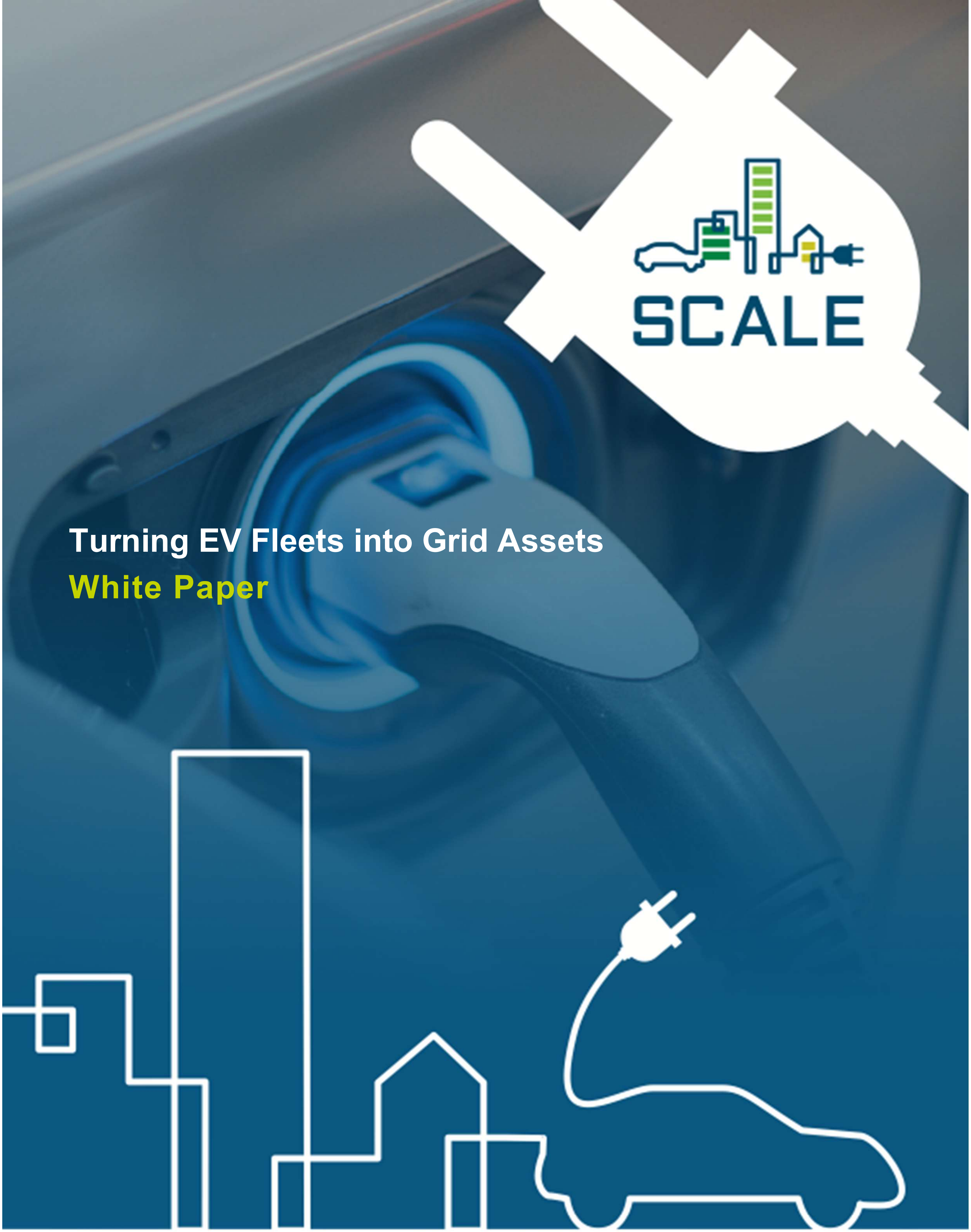

Turning EV Fleets into Grid Assets

White Paper

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SCALE Introduction

SCALE (Smart Charging Alignment for Europe) is a three-year Horizon Europe project that explores and tests smart charging solutions for electric vehicles. It aims to advance smart charging and Vehicle-2-Grid (V2G) ecosystems to shape a new energy system wherein the flexibility of EV batteries' is harnessed. The project will test and validate a variety of smart charging and V2X solutions and services in 13 use cases in real-life demonstrations in 7 European contexts: Oslo (NO), Rotterdam/Utrecht (NL), Eindhoven (NL), Toulouse (FR), Greater Munich Area (GER), Budapest/Debrecen (HU) and Gothenburg (SE). Going further, project results, best practices, and lessons learned will be shared across EU cities, regions, and relevant e-mobility stakeholders. SCALE aims to create a system blueprint for user-centric smart charging and V2X for European cities and regions.

SCALE's consortium comprises 29 cutting-edge European e-mobility actors covering the entire smart charging and V2X value chain (equipment and charging manufacturers, flexibility service providers, research and knowledge partners, public authorities, consumer associations, etc.) It is led by ElaadNL, one of the world's leading knowledge and innovation centres in smart charging and charging infrastructure.

Executive Summary

This white paper outlines the outcomes of a joint initiative between Equigy, Enervalis, and We Drive Solar as part of the EU-funded SCALE project. The collaboration focuses on leveraging the flexibility of electric vehicle (EV) batteries to support the energy system by enabling our participation in the automatic Frequency Restoration Reserve (aFRR) market. The objective of the project was to test and demonstrate the technical feasibility of controlled EV fleet activations in response to aFRR signals, paving the way for future grid-balancing services using distributed EV resources.

Two Proof-of-Concept (PoC) tests were conducted in and around Utrecht, the Netherlands, involving fleets managed by We Drive Solar. Despite the evolving regulatory landscape and certain technological constraints, the results clearly showed that EV fleets can react meaningfully to aFRR signals. The first test involved 112 EVs and targeted 200 kW activations. While the ramp-down response met TenneT's requirements by reaching 134 kW within 30 seconds, some issues were identified and taken as key learning points for subsequent testing.

The second test scaled up to 134 EVs with activation targets of 1 MW and 500 kW. The test delivered around 700 kW of flexibility, indicating promising scalability. In both tests, the system achieved key performance benchmarks set by TenneT, especially in terms of response time, confirming that EV fleets can be viable resources in balancing markets.

To support these activations, Equigy deployed a technical infrastructure including a dual-endpoint system that processed both 15-minute aggregated measurements and high-frequency (4-second) baseline data from Enervalis.

One of the key technological findings was the recurring challenge of managing large volumes of high-frequency data generated during EV charging sessions. Equigy and Enervalis already recommended the implementation of a delta-monitoring strategy in other reports to address this issue. Delta-monitoring involves transmitting data only when significant changes occur in power measurements, significantly reducing communication load without compromising accuracy. The current white paper reaffirms this recommendation, noting that delta-monitoring could help meet TSO data requirements—provided small deviations and post-event data corrections are acceptable. This approach is particularly relevant given the use of mobile communication networks by most charge point operators (CPOs), where bandwidth is limited and costly. The recent work by the Open Charge Alliance on improving monitoring using OCPP also supports this direction.

In addition to technical learnings, the paper emphasizes several strategic recommendations. Regulatory frameworks should evolve to allow for minor, short-term discrepancies without compromising system reliability—especially when dealing with aggregated distributed resources like EV fleets. In addition, scalable and cost-efficient communication technologies, such as 5G and edge computing, should be explored to support real-time monitoring without overloading current infrastructures.

In conclusion, the collaboration between Equigy, Enervalis, and We Drive Solar has successfully demonstrated the feasibility of integrating EV fleets into the aFRR market. With ongoing optimization of data handling, signal communication, and regulatory alignment, these distributed assets can become critical contributors to grid stability and energy system flexibility. The experience gained from these PoC tests lays a strong foundation for future deployments, helping accelerate the adoption of EV-based balancing services across Europe.

1 Introduction

This report presents the outcomes of the collaboration between Equigy and Enervalis and We Drive Solar under the SCALE project, which aims to advance smart charging and Vehicle-2-Grid (V2G) ecosystems to shape a new energy system wherein the flexibility of Electric Vehicles (EV) batteries' is harnessed. Equigy and Enervalis and We Drive Solar focused on activation of fleets of EVs to react to mock automatic Frequency Restoration Reserves (aFRR) signals.

aFFR (automatic Frequency Restoration Reserve) is a grid-balancing service that automatically adjusts power supply or demand to restore the electrical grid's frequency to its nominal value of 50 Hz within a few minutes after a disturbance. Electric vehicle (EV) batteries can participate in aFFR by quickly charging or discharging in response to grid signals, helping stabilize the grid while earning revenue for their owners.

This research is pivotal in advancing the integration of flexible, distributed energy resources, such as electric vehicles (EVs), into grid-balancing services. As grid operators and energy markets evolve, innovative solutions are essential to enhance grid responsiveness and cost-efficiency. The findings of this collaboration demonstrate the significant potential of EVs to support grid stability while also identifying key technical and regulatory challenges. For example, optimizing data transmission and adopting strategies like delta-monitoring can reduce communication overhead and meet the stringent requirements of Transmission System Operators (TSOs). Additionally, the study highlights the need for regulatory adjustments to accommodate new market participants, such as EV fleet managers, and the importance of exploring advanced communication technologies like 5G and edge computing to support real-time grid management.

2 Test Summary & Results

Two tests were realized by a fleet of electric vehicles operated by We Drive Solar in / around Utrecht, the Netherlands, who also participated in the tests. The Proof-of-Concept (PoC) tests successfully demonstrated the potential of EV fleets to provide aFRR services, despite current technological and regulatory limitations. Despite some challenges, the tests confirmed that controlled activations are feasible, and that further optimization can enhance performance.

First Test (13.02) – 112 EVs

- **Activation targets:** 200 kW (twice)
- **Ramp-down performance:** Reached **134 kW in 30 seconds**, meeting TenneT's requirements.
- **Key Observations:**
  - The update frequency of the baseline data increased suddenly at the start of the first activation, leading to correction of the baseline in the opposite direction of the activation, making it look like a **mirroring effect**. This phenomenon was identified during the second test, and this was considered in the lessons learned.
  - The power reduction response was slightly unstable due to missing repeat signals, which can be refined in future implementations.

Second Test (19.02) – 134 EVs

- **Activation targets:** 1 MW (first), 500 kW (second)
- **Ramp-down performance:** Reached 198 kW in 30 seconds, fully aligned with TenneT's requirements.
- **Key Observations:**

- While the 1 MW target was not fully reached during the first activation, the fleet delivered a substantial volume of around 700 kW, demonstrating strong potential.
- There were short intervals where power values dropped below thresholds,
- The baseline was again corrected suddenly at the first test activation, making it look like a mirroring effect because of to the sudden increase in data frequency and corresponding adjustment of the curve.

These tests underline the feasibility of large-scale EV fleet integration into aFRR markets. The results confirm that even with existing infrastructure, meaningful activations are possible. Further improvements—such as refined threshold monitoring, optimized baseline calculations, and adjustments to charger constraints—will further increase accuracy and reliability.

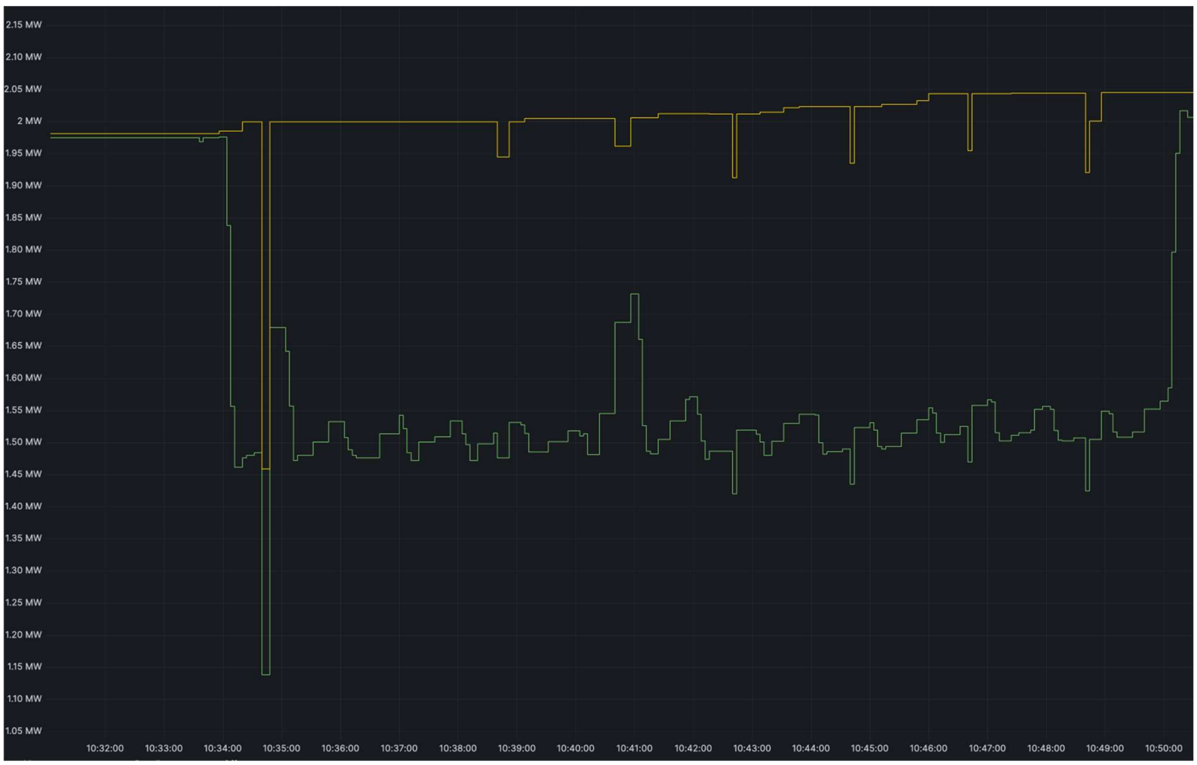

Figure 1: Enervalis' Grafana dashboard during the second test

3 Technologies in Use

Equigy has implemented advanced data management and visualization technologies to support the integration of EV fleets into the aFRR balancing market. A dual-endpoint system within the Central Business Platform (CBP) processes two types of datasets from Enervalis: aggregated 15-minute measurement data and detailed 4-second baseline data. These datasets are stored and managed using a centralized storage suited for analysis of real-time and aggregated datasets. Equigy also uses a scalable, secure cloud-based database engine combined with visualization dashboards for real-time monitoring, discrepancy analysis, and actionable insights.

Equigy leverages SQL-based analytics and Grafana visualizations to compare datasets, detect discrepancies, and analyze metrics such as variance, average difference, and standard deviation. This provides insights into EV fleet accuracy and responsiveness in delivering aFRR services. The system's infrastructure ensures smooth integration for flexibility service providers (FSPs), facilitating real-time monitoring, reducing onboarding complexity, and enhancing transparency in balancing markets.

Enervalis has established an innovative aFRR software platform designed to efficiently manage data streams from the CSMS of individual charge points. This platform addresses the essential task of converting standard 15-minute interval data into precise 4-second interval data through complex algorithms and sophisticated estimation methods. However, 15-minute interval data alone is insufficient for real-time aFRR activations and validation, necessitating higher data granularity for accurate responsiveness.

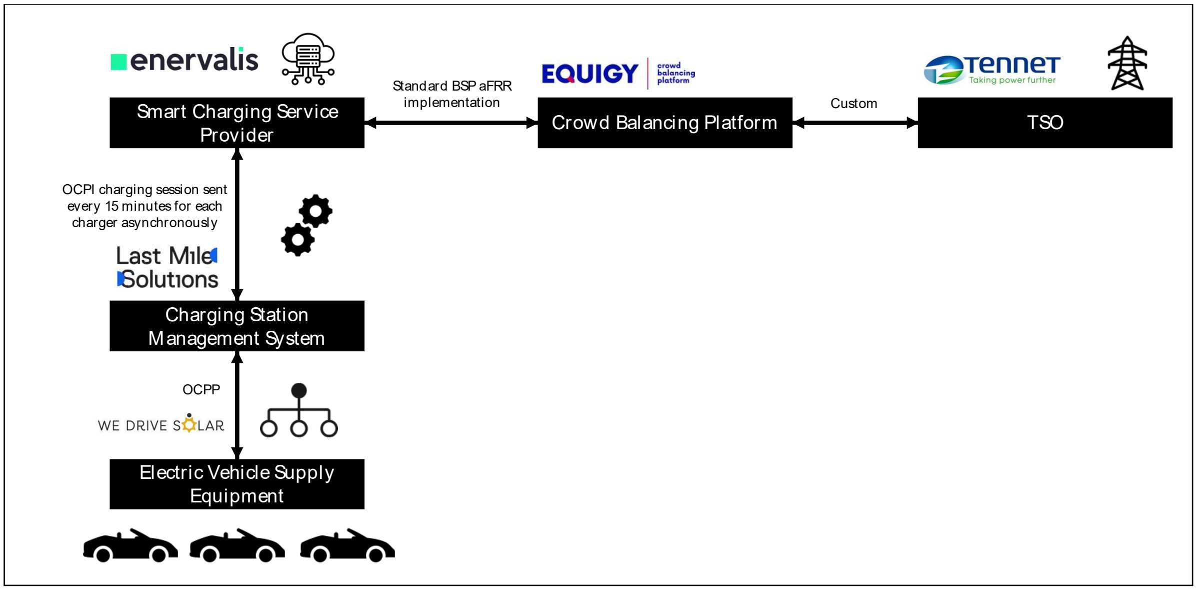

Figure 2: Data flow of the test aFRR activation

During the SCALE project testing phases, the aFRR activation signals are simulated and processed by this platform, then translated into specific setpoints for each EV charger. Distribution of setpoints accounts for the unique characteristics of each charging session and the inherent flexibility of each Electric Vehicle (EV). The platform is also capable of handling real-time setpoints, a capability validated through other successful aFRR projects, demonstrating the robustness and practical applicability of these software solutions.

Additionally, the software manages critical aspects such as baseline calculations and power activation handling. Both baseline and activated power data are continuously transmitted to the Equigy Crowd Balancing Platform (CBP), ensuring accurate, real-time communication and facilitating reliable grid balancing services. This integration highlights interoperability, significantly enhancing the responsiveness and stability of the electric grid.

4 Key Findings & Recommendations

The primary objective of Transmission System Operator (TSO) balancing teams is to maintain grid stability and security. To achieve this, TSOs define strict participation requirements that minimize the risks of market participants defaulting on their balancing obligations, communication failures, or vulnerabilities to malicious actors across the value chain. However, these requirements must also be designed to allow access for emerging market players with flexible capacity – such as aggregators of electric vehicles – who can contribute to a more dynamic, responsive, and cost-efficient balancing market.

Thus, TSOs face a fundamental trade-off: on one end, stringent entry conditions ensure maximum grid security but limit participation and reduce liquidity; on the other, more relaxed requirements promote market inclusivity and liquidity but may increase operational risks. Striking the right balance is essential for enabling innovation—such as the integration of EVs into the aFRR (automatic Frequency Restoration Reserve) market—without compromising system integrity.

- **EV chargers can meet current aFRR response times** but require optimized data transmission.
- **Baseline "mirroring" is an issue** caused by sudden data frequency increases after activation. **Higher data granularity of the data (every 4 sec or threshold-based data transmission) is necessary** to maintain power stability and avoid TenneT rejections. In this particular case, a valid activation would have been rejected due to the sudden change in power observed in the beginning.
- As already highlighted in report D2.4, **where Enervalis and Equigy recommended the implementation of a delta monitoring communication strategy** to reduce communication frequency and data transfer (particularly given the high volume of active charging sessions needed to reach 1MW flexibility). Delta-monitoring – i.e., estimating the power output based on current measurements at the charging point level – could help meet the data requirements and is highly recommended for grid services. This approach assumes that TSOs are willing to accept small deviations and allow for data corrections after the actual power measurements are received and processed. This functionality is already available in the 2.0.1 Standard, as can be seen in the report of the **Open Charge Alliance**, from August 2024 (*Improving Uptime Monitoring with OCPP*).
- **Prequalification models should be refined** to better predict power deviations and baseline shifts.
- **Regulatory adjustments may be needed** to account for short-term deviations without compromising grid stability. TenneT in the Netherlands and other TSOs in their corresponding countries could work on new requirements that accommodate new actors managing electric vehicles and charging stations, and allow them to submit high frequency data that can be corrected in the short or medium term and tolerate some deviation between real-time and ex-post corrected data.
- **Cost-effective communication solutions (5G, edge computing) should be explored** to enable real-time data exchange.

5 Conclusion

The collaboration between Equigy and Enervalis has successfully demonstrated that **EV fleets have strong potential to participate in the aFRR balancing market**. The tests confirmed that controlled activations are feasible, and with further refinements in data handling and signal transmission, performance can be significantly enhanced.

By integrating high-frequency datasets and real-time visualization tools, the project improves transparency, simplifies operations for service providers, and supports grid operators in efficiently managing distributed flexibility assets. These insights pave the way for broader adoption of EV-based flexibility solutions.

Moving forward, efforts should focus on refining data models, enhancing prequalification frameworks, and optimizing communication protocols to ensure seamless scalability and unlock the full potential of EV fleets in grid balancing services.