Inverters on the Edge

Why faster is not always better

ESIG Spring Technical Workshop:

Session 1A - IBR Dominated Systems

Smartstack™

17MAR26 – Tucson, AZ

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OUR MISSION

Transform the way we power our world to create a more sustainable future

PURPOSE-BUILT

PURPOSE-DRIVEN

ENERGY STORAGE SOLUTIONS (1)

50
TOTAL GWh

296
PROJECTS

SERVICES (2)

13
TOTAL GW

OPTIMIZATION SOFTWARE (2)

NISPERA APM

21
GW OF RENEWABLE AND STORAGE ASSETS UNDER MANAGEMENT

(1) Deployed or contracted as of Dec 31, 2025

(2) Contracted or assets under management as of Dec 31, 2025

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Overview

- **Setting the Scene for Speed**
- **Truth vs. Reality vs. Reliability**
- **What is at risk?**
- **What standard procedures are missing?**
- **Intermediate Mitigation**
- **Mid Term Improvements**

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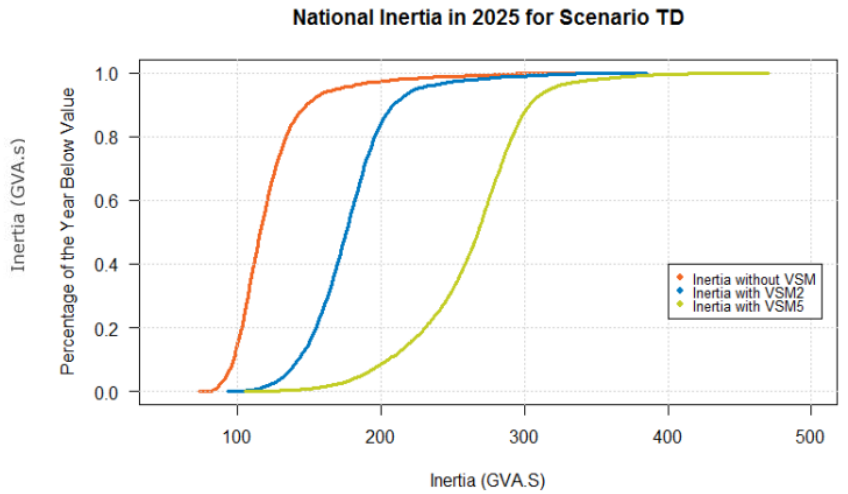
Setting the Stage for Speed

How will my grid evolve?

2020 is coming and things are changing…

- Renewables are on the rise
- Aged coal and nuclear plants are retiring
- Inertia is falling
- BUT the price of BESS is also falling
- New technologies allow for new tools to mitigate issues with frequency stability



$$30\,s \gg 3s \gg 1s \gg 500ms \gg 250ms \gg 150ms$$

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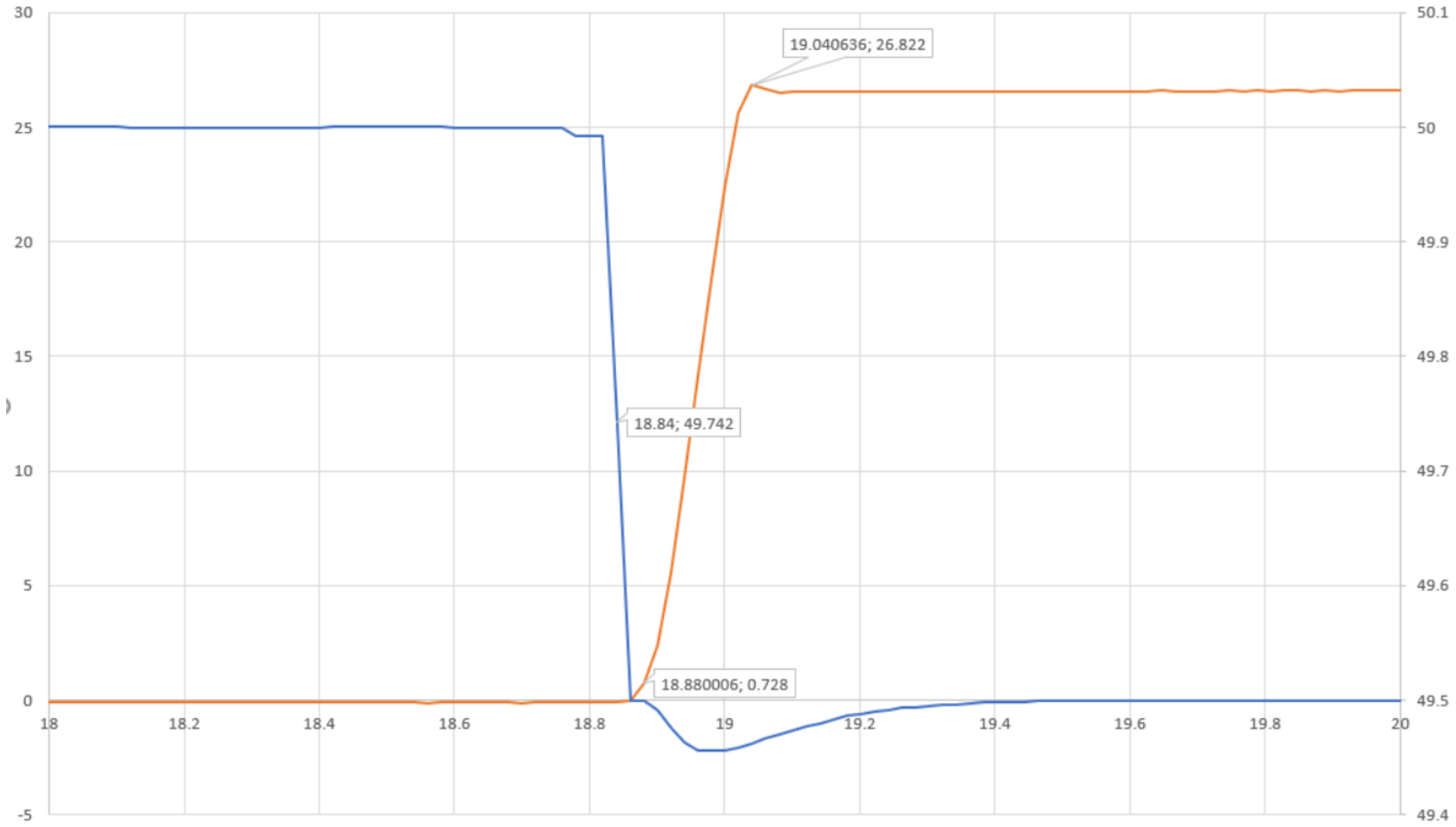
Grids were Right – BESS Can Deliver Lightning Fast FR

Example of <150ms



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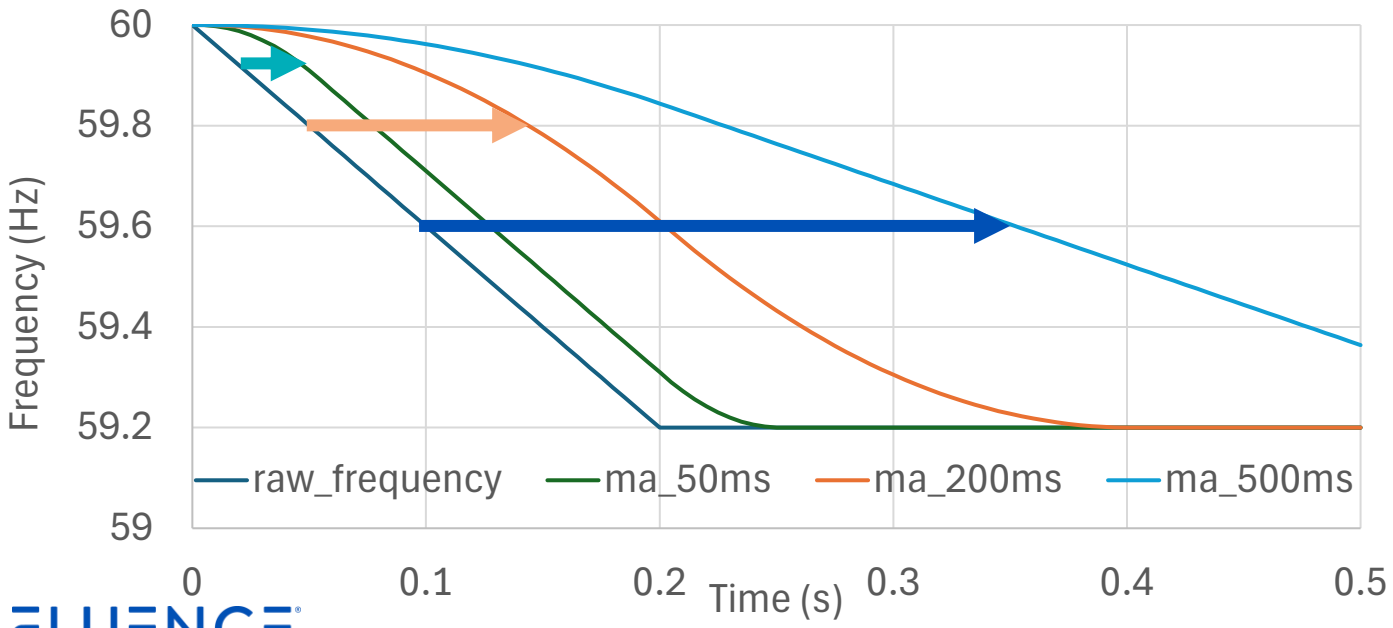
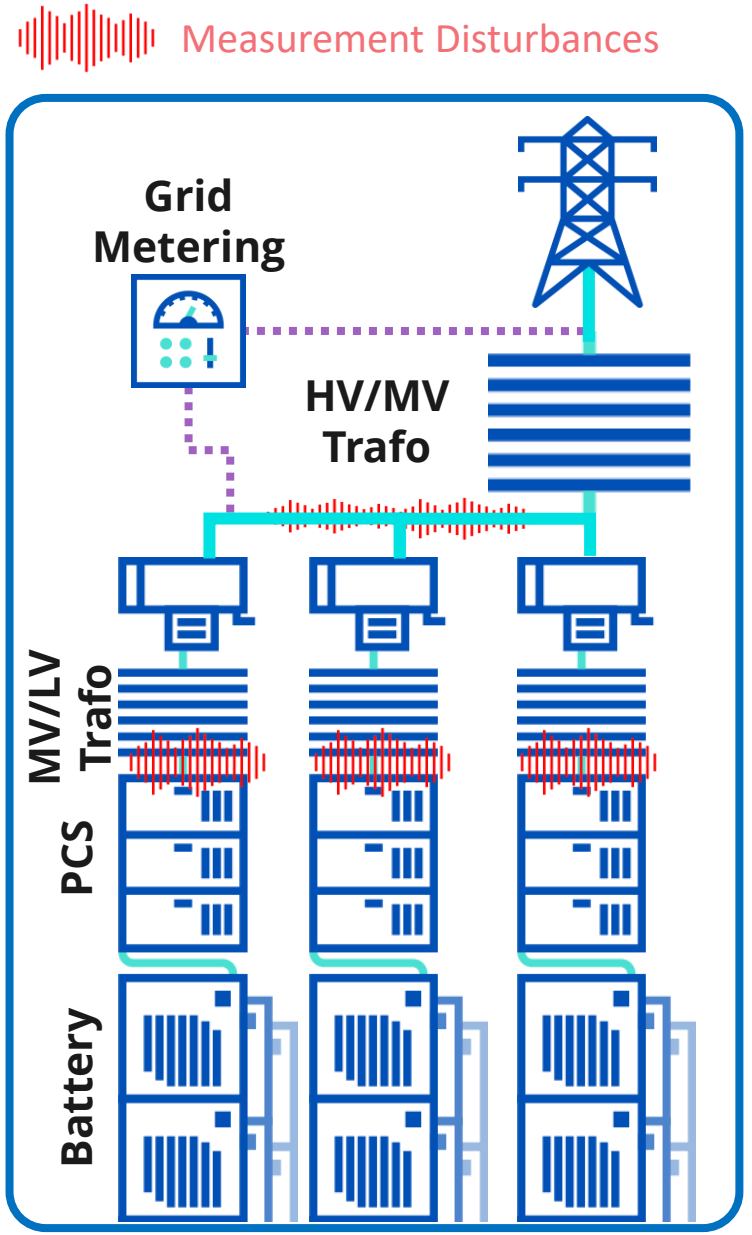
Truth vs. Reality vs. Reliability

- “Fast” but increased averaging/filtering delays response and effectively expanding deadbands
- Without averaging disturbances can lead to false triggering
- Voltages, thus frequency, becomes more disturbed lower into the system
- Fast PCS ramp can cause local angle shift disturbing frequency





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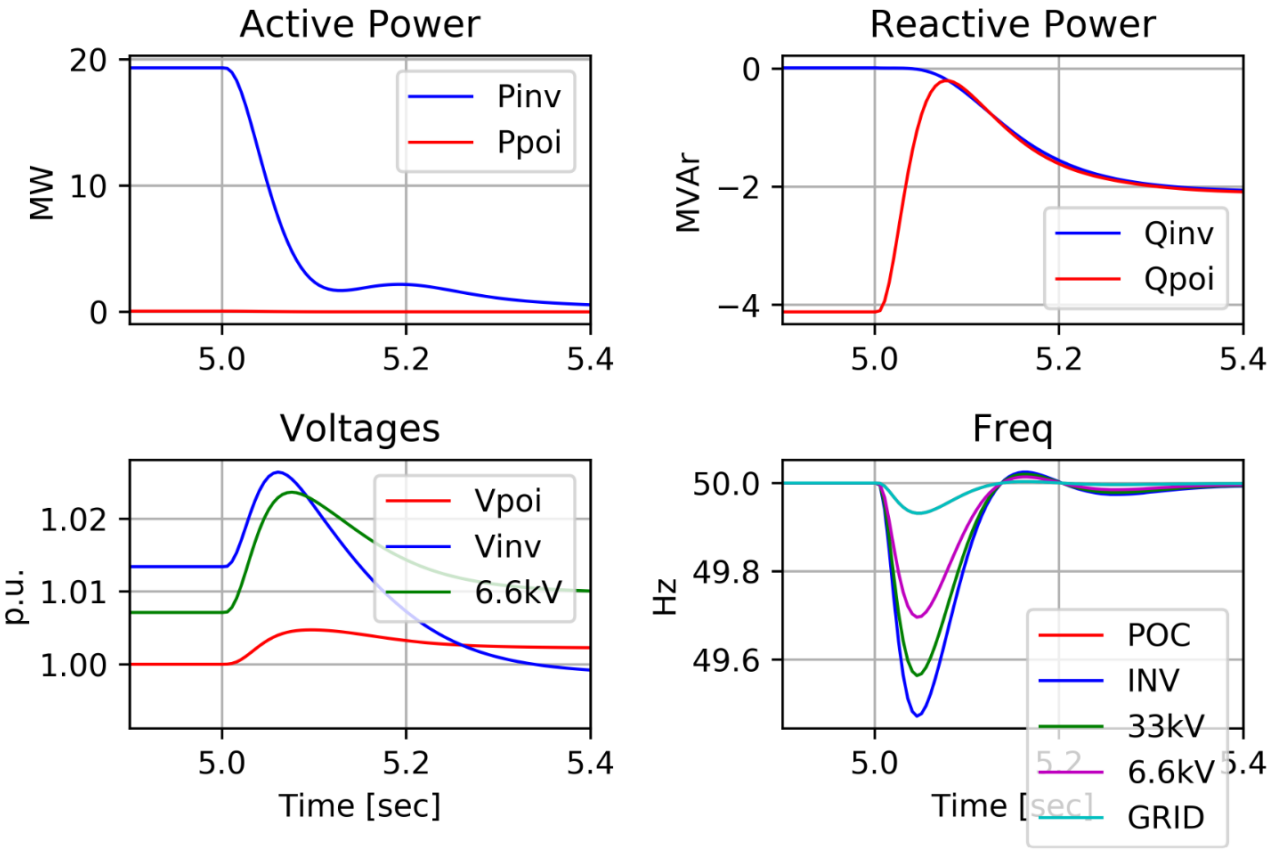
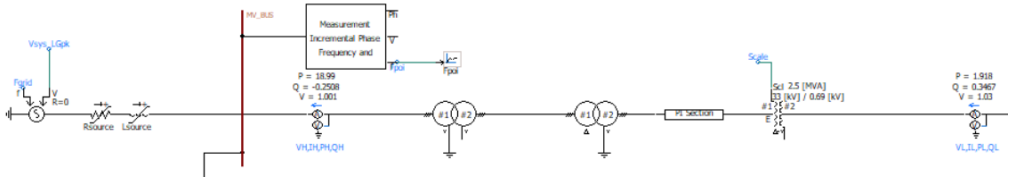
Truth vs. Reality vs. Reliability

Point of Measurement Matters





More Impedance → More Decoupling

- Standard 33kV BESS Connected to existing 110/6.6kV high voltage transformer
- PSCAD Simulations for forced power “step”
- Potential for false FR Triggering when using:
  - LV “INV” Measurements
  - Both MV Connections Points
- MV-BESS should have HV voltage/frequency measurements for robust FR

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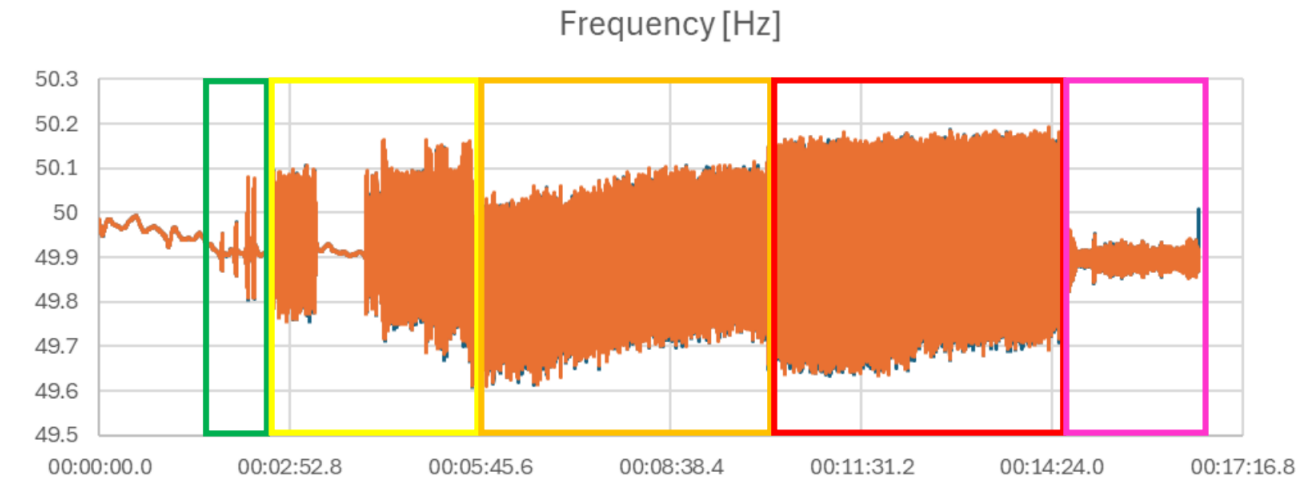
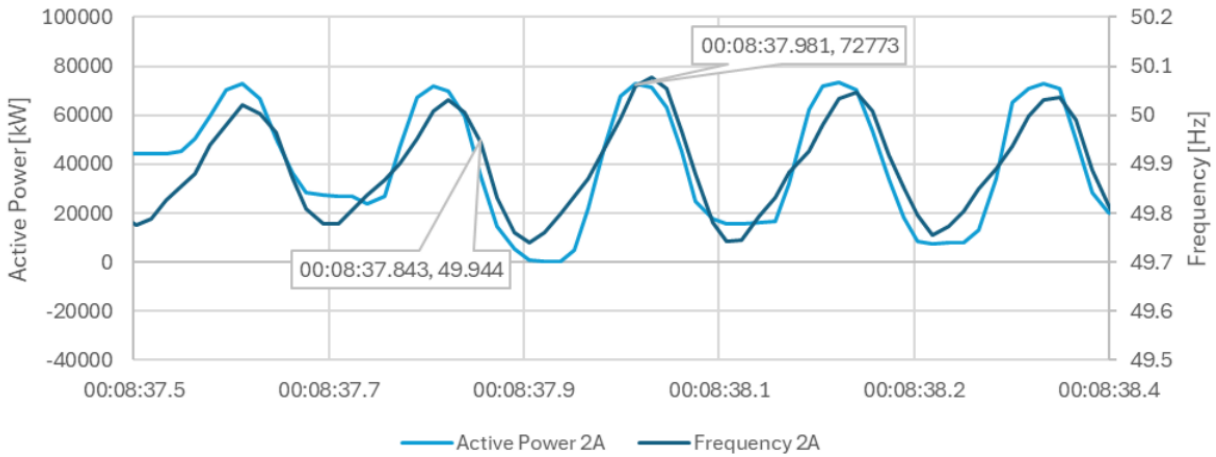
What is at risk?

When fast is not fast enough

The recipe for (potential) disaster

- High Penetration of Non-Synchronous Gen
- Low Inertia – Below TSO's own limit
- Aggressive P(Δf) Droop : 0→100% in 100mHz
- "Fast" GFL rather than Inherent/Instant GFM
- $\frac{\Sigma P_{BESS}}{P_{Grid}} > X\%, \text{e.g. } X \geq 4\%$
- No prescriptive frequency calculation method
- Response drifts to be in phase with frequency





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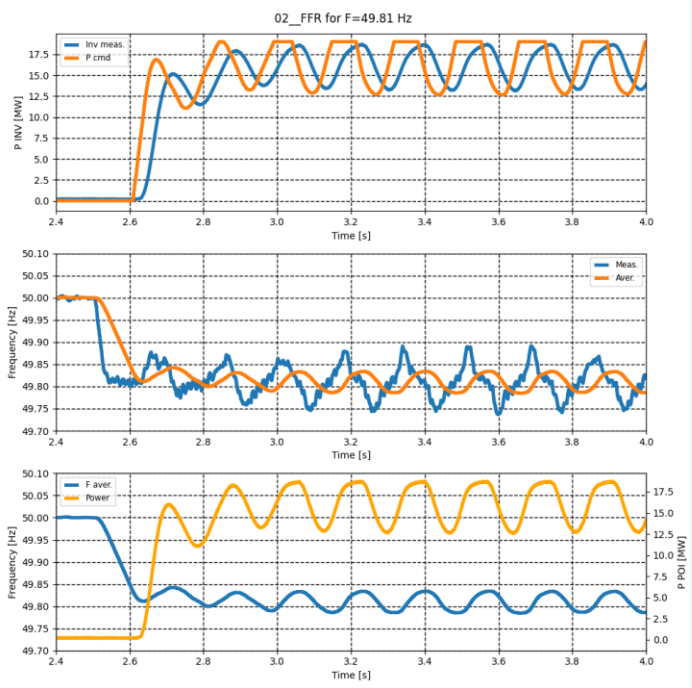
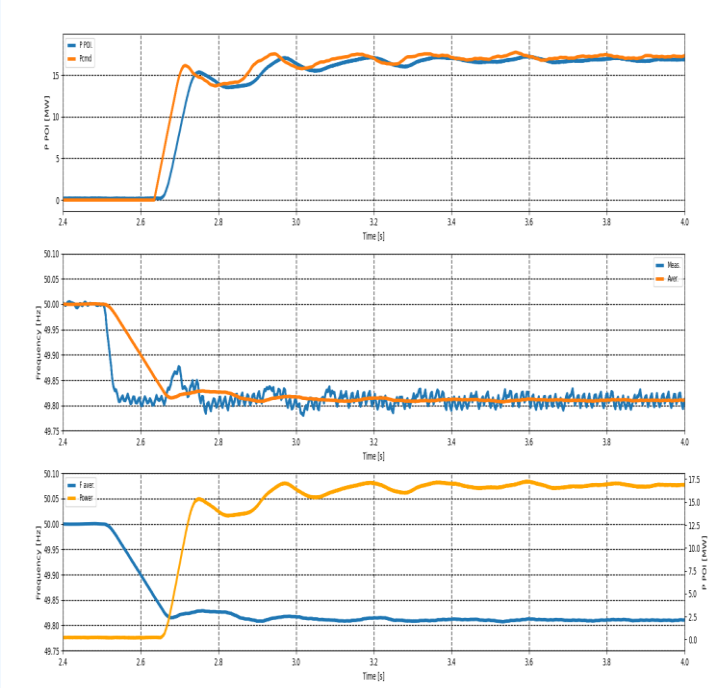
Intermediate Mitigation

Slow down to (stably) speed up

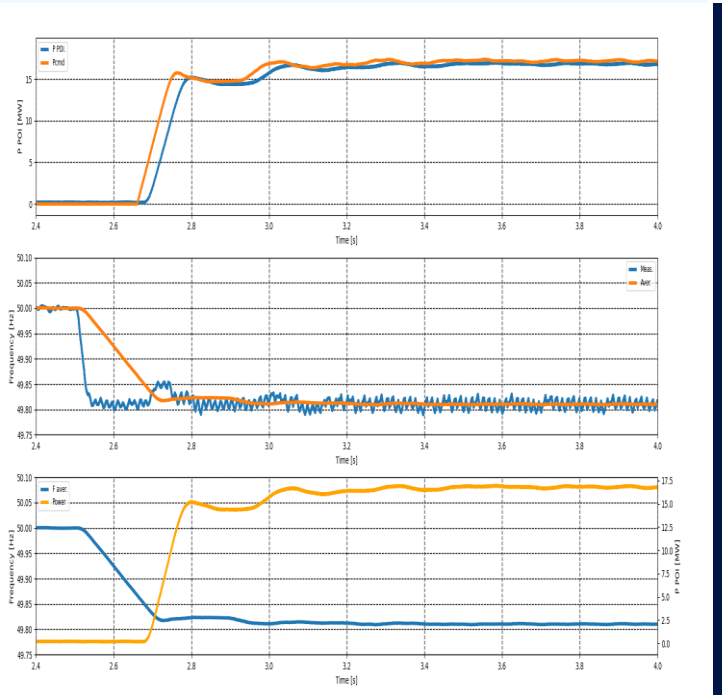
100ms



150ms



200ms-Agreed with TSOs



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Why was this missed?

Issues Often Arise Long After Handover

Simulation

- Simulations typically presume Infinite grid
- Programmed f(t) profile doesn't allow for any P&f coupling of controls
- 3rd party consultants/customers apply generic meter models with unknown averaging/filtering
- Limited Range of Required POD Studies

On-Site

- Frequency Response Services are tested via synthetic voltage/frequency waves/profiles on the control meter → P&f are de-coupled
- Multi-day FR stability tests may miss niche hours of low inertia and/or luck out without any significant events during testing
- BESS/Grid Ratio is increasing
- Grid Inertia is decreasing

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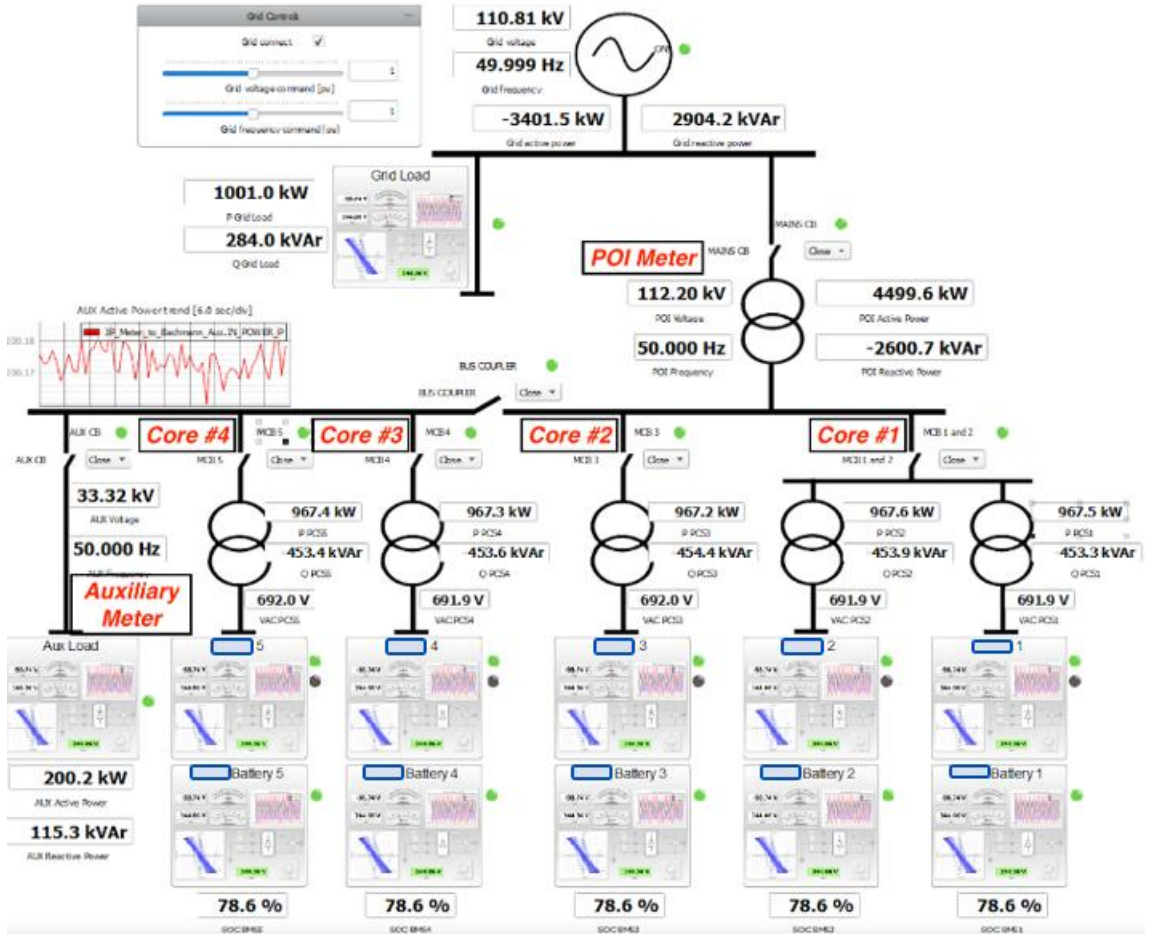
Mid-Term Improvements

(Besides Grid-Forming…)

Balancing Speed and Sensitivity

- Dictate averaging/filtering methodology and maximum sampling rates for FR
- Allow for VTs on HV even if BESS is on MV
- Re-asses and adapt P(Δf) Droop
- Include Aggregate Grid Inertia in Studies
- Apply Actual Meter Models vs. Generic
- Project Specific HiL Testing with PPC and POI Meter in the Loop to capture delays



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Q&A

Thank you for your attention!

Any Questions?

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