From SCR to Frequency-Dependent Strength

Impedance Scanning to Screen IBR Interactions and Target EMT Studies

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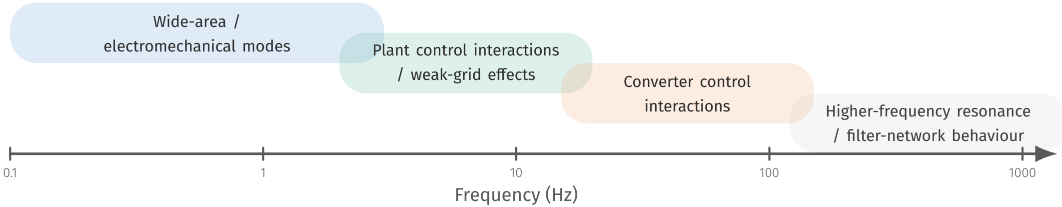
Why oscillations keep showing up in IBR connection studies

Key message: The hard part is not only detecting an oscillation. It is understanding *which interaction*, at *which frequency*, and *what to do next.*

- IBR-rich systems can exhibit **oscillations** over a **much wider frequency range** than conventional machine-dominated systems.



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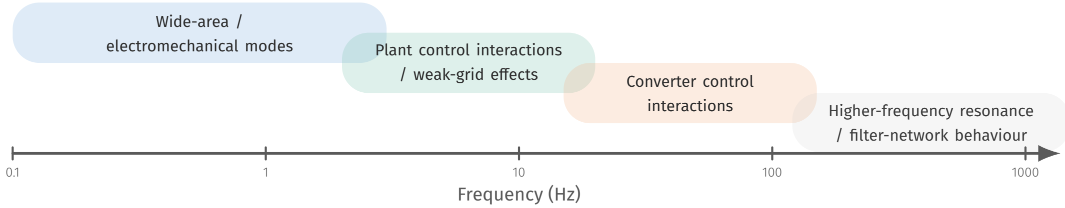

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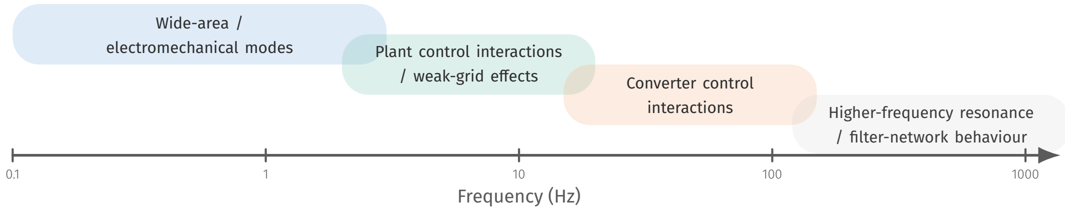

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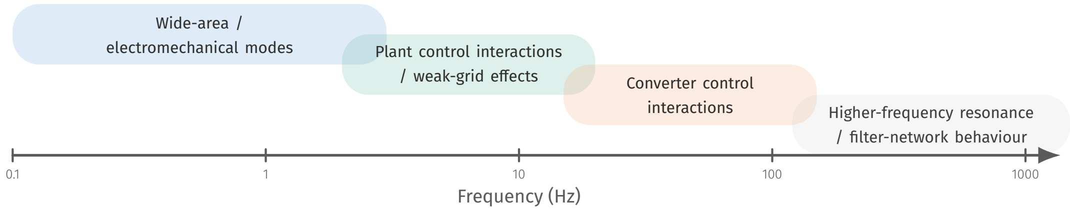
Is SCR a reliable metric?

If I tell you the SCR is 2, you still do not know whether the real risk sits at 2.8 Hz, 11.6 Hz, or 69 Hz.



Where impedance-based analysis (IBSA) sits in the study toolbox

Key message: Best role for IBSA: a transparent screening-and-diagnosis layer between simple strength metrics and full EMT confirmation.

	SCR / short-circuit metrics	Impedance-based stability analysis	EMT simulation
Best at	quick location screening	interaction screening, mode insight, option comparison	final confirmation, large disturbances, detailed waveforms

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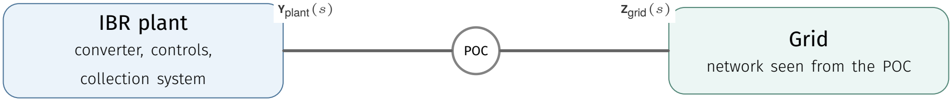
Best at	quick location screening	interaction screening, mode insight, option comparison	final confirmation, large disturbances, detailed waveforms
Typical question	"Is this location weak?"	"Which interaction is risky and how do options change it?"	"Does the final design survive realistic disturbances?"
Misses	frequency-dependent behavior	large-signal effects and protection/limiter behavior	fast root-cause isolation and transparent sensitivities
Why?	necessary but not sufficient	insight engine	final truth test

Use both IBSA and EMT!
IBSA for screening and diagnosis; EMT for final confirmation.

IBSA in plain English

1. Separate the problem at the point of connection into a **plant side** and a **grid side**.



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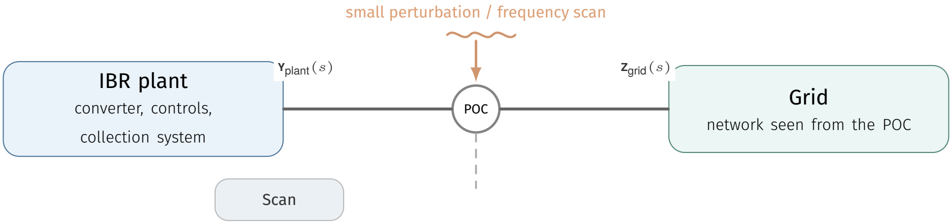

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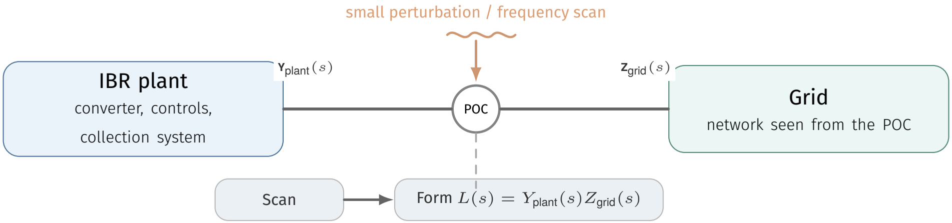
$$L(s) = Y_{\text{plant}}(s)\, Z_{\text{grid}}(s)$$



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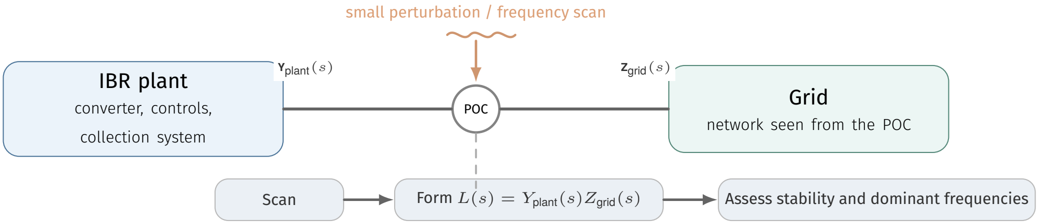
4. Use the resulting plots to answer two practical questions:
   - **Is it stable?**
   - **If not, which frequencies and which devices matter most?**



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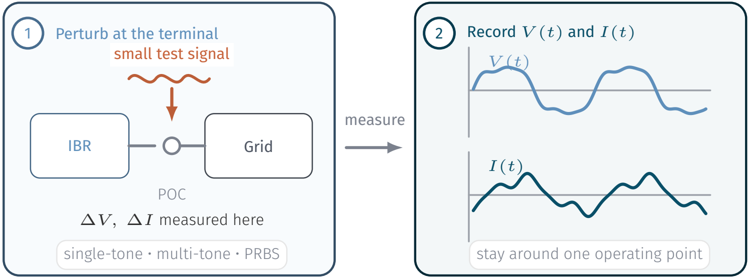

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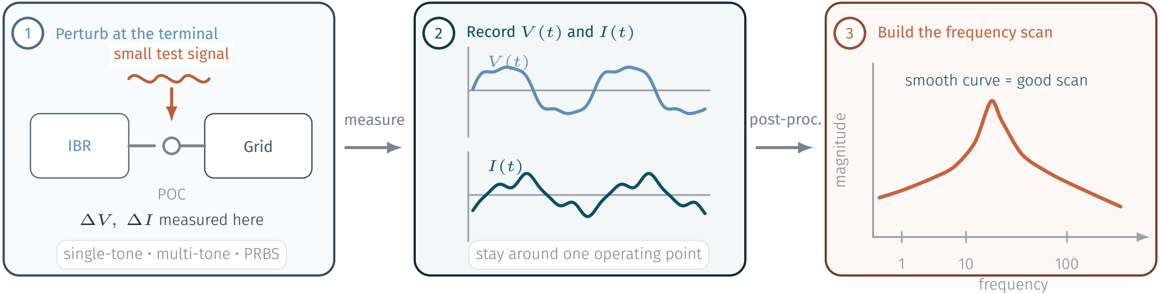

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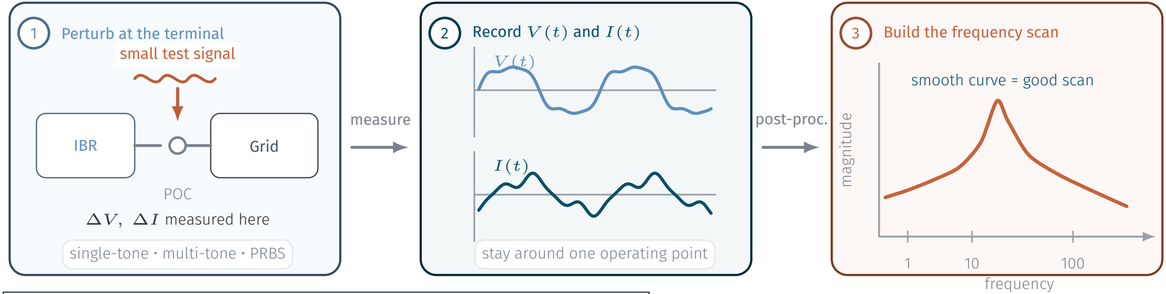

Practical scan notes

- Three-phase inverter scans are usually done in the **dq domain**.
- Keep excitation **small but visible**: too large causes nonlinearity; too small is lost in noise.
- Scan window must be **steady**: avoid start-up transients, reference steps, faults, etc.
- Avoid **limiters, tap changes, shunt switching, & other discrete actions**.

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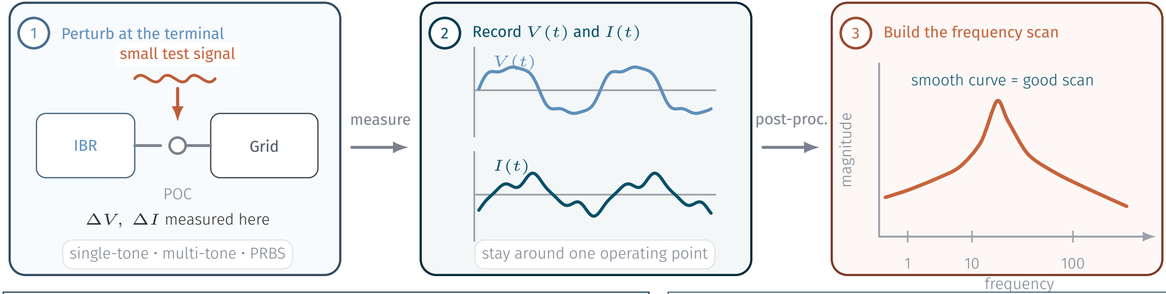

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Signal-processing notes

- Check for **aliasing** and **spectral leakage**.
- Choose frequency points that capture the dynamics of interest.
- More concurrent tones can speed up scan, but may reduce quality.
- A **smooth, physically consistent** scan is good; noisy or jittery curves usually mean refinement is needed.

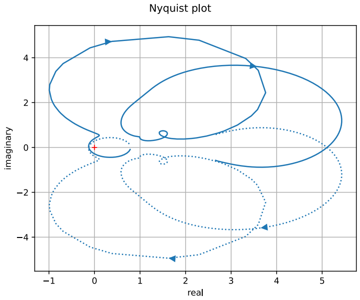
Same plant–grid model, two different questions

Key message: Nyquist answers **stable/unstable**. Closed-loop response answers **where the trouble is** & **how severe it is**.

A. Nyquist = open-loop interaction view

$$L(s) = Y(s)\,Z(s)$$

- **How we get it:** use the scanned $Y(s)$ and $Z(s)$ to form $L(s)$, then plot either $\det(I_m + L(j\omega))$ or eigenvalues of $L(j\omega)$ as frequency sweeps.
- **Why it is useful:** if plant and grid are stable on their own, **no critical-point encirclement** means the interconnected system is stable.



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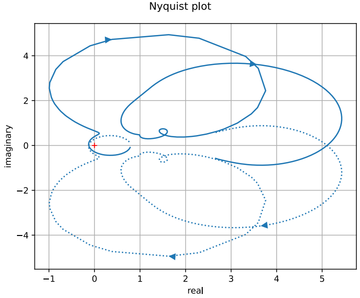
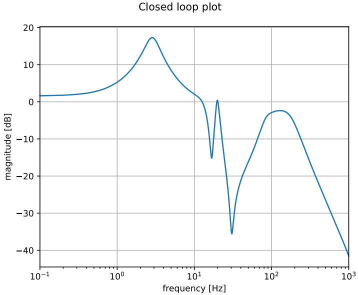


B. Closed-loop response = interconnected-system view

$$Z_{\mathrm{CL}}(s) = Z(s)\big(I_m + Y(s)Z(s)\big)^{-1}$$

- **How we get it:** use the same scanned $Y(s)$ and $Z(s)$, interconnect them, and evaluate the closed-loop response versus frequency.
- **Why it is useful: peaks reveal modes**; peak frequency tells you where the mode is, and peak sharpness tells you how well damped it is.



From encrypted PSCAD models to defensible stability decisions

Stage 1- Funded by ARENA in 2023

MONASH University

Delivered with AEMO + Powerlink
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Rezonance

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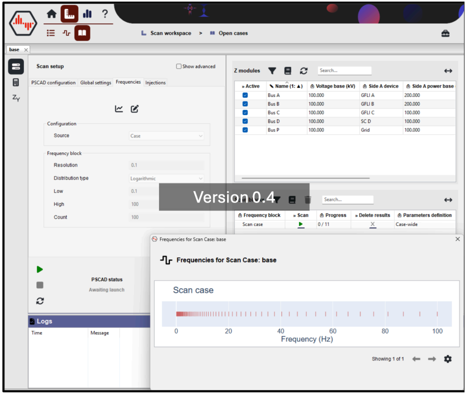
Why Rezonance is practical

- **Encrypted vendor models:** black-box ready for PSCAD workflows.
- **One workflow:** scan, manage, and analyse in one environment.
- **Built for practice:** connection studies, tuning, and oscillation diagnosis.
- **Flexible use:** GUI + Python API for engineers, consultants, and operators.
- **Cybersecure deployment:** local-first, zero telemetry, signed and security-scanned releases.



Scan in PSCAD › Manage projects / cases / data › Analyse modes, margins & participation › Decide with evidence

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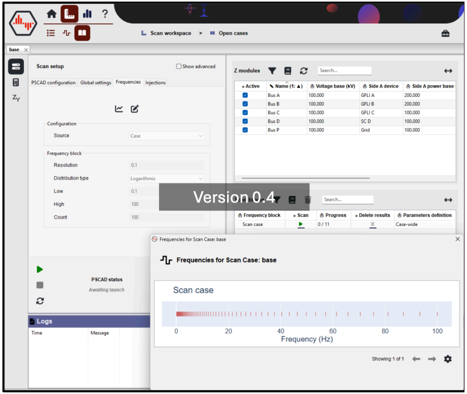

Early Access Program: operators, NSPs, consultants, and OEMs — priority onboarding, hands-on support, and direct workflow feedback.

Scan for Rezonance & Early Access form

https://rz-v0.gridzync.com.au

contact@gridzync.com.au

Scan in PSCAD › Manage projects / cases / data › Analyse modes, margins & participation › Decide with evidence

Practical workflow: from PSCAD model to engineering decision

1. **Integrate the scan module** at the plant point of connection in PSCAD.
2. **Configure the scan** - frequency range, injection settings, base values, and device labels.
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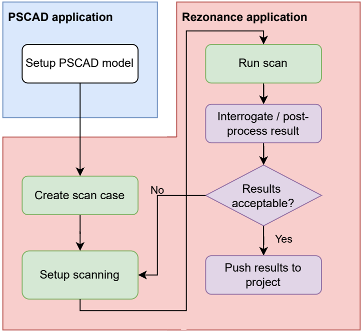

Impedance scanning workflow overview.

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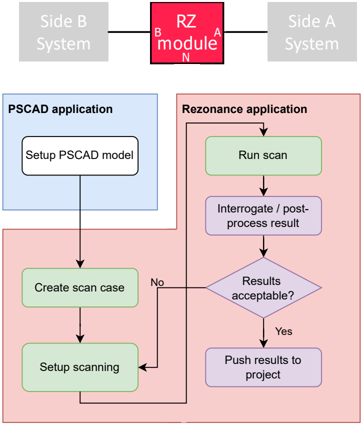
Important nuance

The scan is not the end. The engineering value comes from comparing cases and turning the scan into a decision.



Impedance scanning workflow overview.

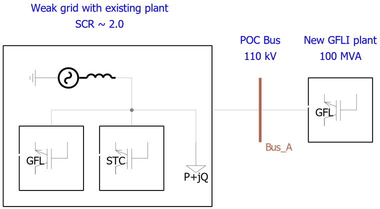
Where this method helps in practice

Key message: Three high-value use cases: connection screening, controller/plant design, and multi-plant oscillation diagnosis.

Use case 1

Connection screening

“Will this plant connect stably at this POC, and what grid conditions matter most?”



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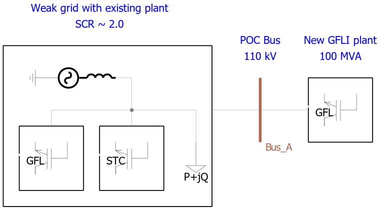
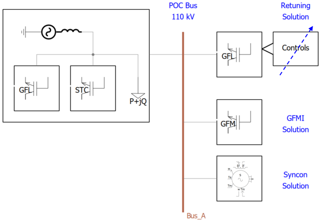
Use case 2
Tuning / design comparison

"Should I retune controls, add a syncon, or add grid-forming support?"





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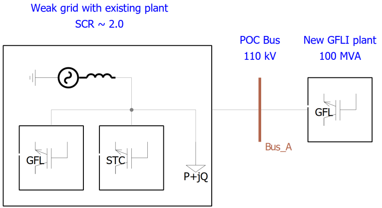
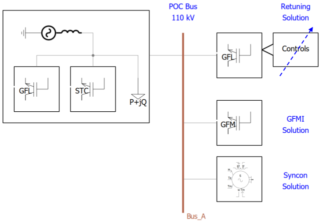
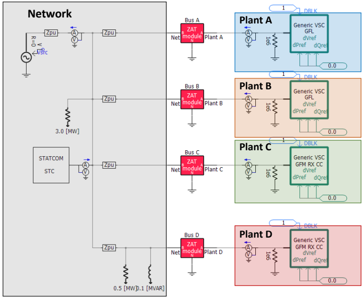
Use case 3
Oscillation root-cause analysis

"Which plant is the source and which plants actually help damping?"





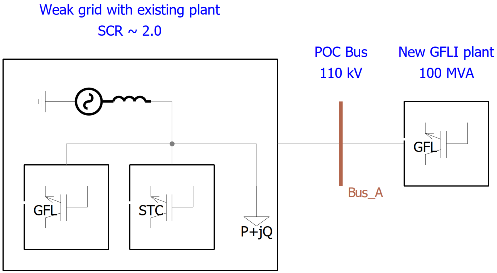


Case study 1 - a weak-grid connection question

Key message: This is the kind of question proponents and network operators face every day: a real connection point, a weak grid, and multiple remedy options.

Setup

- New **100 MVA grid-following IBR** plant.
- Point of connection has **SCR** $\approx$ **2.0** - clearly weak.
- Existing IBR capacity is already present in the surrounding grid.
- Goal: identify a connection solution that is stable *and* practical.



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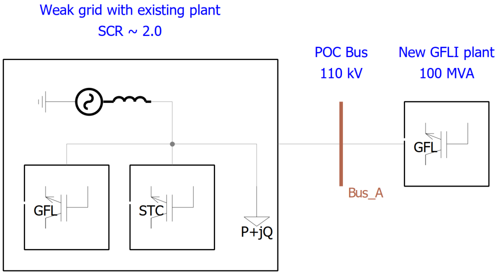


Question?
"If the base design is unstable, what is the cheapest credible fix that actually works?"

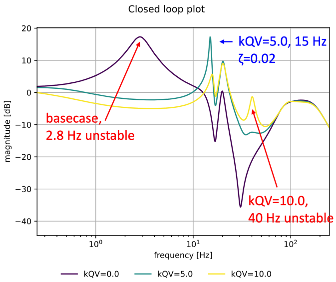
Base case
2.8 Hz unstable mode observed in the starting design.

Case study 2 - what the option screening said

Key message: The real value isn't just "stable/unstable"; it's that the method ranked remedies before a heavy EMT loop.

Option	What the analysis showed	Engineering read-out
Retune GFLI	Improved the response, but the best setting was still too oscillatory for a robust solution.	Not a convincing connection design on its own.

Retuning



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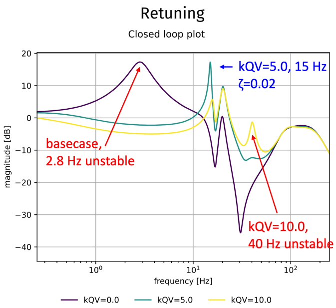

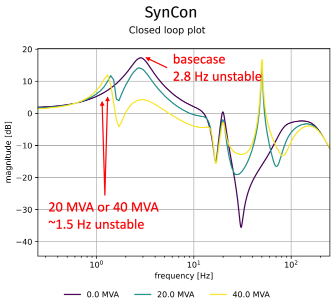

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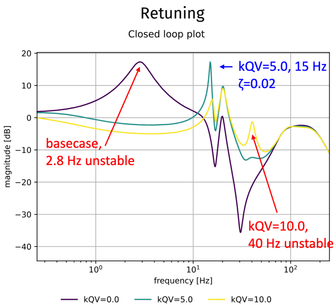
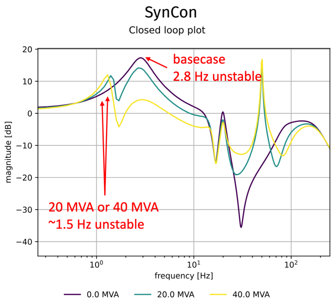
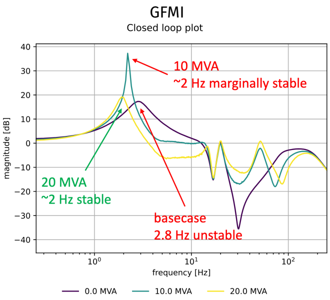
GFMI support	10 MVA was marginal; **20 MVA delivered stable & acceptable performance**.	Best solution among the studied options.

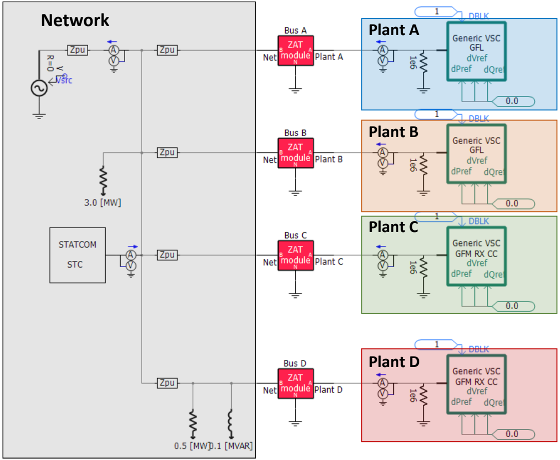






Case study 3 - when several IBRs share the problem

Key message: In a multi-IBR system, the first question is not “is there a mode?” It’s “who’s creating it, who’s following it, & who’s helping?”



Multi-IBR network with several plants connected through a shared transmission corridor.

What do we mean by system view and plant view?

System-level view	all plants grouped together vs the network reveals the global modes of the overall system
Plant-level view	one plant vs the rest of the system reveals which plant drives, follows, or damps each mode

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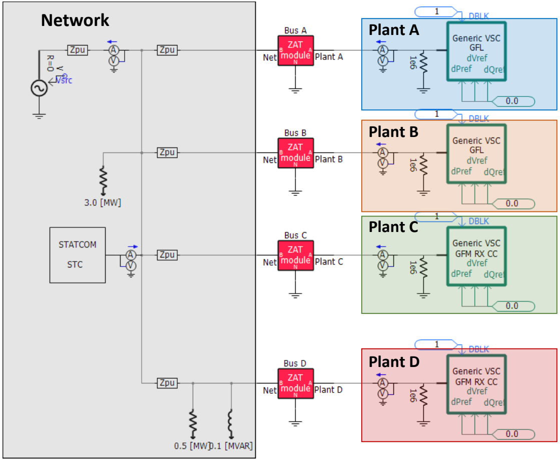

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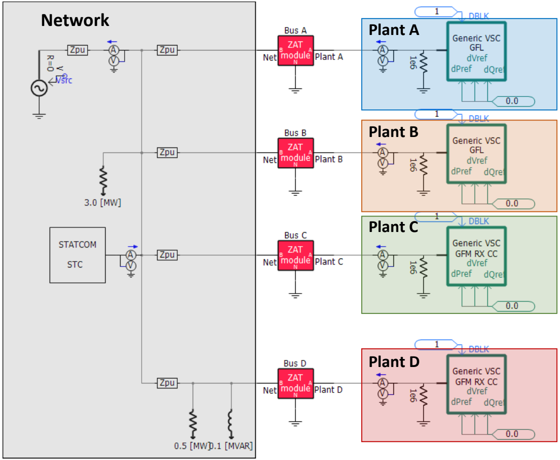

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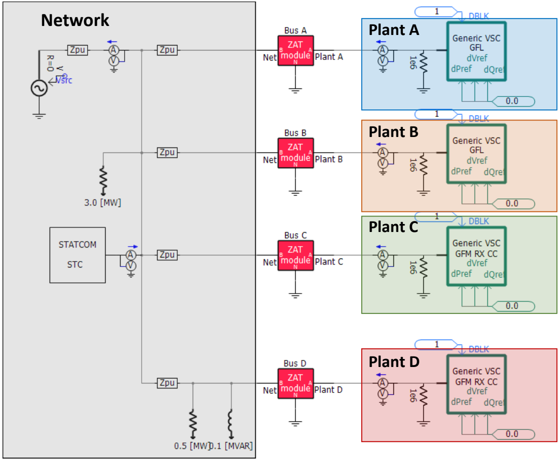

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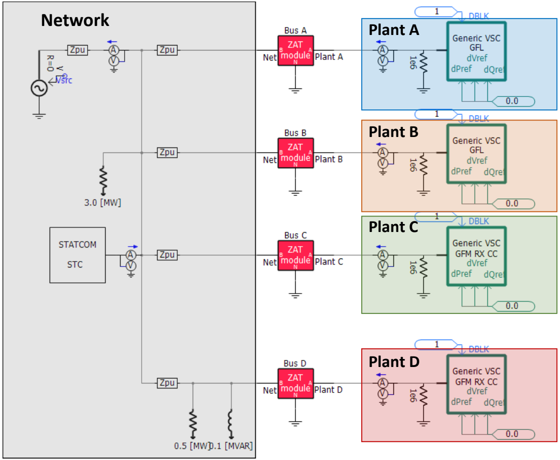

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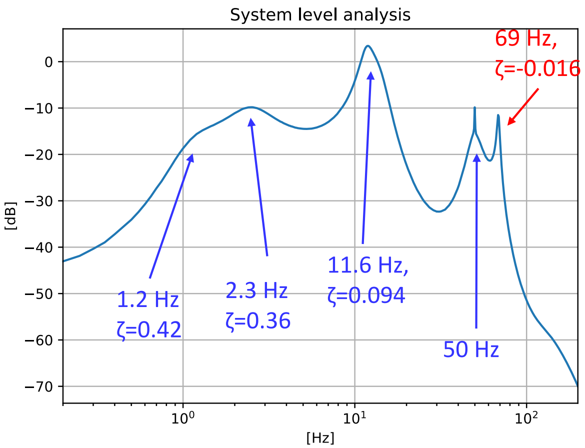
Simple interpretation
System level tells us **what the problem is**.
Plant level tells us **who owns the problem**.

Case study 3 - the system-level diagnosis

Key message: One system-level closed-loop view turned a vague oscillation problem into a short list of critical modes.

69 Hz

Unstable mode - this is the urgent one.



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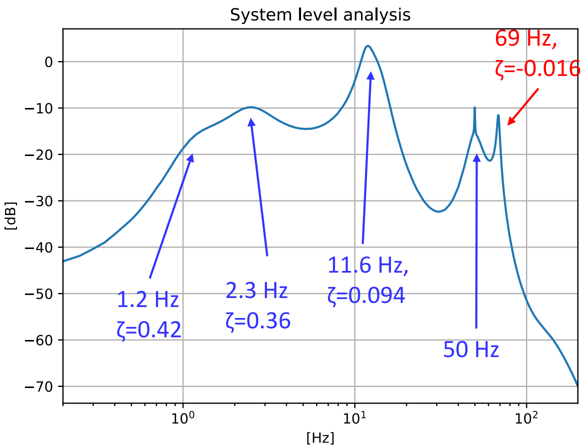

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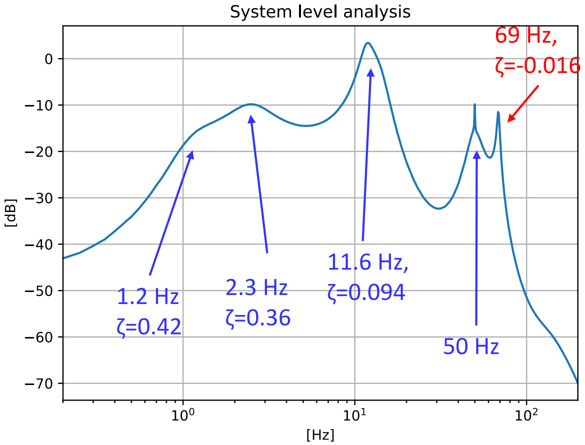

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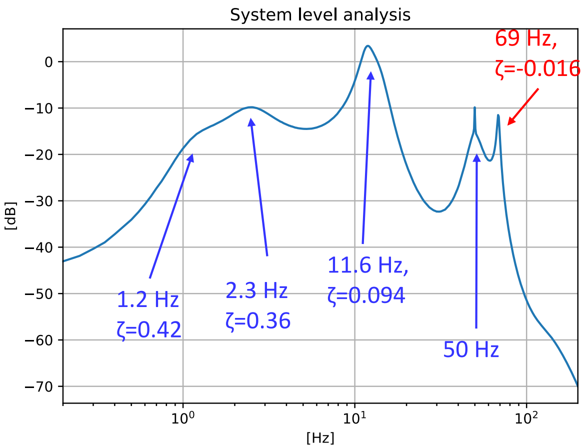
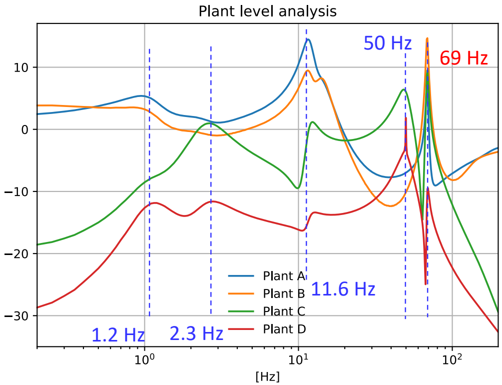
- Note that **not every visible mode is the problem that matters**.



Case study 3 - source, participant, or helper?

Key message: Participation alone is not enough. Sensitivity tells you which plant is the source and which plants are actually improving damping.



Sensitivity	11.6 Hz mode	69 Hz mode
1.2 x Plant A	-6.9e-3	9.9e-3
1.2 x Plant B	-0.5e-3	-39.9e-3
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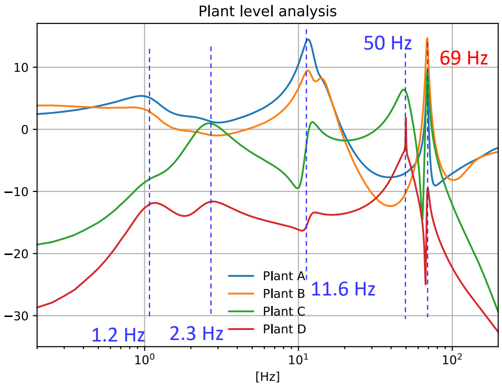

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- **69 Hz mode**: Plant B had the strongest participation and was identified as the **source**; Plant A was helping damp that mode.

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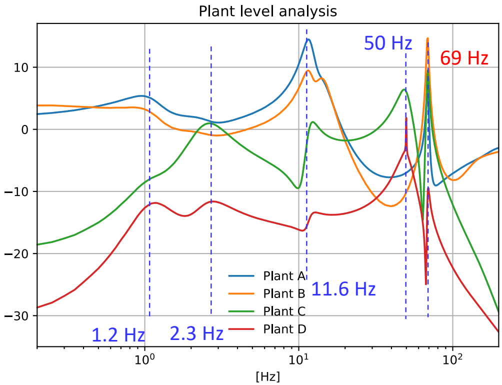

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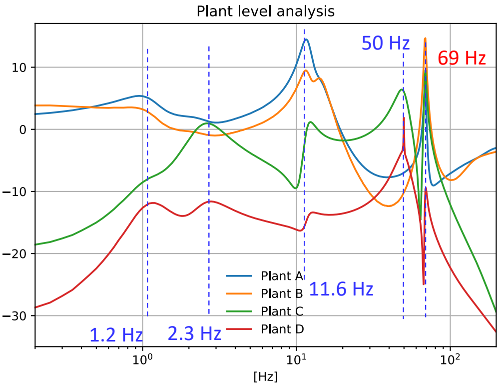

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- This matters operationally because the right intervention is then **targeted**, rather than broad-brush strengthening or plant-wide retuning across everybody.

Conclusions

1. **Treat system strength as frequency-dependent.** A single short-circuit number cannot tell you where plant-grid interactions will appear.

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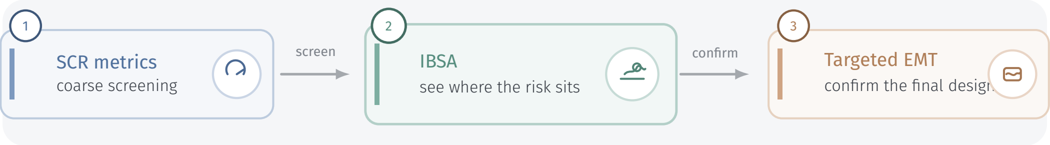

orientation → insight → confirmation

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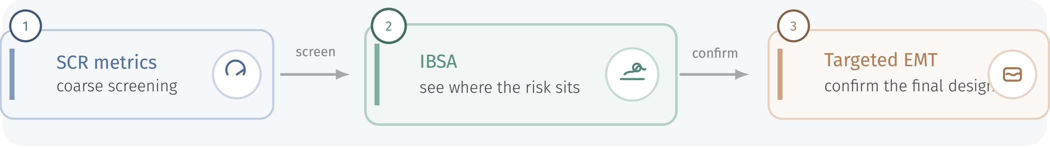

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2. **Use IBSA to screen, tune, and diagnose.** It is most powerful when used before final EMT confirmation, not instead of EMT.
3. **For oscillations, source localization matters as much as detection.** The multi-IBR value is not just seeing a mode - it is finding the devices that create it and the devices that help damp it.

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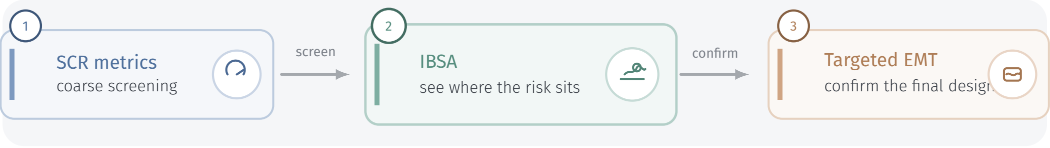

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