Analysis of Oscillations in AEMO's West Murray Zone

Shahil Shah[1], Jingwei Lu[2], Nilesh Modi[2]

[1]NREL (National Renewable Energy Laboratory)

[2]AEMO (Australian Energy Market Operator)

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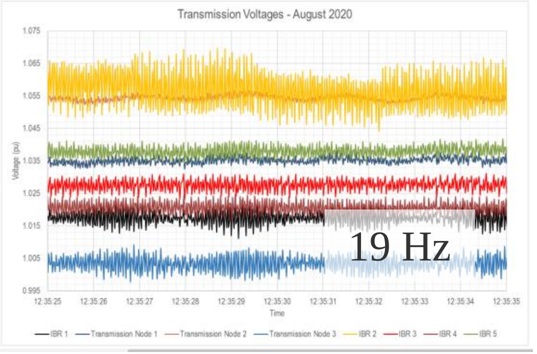
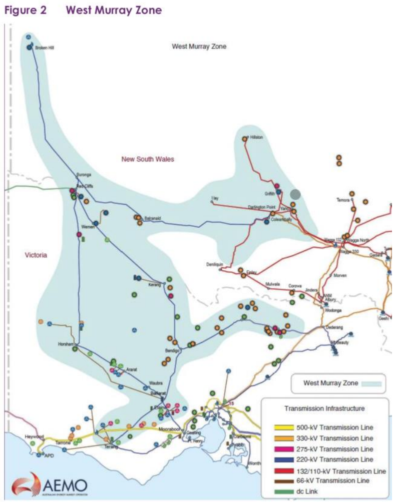
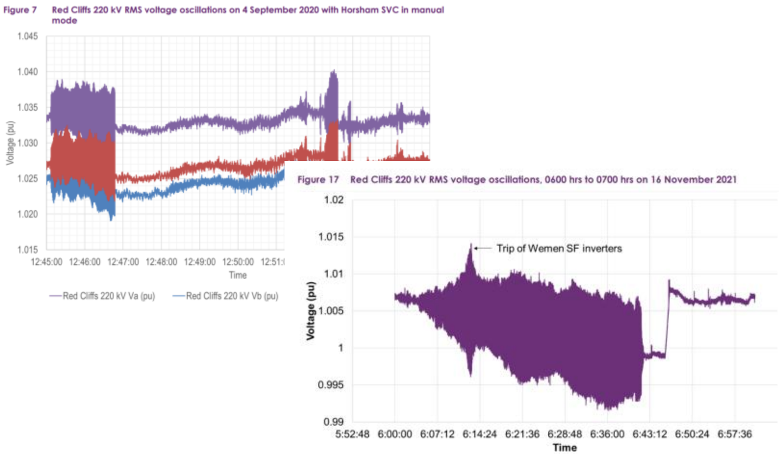
Outline

Subsynchronous Oscillations in AEMO Grid



Source: Jalali, et. al. (AEMO), CIGRE 2021.



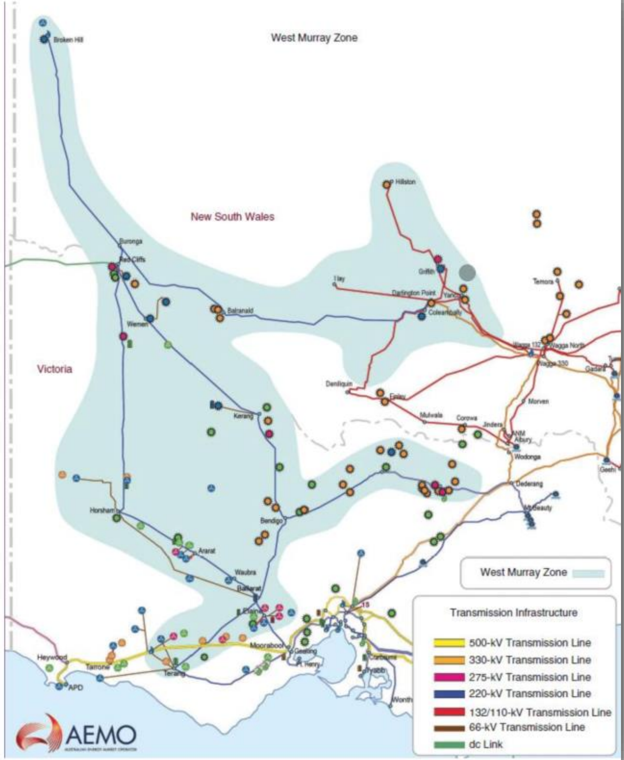


Source: West Murray Zone Power System Oscillations, AEMO, Feb. 2023.

- AEMO (Australia) has experienced 17-20 Hz oscillation events in the West Murray Zone since August 2020. They are triggered often in the absence of a disturbance.
  - Question: What is triggering these oscillations?

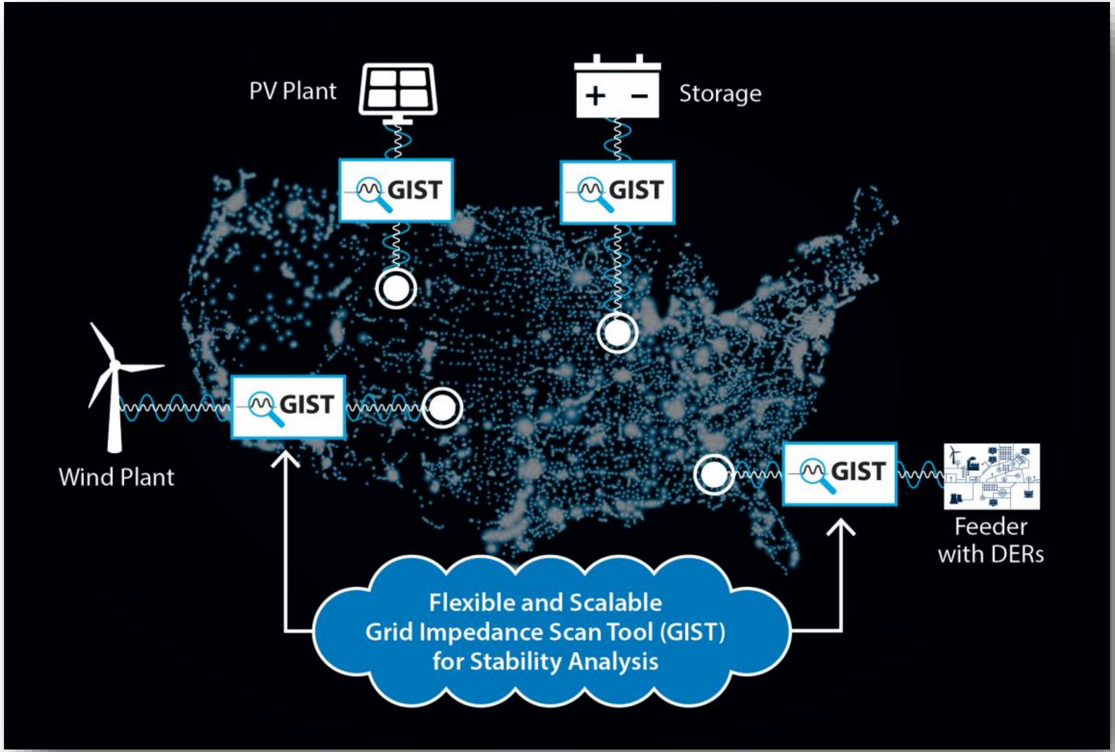
AEMO’s Previous Findings

Figure 2 West Murray Zone



- Source: AEMO Feb. 2023 Report
  – Oscillations contained within area west to the Bendigo and Darlington Point
  – Oscillations were observed during outage of Red Cliffs to Burongo 220 kV line and during periods when Murraylink DC was disconnected
  – Likely source of oscillations within north-west Victoria.

Grid Impedance Scan Tool (GIST)

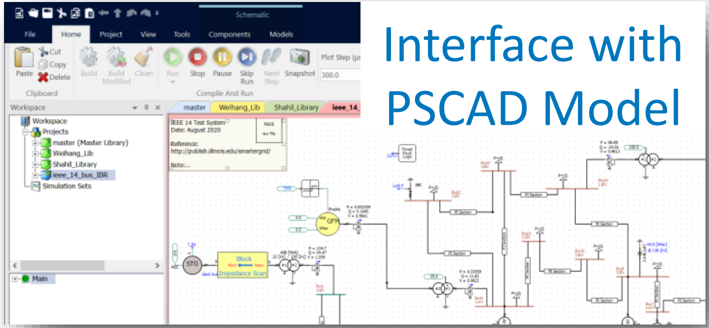


- GIST scans IBR and grid impedances using PSCAD models across wide range of frequencies
- GIST evaluates the impact of the IBR on grid stability using impedance Scans
- Fully automated scans
- Performs accurate scans even when the fundamental frequency is not exactly 50 or 60 Hz
- Outputs scan data in all reference frames: stationary, rotating (dq), power-domain

GIST

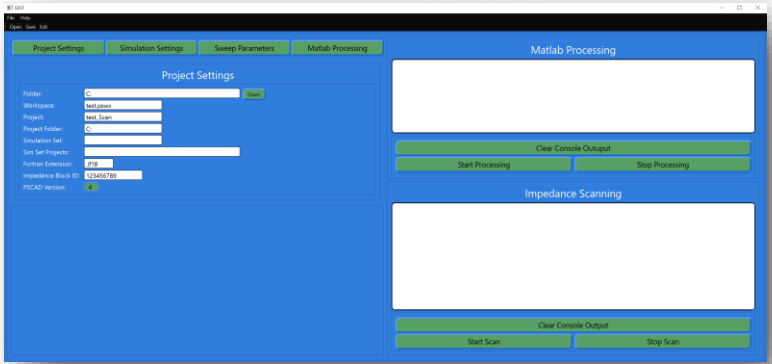
GIST Workflow

- GIST block is inserted between an IBR and the rest of grid inside a PSCAD model.

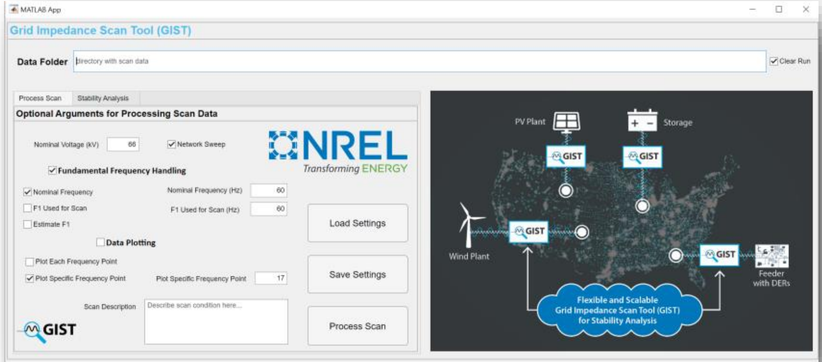


Interface with PSCAD Model

Impedance Scan Interface



Postprocessing/Analysis Interface



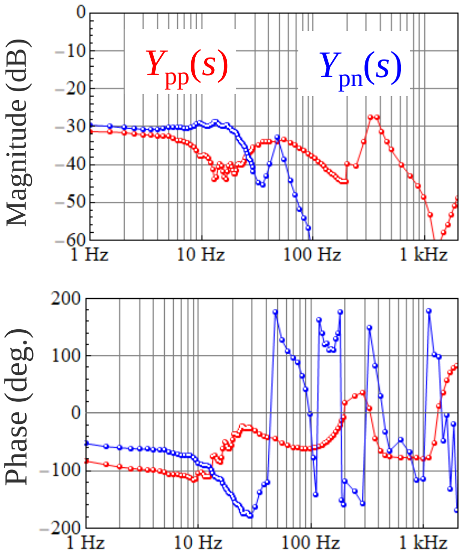
Approach for Impedance Scan Analysis

- **Step 1**: Identify IBRs and their operation conditions that are suspected to have significant role in the observed oscillations.
- **Step 2, SMIB IBR Scan**: Perform impedance scans at IBRs in SMIB (single machine infinite bus) format
  - Identify internal resonance modes of IBRs and evaluate their ability to operate stably with grids of different strength conditions (SCR, X/R)
- **Step 3, Wide Area Network Scan**: Perform impedance scans of the grid at the terminal of an IBR using wide-area network EMT model
  - Identify oscillation modes in the grid and contribution of the IBR to its damping
  - Repeat this step as needed at other IBRs

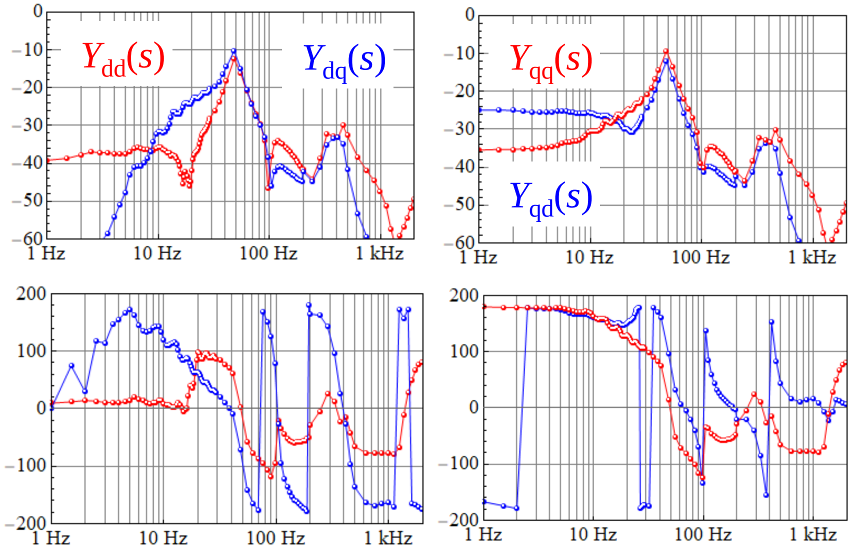
GIST

Impedance Scan of an IBR; Operating Condition 1 (Low-Risk)

Sequence Admittance

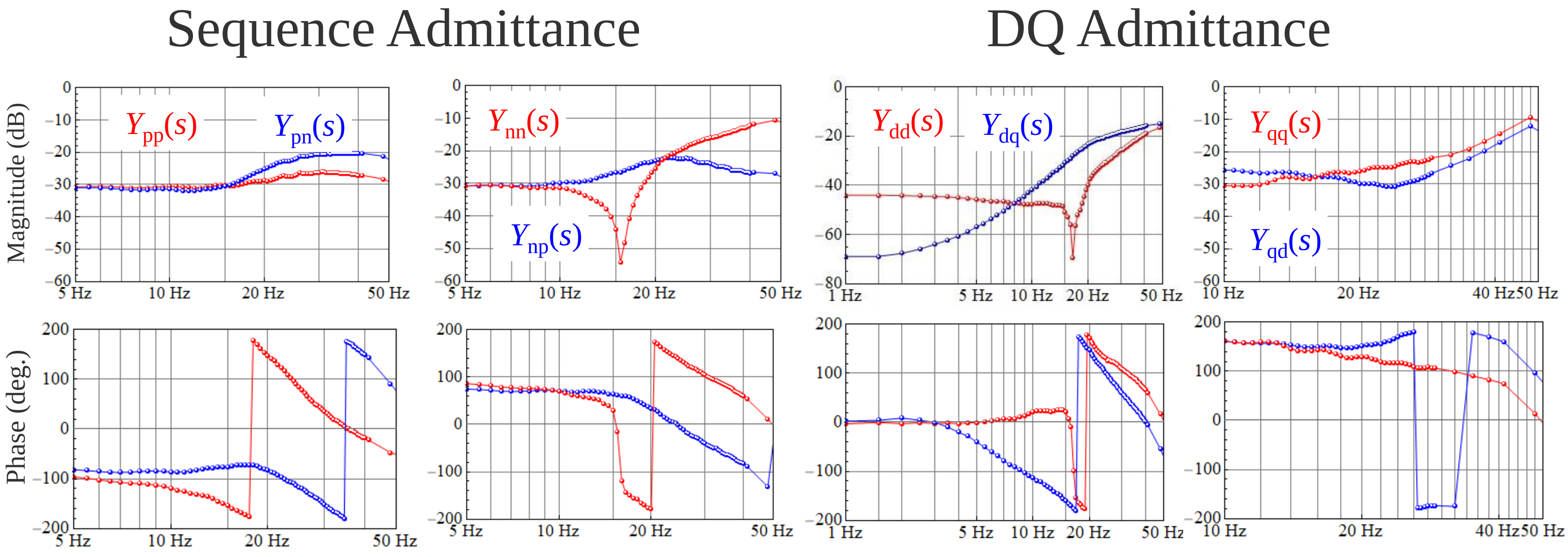


DQ Admittance



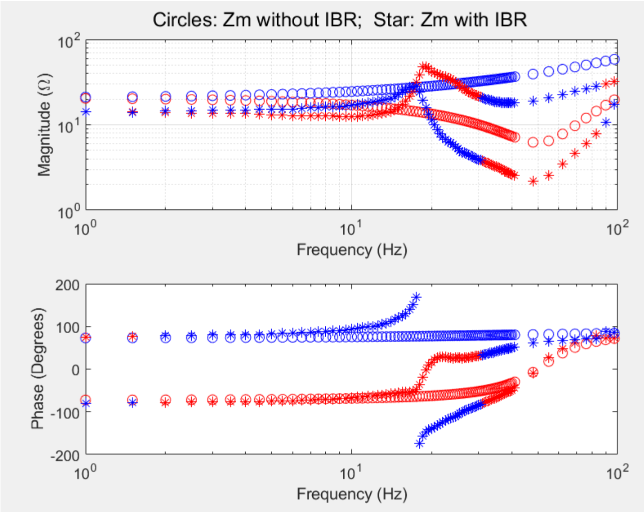
- $Y_{dd}(s)$ shows damped of resonance near 18 Hz.

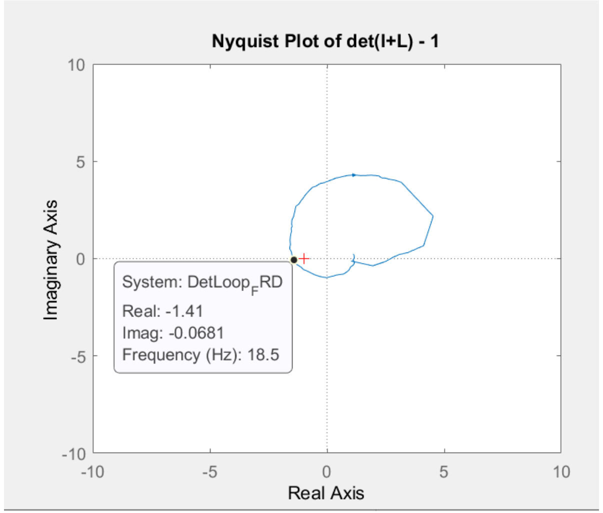
Impedance Scan of an IBR; Operating Condition 2 (High-Risk)

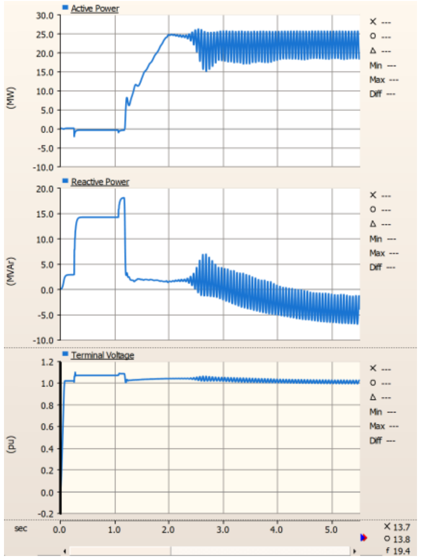


- Severe resonance at 17 Hz in $Y_{dd}(s)$

Stability Analysis for SCR 2.1 and X/R 3.2

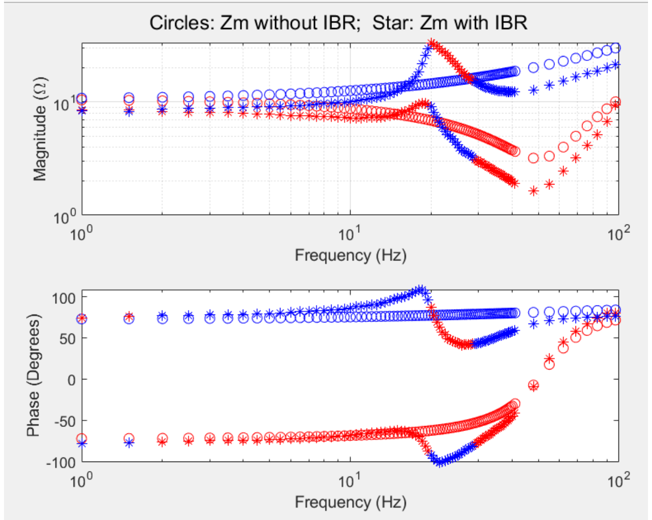


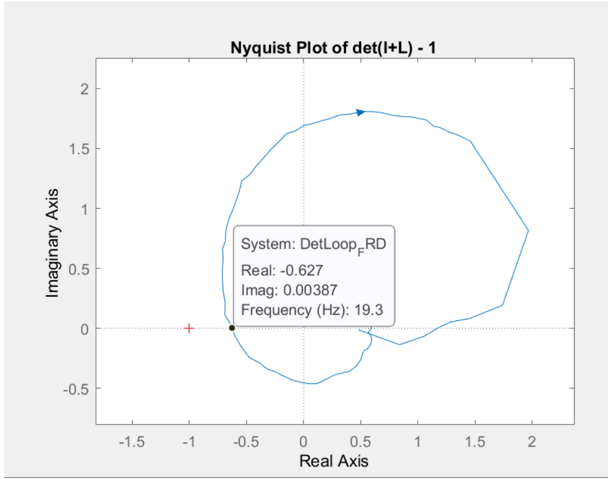


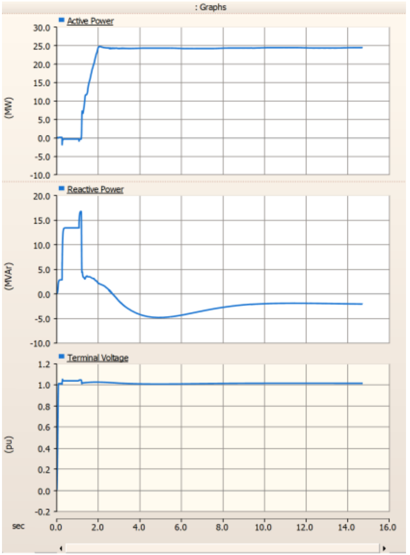


- IBR plant is unstable – confirmed by time-domain simulations (17.4 Hz)

Stability Analysis for SCR 4.1 and X/R 3.2





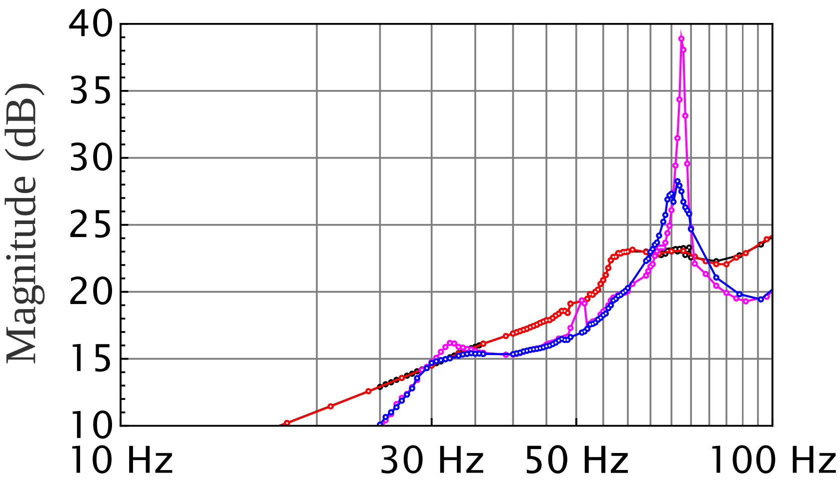


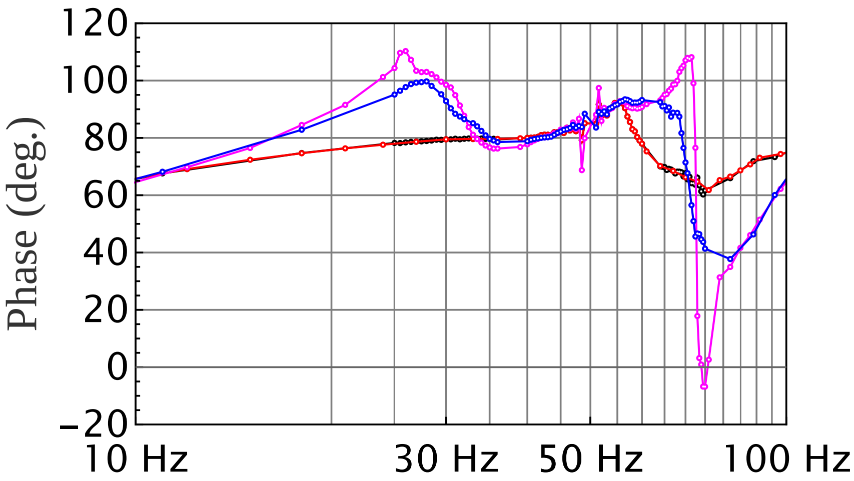
- IBR plant is stable with low stability margin – Plant still has highly underdamped resonance mode, but it will not excite oscillations in the absence of a disturbance

Outcome of SMIB IBR Scan Study

- Some IBRs have underdamped 17 Hz mode for a particular operating condition
- The mode becomes unstable if any of the IBR is connected to a grid with SCR below 2.1
  - Grid strength estimated using positive sequence power flow models is significantly higher than 2.1.
- The SMIB analysis models grid as an R-L branch
  - It does not reveal complex control interactions among IBRs
  - It does not reveal how certain IBRs modify the grid characteristic seen by other IBRs in proximity

Impedance Scan of WMZ Grid from IBR-1



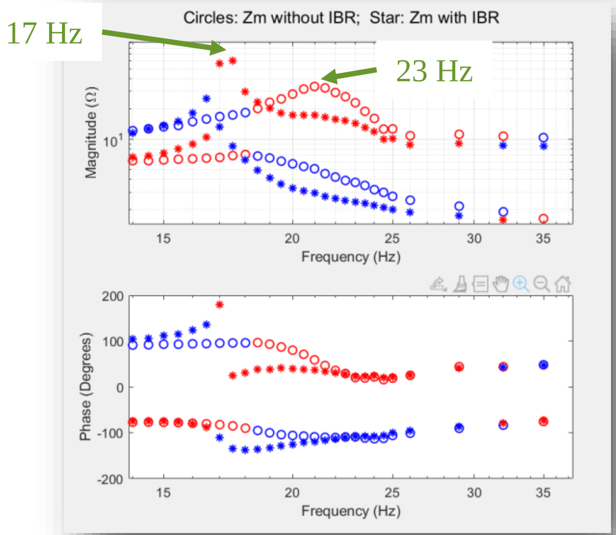


- IBR-2 and IBR-3 are disabled; IBR-2 and IBR-3 operate at low-risk condition; IBR-2 operates at high-risk condition and IBR-3 is disabled; IBR-2 and IBR-3 operate at high-risk condition

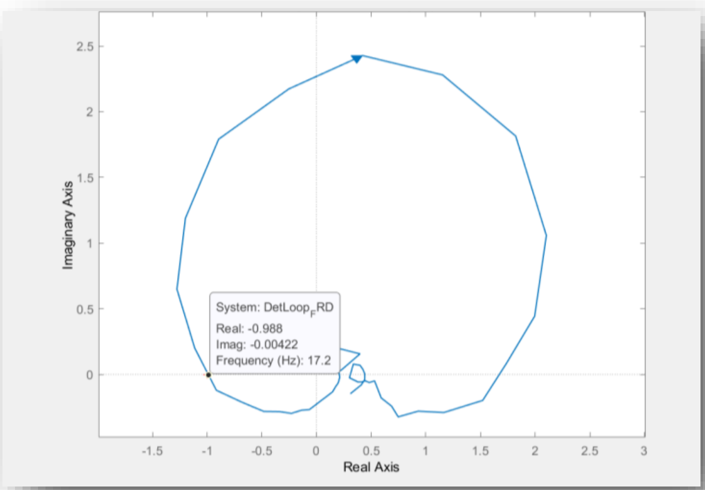
GIST

Stability Analysis using Wide Area Network Scan

- Stability Analysis at IBR-1



Nyquist plot of $Z_{net.}/Z_{IBR}$



- IBR-1 forms an unstable resonance mode at 17 Hz with WMZ system
  - It moves a 23 Hz mode in WMZ grid to 17 Hz and reduces its damping

Summary

- Impedance-based analysis provides a systematic solution for evaluating the root-cause of power system oscillations using highly accurate Blackbox EMT models of IBRs.
- Use of SCR can result in over-optimistic estimation of grid strength

Thank you!

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Shahil.Shah@nrel.gov

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