Reactive Technologies

DaaS for Power System Stability Monitoring

Visibility before Vulnerability©

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Reactive is enabling many of the world's leading power grid operators to operate their grids at **higher performance** by measuring new critical grid parameters like **grid inertia, oscillations and system strength** to achieve Net Zero safer and faster.

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Trusted by…

NESO National Energy System Operator

NEW YORK STATE OF OPPORTUNITY. NYSERDA

New York ISO Independent System Operator

KAHRAMAA

نقل الكهرباء National Grid SA

TAQA Transmission

台湾電力公司 TAIWAN POWER COMPANY

AEMO

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Monitoring Systems Now and Future

Traditional Monitoring Approaches

Siloed Data Systems

Traditional monitoring ties data to specific vendors, limiting interoperability and holistic analysis across systems.

Resource Constraints

Budget limits, aging infrastructure, and scarce data science resources hinder large monitoring projects.

Scalability Challenges

Legacy approaches struggle to handle growing data volumes, causing delayed insights and operational complexity.

Need for Flexible Models

Growing grid complexity demands service-based data delivery models to reduce risk and speed decision-making.

Data as a Service for Grid Observability

Shift to Data as a Service

DaaS transforms grid management by providing on-demand, high-quality measurement data without heavy infrastructure.

Operational Benefits

DaaS reduces operational burden and enables faster, actionable insights into abnormal grid conditions.

Enhanced Grid Observability

Integrating synchrophasor and waveform data enables continuous and dynamic visibility of grid conditions.

Future-ready Grid Solutions

High-resolution measurements support modern, inverter-rich power systems with practical, utility-ready services.

Data as a Service Benefits and Challenges

Benefits

Cloud-Based Data Delivery
DaaS delivers data on demand via cloud platforms, removing the need for users to manage infrastructure.

Real-Time Data Access
It provides real-time or near-real-time access to high-quality, curated data for timely decision making.

Utility-Like Data Service
DaaS lets utilities consume measurement data as a service, similar to electricity or telecommunications.

Decoupled and Scalable Data
The model decouples data from applications, enabling reuse and scalable enterprise-ready data products.

Cost Reduction via Outsourcing
DaaS reduces capital expenditures and maintenance costs by shifting infrastructure ownership to providers.

Challenges

Barriers to Adoption
Risk aversion, regulatory uncertainty, and legacy system integration pose significant barriers to DaaS adoption in utility sectors.

Data Quality and Security
Ensuring data quality, cybersecurity, and regulatory compliance is critical when outsourcing data services to external providers.

Trust and Governance
Trust in providers and clear data ownership and governance frameworks are essential for successful DaaS implementation.

Resource and Skill Limitations
Limited internal resources and skills can slow down adoption despite clear long-term benefits of DaaS.

High-frequency oscillations visibility is key in High PE-dominated grids

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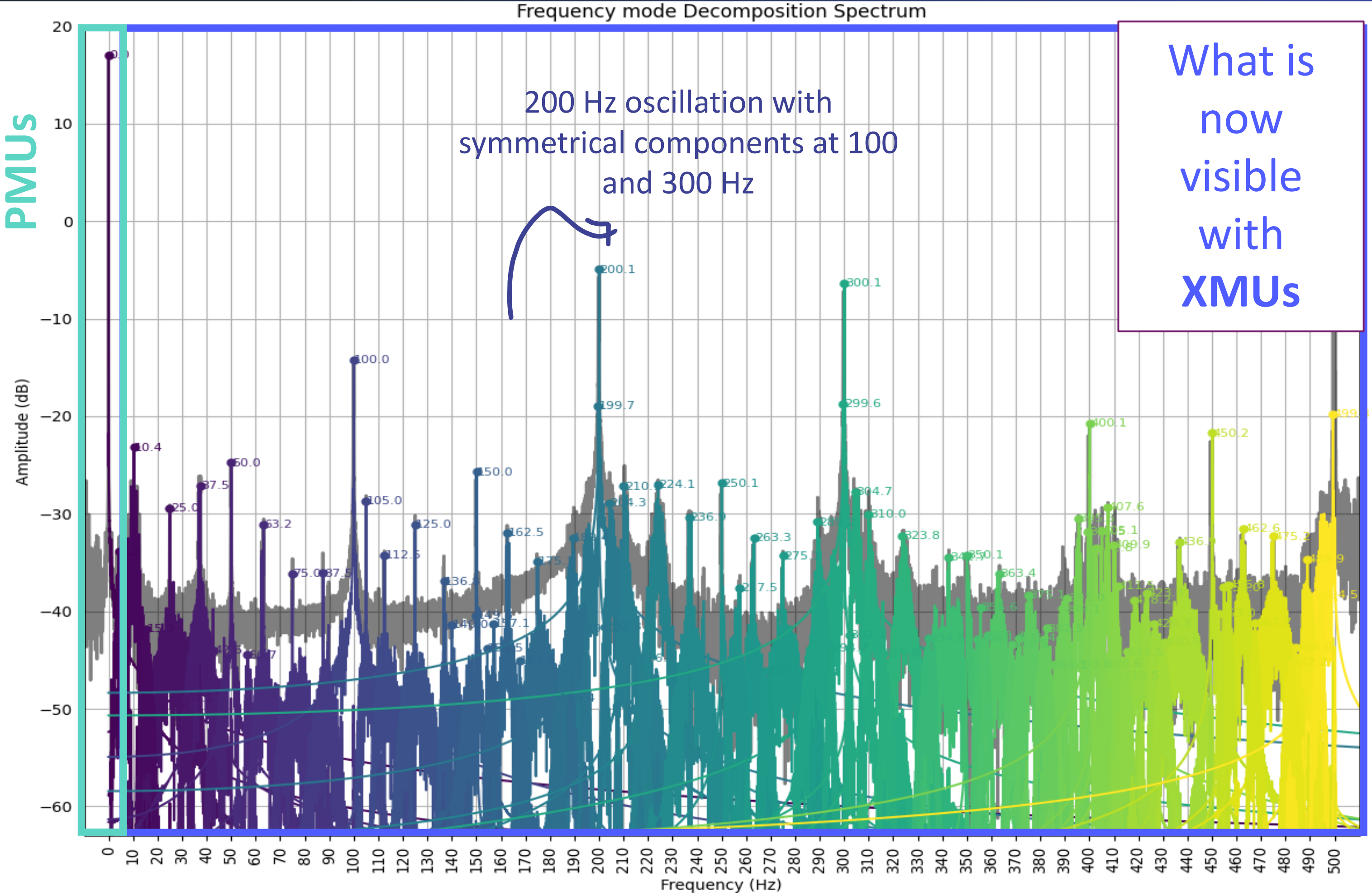


Low-frequency oscillations (0.1–5 Hz)

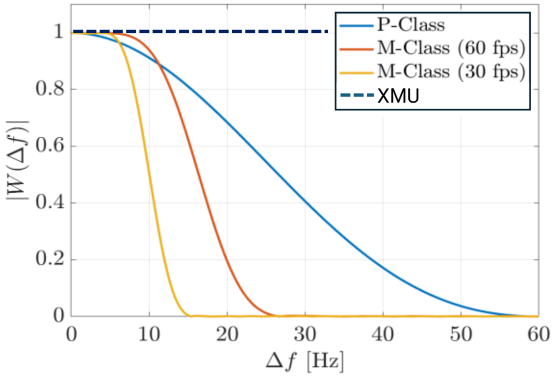
- Align with bulk-power electromechanical modes
- Can cause forced excitation of poorly damped system modes
- May lead to line power oscillations, relay misoperations, or system instability

High-frequency oscillations (5–55 Hz) - POW

- Originating from intra-cycle GPU activity or converter switching
- Can couple into generator torsional modes
- May cause shaft torque pulsations, fatigue, and reduced machine lifetime

High-frequency oscillations visibility is key in High PE-dominated grids

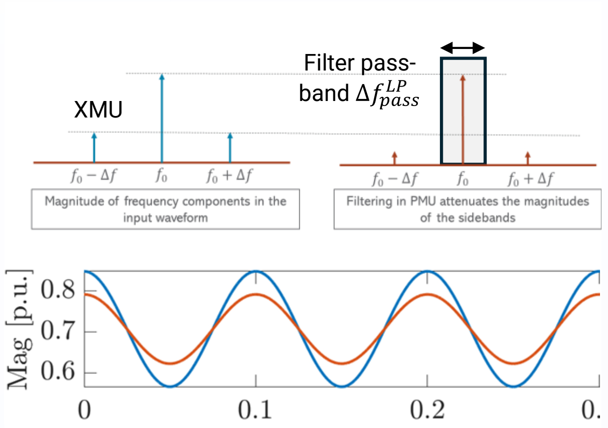
Low-pass filtering



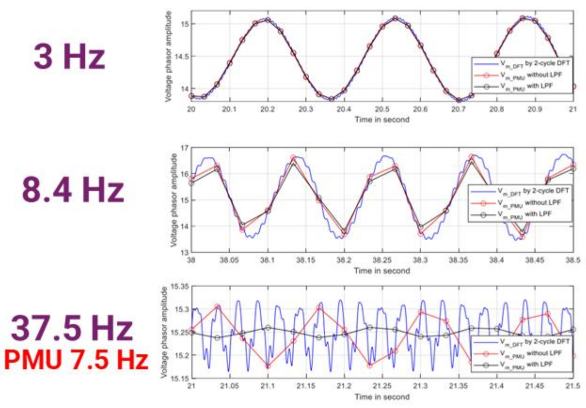
P- and M-Class reference filters from the IEC/IEEE Std. 60255-118-1

(*) XMU response was superposed

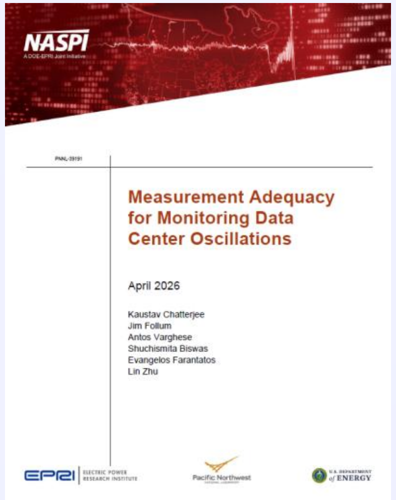
Amplitude Attenuation



Aliasing (PMU 30fps)



2026 Ou, Bowen. *Applicability and Limitation Analysis of PMU Data and Phasor Concept for Low- and High-Frequency Oscillations*.

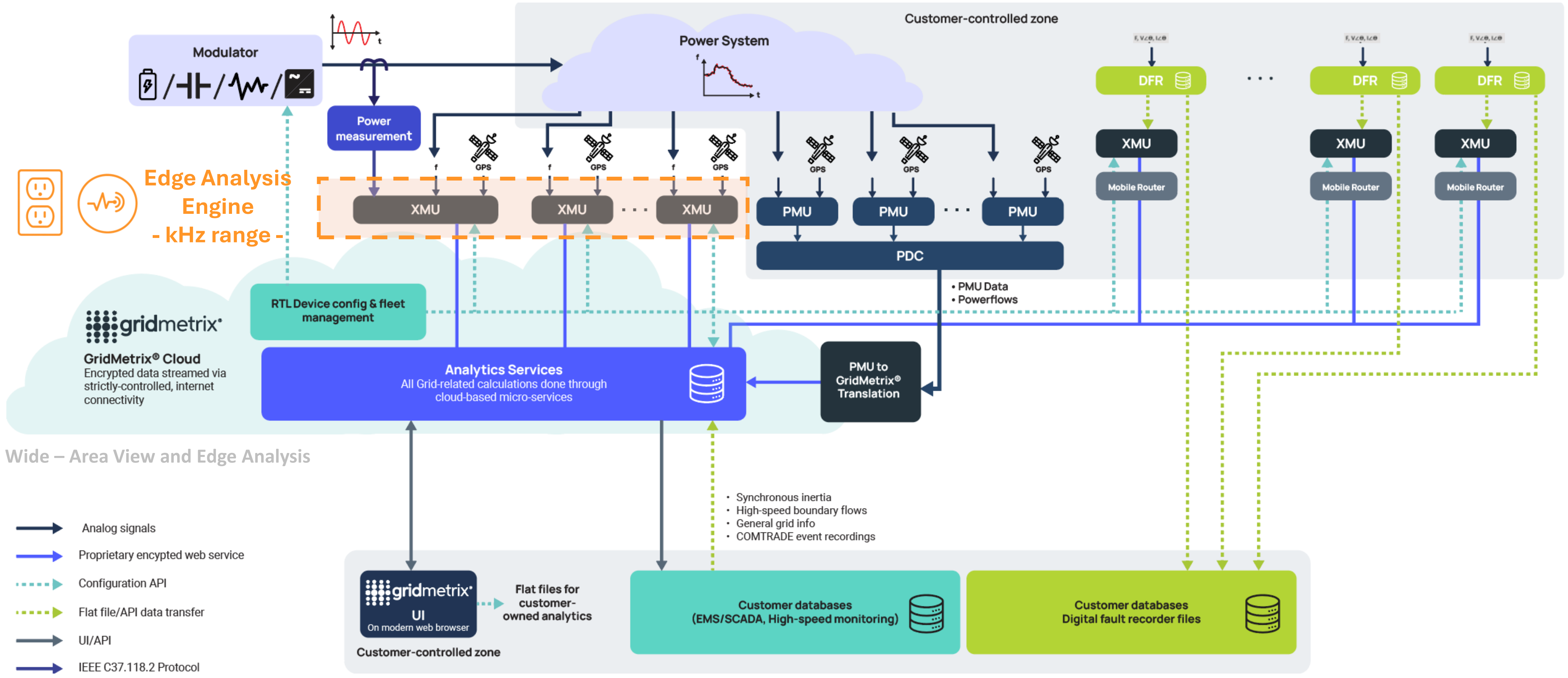


2026 Chatterjee, Kaustav. *Measurement Adequacy for Monitoring Data Center Oscillations*.

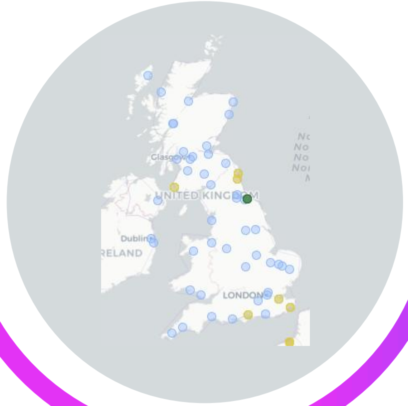
Complementing PMUs

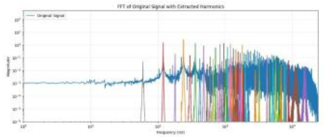
- Raw waveform capture at the edge
- Co-POW streaming
- Local computations at edge

Emerging Solutions Central Analysis Wide-Area View and Edge Analysis



Oscillation Road Map – Low and HF Oscillations





S1 MULTI MODE

Multi-Mode – shows all Oscillations on the grid

Up to 30 Hz

Existing or 2-4 months

S2 HIGH FREQUENCY

Increasing Oscillation Frequency in required locations

Up to 1.2 kHz

6-8 months

S3 SET ALARMS AND ALERTS

Set alerts and alarms for planning and operations teams

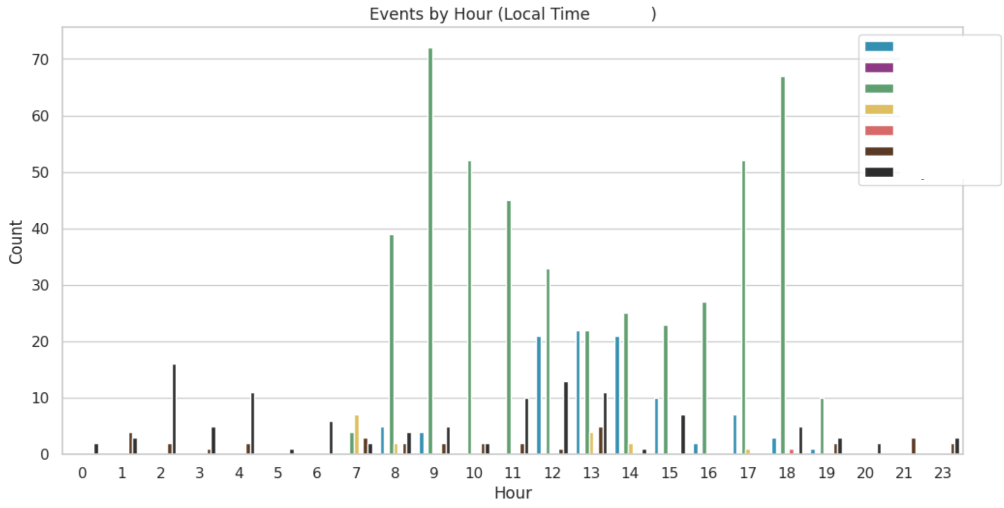
10-12 months

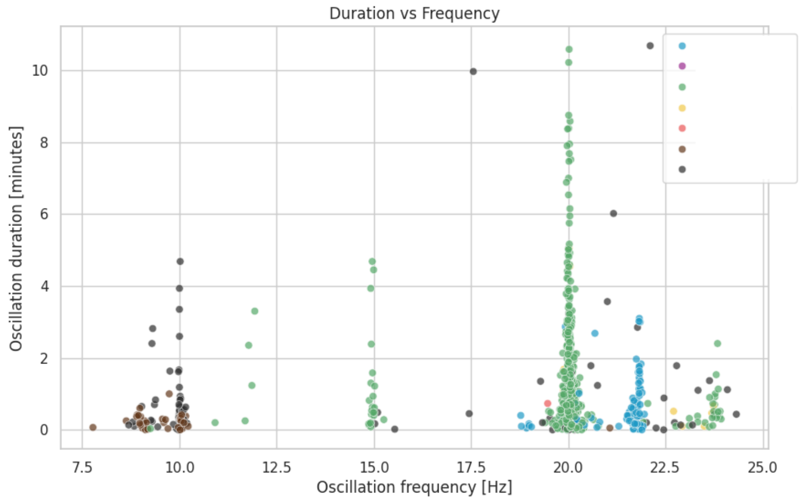
S4 ENGINEERING/ CONSULTING REPORTS

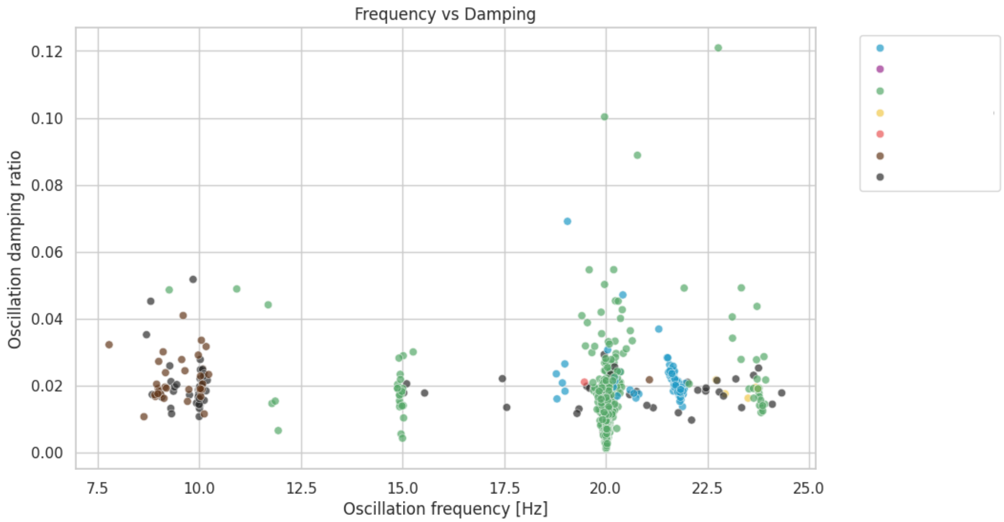
Deliver quarterly reports

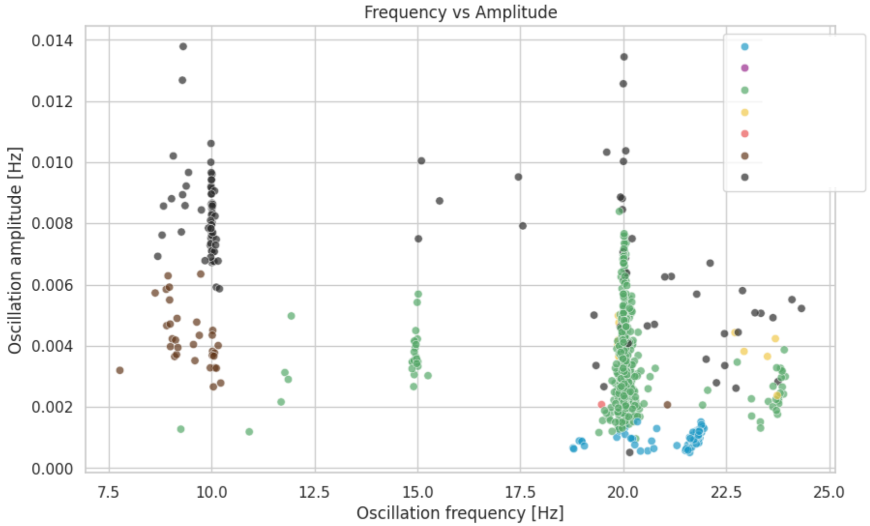
Analysis of events per year

Oscillations Events – Oscillation Event Duration





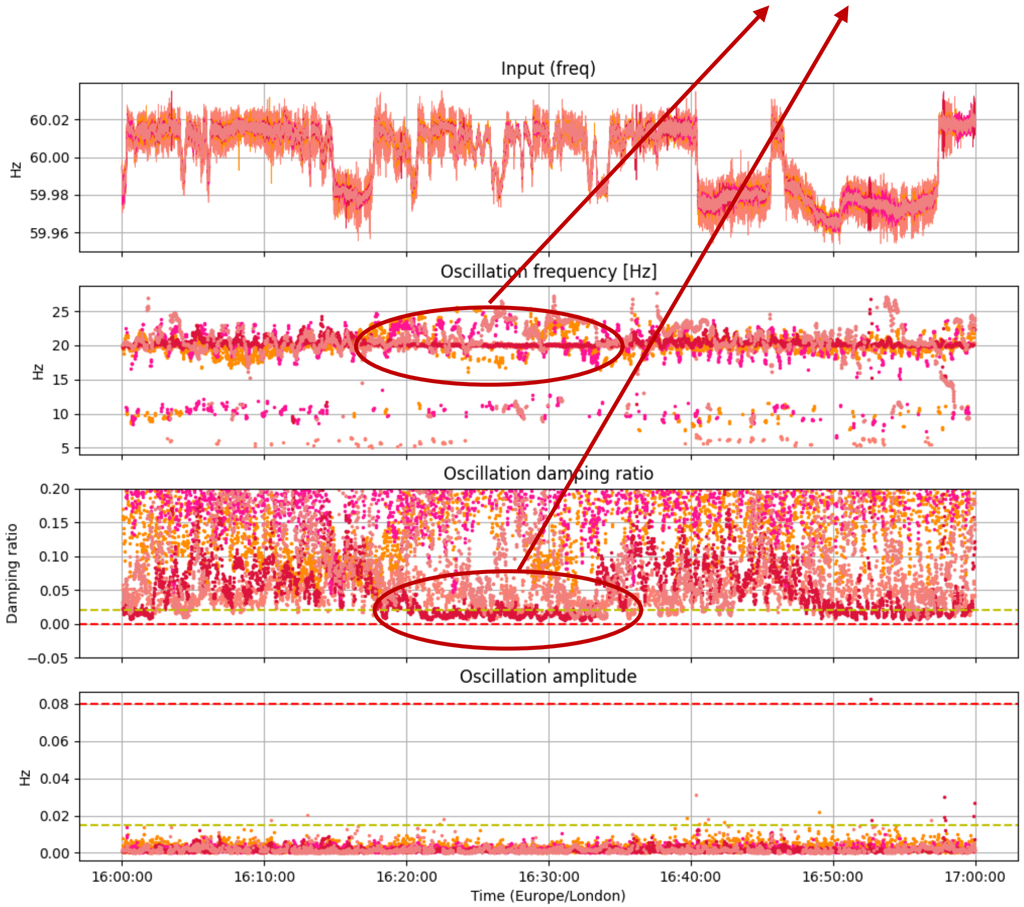


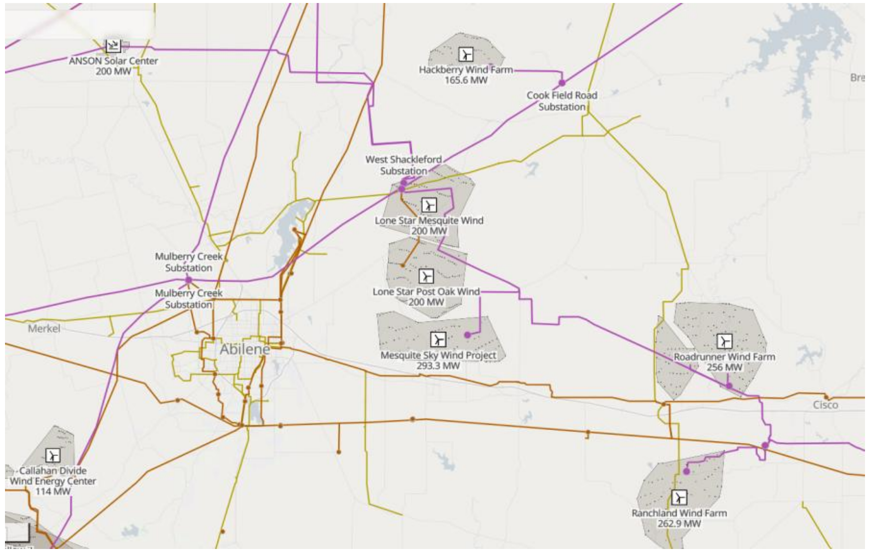


Substation 2 - 16 and 20 Hz SSO near WTG, SM and Computing Loads

duration_s	mean_frequency	min_damping	median_damping	mean_amplitude	freq_bin	month	hour_CDT
95	15.92519273	0.014748451	0.018790563	0.01493014	16	2026-01	0
110	16.00747238	0.016736019	0.01826612	0.013950116	16	2026-03	1
185	15.89269441	0.00930741	0.013269821	0.012196684	16	2026-01	0
165	15.98183674	0.011580953	0.015670411	0.011591978	16	2026-01	1
80	10.575973	0.013033847	0.017962661	0.011435047	11	2026-01	18
995	15.93595621	0.009027743	0.014071753	0.011282166	16	2026-01	23
65	19.96830754	0.004420427	0.017856432	0.011256127	20	2026-03	9
170	15.92445588	0.009720184	0.015906676	0.010824028	16	2026-01	0
75	15.92339271	0.013883143	0.016704864	0.010550179	16	2026-03	15
70	19.74754872	0.003233996	0.012261815	0.010429375	20	2026-02	10

20 Hz Oscillation mode
Not well damped





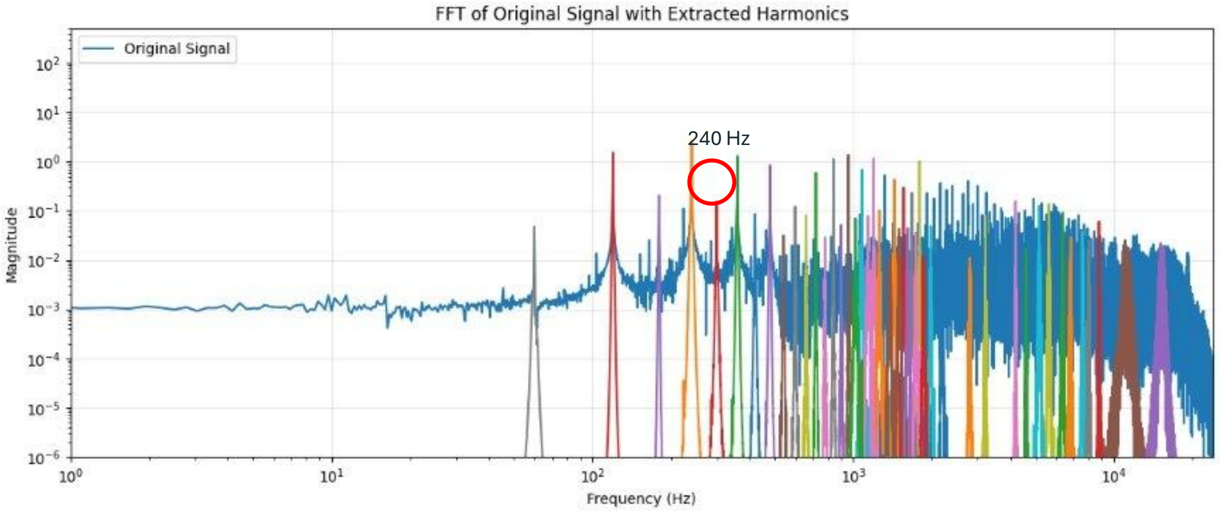
Substation 2 – SVMD Derived Oscillation Analysis

- **High-Resolution Analysis:**
  This SVMD analysis utilizes 48 kHz PCM voltage waveform data to calculate instantaneous frequency, targeting the Substation 1 region, a known high IBR density area – during a period of high wind generation.

- **Spectrum Overview:**
  The initial FFT reveals a complex spectrum of supra-synchronous oscillations, harmonics and inter-harmonics.

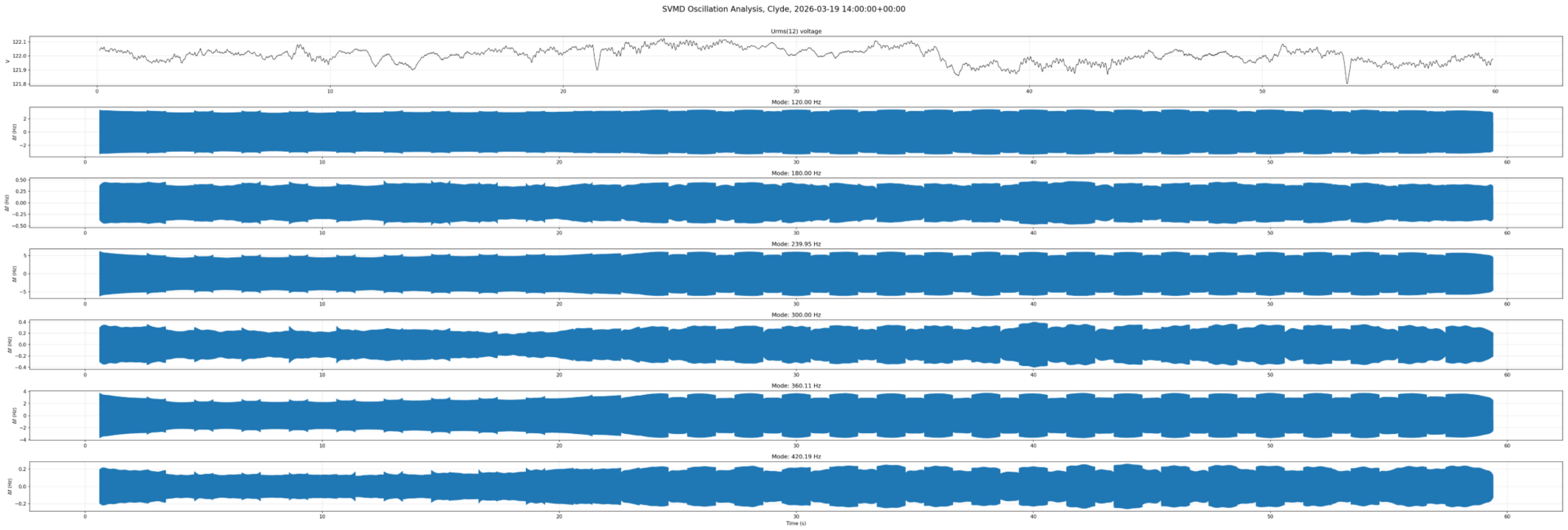
- **Dominant 240 Hz Mode:**
  The most prominent peak occurs at 240 Hz (the 4^{th} harmonic), reaching an amplitude of ~ 4 Hz (0 to peak).

- **Oscillation Groupings:**
  Beyond isolated peaks, the scan reveals distinct families of grouped oscillations. These groups contain unique frequency signatures that point to specific interactions between IBR control systems and the wider grid. These are explored further in the following slides.



Substation 2 – SVMD Derived Oscillation Analysis

- **Harmonic Modulation Family:** This scan isolates the dominant 240 Hz mode and its associated harmonics, which are distributed across the frequency spectrum in 60 Hz steps.
- **The Even Harmonic Anomaly:** The analysis reveals an alternating amplitude pattern. The even-order harmonics (120 Hz, 240 Hz and 360 Hz) exhibit significantly higher amplitudes than the odd-order harmonics (180 Hz and 300 Hz).
- **Indicators of Asymmetry:** In a healthy, balanced power system, even harmonics should be near zero. Their dominance indicates waveform asymmetry. This may be caused by an unbalanced load.
- **Implications for Grid Hardware:** High concentrations of even-order harmonics can induce magnetic saturation in transformers and cause improper operation of protection.



Key Takeaways

Grid monitoring is evolving → **Data as a Service (DaaS) enables scalable observability**

PMUs alone are insufficient → **limited visibility for high-frequency dynamics**

High-resolution waveform data is essential → **captures IBR-driven and fast oscillations**

Hybrid architectures (PMU + POW + edge analytics) → **practical and scalable solution**

Transform data into visibility → **better situational awareness and operational confidence**

High-resolution data and distributed analytics at the edge and in the cloud transform monitoring into a dynamic visibility service for modern grids