrective measures. System operators therefore need fast, distributed flexibility that can stabilise frequency without relying solely on large plants.

One such asset is scaling rapidly: the electric vehicle (EV). EVs combine three ideal factors: an energy buffer (the battery), a connection to the grid when plugged in, and long parking times. Household vehicles are parked for roughly 95 percent of a typical day. Turning that idle capacity into a grid stabiliser is primarily a control and market-integration problem.

What is FCR, in practical terms?

FCR (often referred to as primary control reserve) is procured by transmission system operators (TSOs) to stabilise frequency across an entire synchronous area. It is a proportional frequency response where power changes are proportional to frequency deviations, up to full activation at a defined deviation. In Continental Europe, full activation is reached at ±200 mHz.

Normal operation targets a narrow band around 50 Hz. FCR is activated outside the deadband, i.e. when the frequency deviates by more than ±10 mHz from 50 Hz.

If deviations from the nominal frequency of 50 Hz become too large, additional system defence mechanisms like aFRR and mFRR are activated. If even these mechanisms are unable to stabilise the grid frequency, load or generation shedding becomes necessary. At very low frequency, automatic under-frequency load shedding is triggered, usually referenced with a first step around 49.0 Hz. Similar defence measures exist for excessive over-frequency, often reached around 51 Hz, depending on the applicable grid code and protection settings.

These system-defence mechanisms are definitely out of scope for domestic EV charging. EV-based FCR is about stabilising grid frequency well before such thresholds are reached.

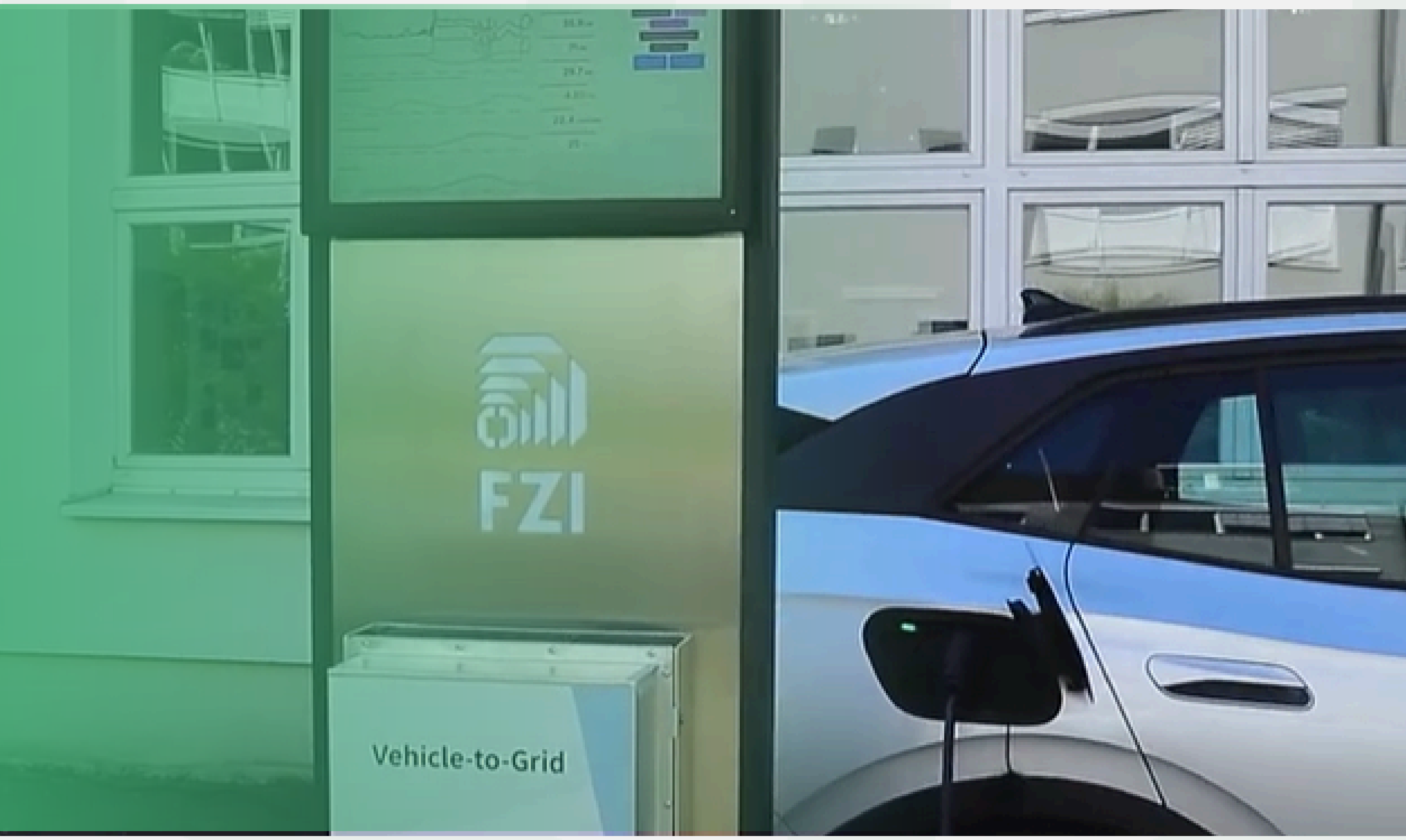
A valuable asset: distributed FCR

Inertia is a physical stabiliser: it slows the rate-of-change-of-frequency immediately after a disturbance. Wind and PV plants are connected through power electronics and do not inherently provide the same electro-mechanical coupling as synchronous machines. The consequence is straightforward: frequency control in the seconds-to-minutes window becomes increasingly critical.

How EVs can provide FCR while charging

Providing negative FCR does not necessarily mean an EV must export energy to the grid. FCR is about changing active power relative to an operating point. This makes it feasible to provide FCR with EVs even when using “conventional” unidirectional charging.

For an EV charger, the controllable quantity is charging power. If frequency is above 50 Hz, a generation surplus exists and the charger can contribute by increasing charging power. If frequency is below 50 Hz, a generation deficit exists and the charger can provide FCR by reducing charging power. This is the fundamental concept: controllable demand can stabilise frequency just like controllable generation.



This is why baseline selection matters. To provide a symmetric response, an EV cannot operate at the minimum or maximum charging power of the charge point or on-board charger when providing FCR. Instead, it must remain at a setpoint above the minimum and below the maximum. This leaves headroom to ramp charging power up or down while still meeting the user's required state-of-charge (SoC) by the departure deadline.
Charging times may increase when providing FCR, because the baseline setpoint must be below the maximum charging power. However, since vehicles are stationary for most of the day, the impact can often be limited, provided that the control strategy respects the user's departure constraints and adjusts offered FCR accordingly.

A real-world constraint: the 6 A minimum and interruptibility

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EV charging power is controllable by the charge point, but not without limits. In AC charging, 6 Ampere (A) is the minimum current for stable charging. The well-known control-pilot mapping corresponds to 6 A at 10 percent duty cycle. Below that minimum, many vehicles will not behave consistently. They either terminate the charging process or remain at 6 A.

For FCR services, this implies a minimum controllable power of 1.38 kW per phase at 230 V, i.e. 4.14 kW on three phases. These limits do not exclude EVs from FCR, but they do mean that control strategies and participation conditions must be designed around behaviour that is standard-compliant and reliably supported across vehicles.

Bidirectional charging: a way to improve FCR availability

With unidirectional charging, an EV can only modulate consumption between the minimum charging power and the maximum charging power the charge point or vehicle supports. FCR availability is therefore limited to a charging session. Bidirectional charging (V2G/V2H) extends controllability to export as well as import power and defines the required bidirectional power-transfer communication sequences. This enables longer availability windows, even when charging is already complete. Easier symmetric response around zero, and less need for artificial mid-level charging baselines are the consequence.

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Hardware compatibility, warranty policies, metering, and market rules are still maturing. However, bidirectional capability is the clearest route to scaling EV-based ancillary services without compromising user convenience and further increasing the amount of FCR that can be provided by EVs. In particular, providing FCR is no longer limited to the duration of an active charging process. The entire pluged-in duration can be used to provide FCR continuously.

WeForming vision: EV-based FCR for smart buildings

In buildings, EV chargers are among the few assets that can deliver multi-kilowatt, fast, controllable power. In WeForming, the wider goal is to turn intelligent grid-forming buildings (iGFBs) into active flexibility providers. EV-based FCR fits naturally into that vision. A building energy management system can align user constraints (departure time, minimum SoC), local limits (transformer capacity, PV self-consumption), and grid needs (frequency response). If designed well, frequency support becomes almost invisible to users, yet extremely valuable for system stability.

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Funded by the European Union

The WeForming project has received funding from the European Union's Horizon Europe Programme under the Grant Agreement No. 101123556.

UK Research and Innovation

The UK participant is co-funded by UKRI.