Frequency Scan and Stability Analysis Tool (FSAT)

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ATC RTDS APPLICATIONS & TECHNOLOGY CONFERENCE

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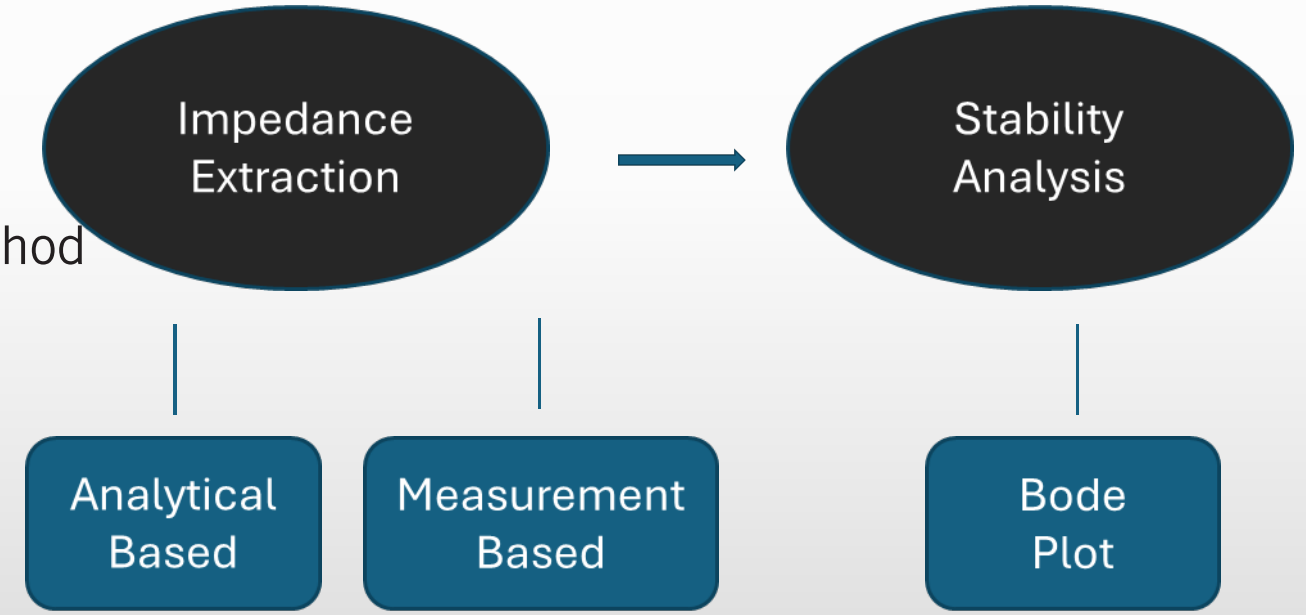
RTDS Technologies
AMETEK

OVERVIEW

- Frequency Scanning always been achievable on the RTDS
- Automated all operations and combined into FSAT Tool
- FSAT Tool
  - Frequency Scanning
    - Analytical Method
    - Measurement Based Method
  - Stability Analysis

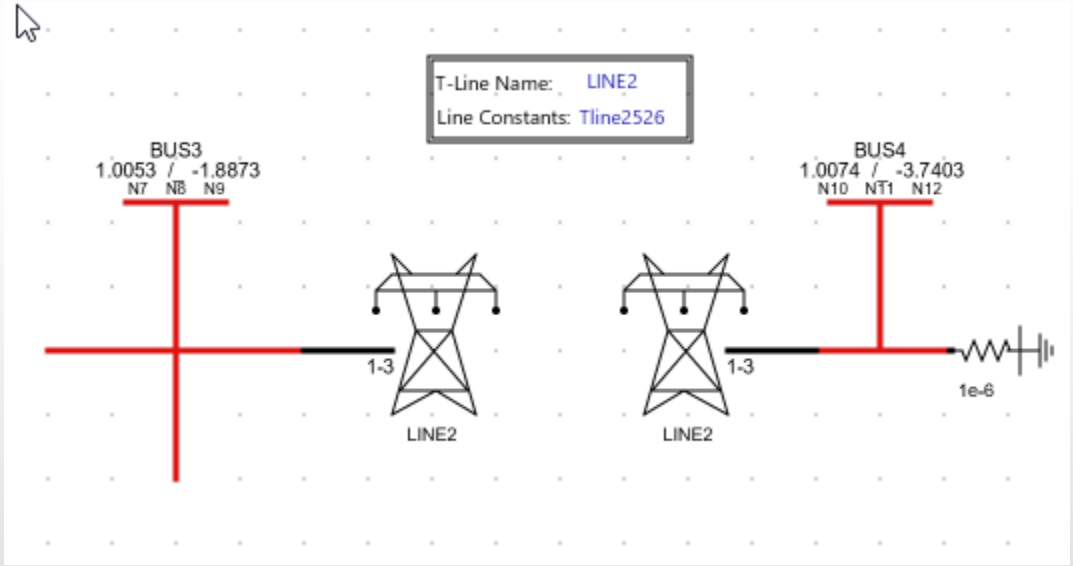


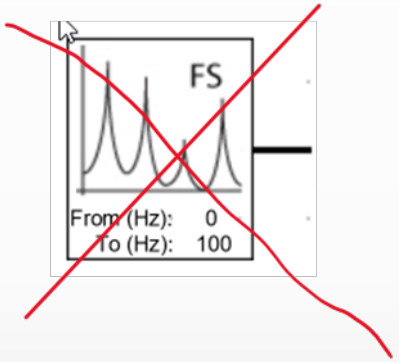
ANALYTICAL METHOD

- Applications
  - Network Validation with different software platforms
  - Resonant frequency
  - Frequency dependent transmission line impedance
  - FDNE source
- Single phase components are not supported

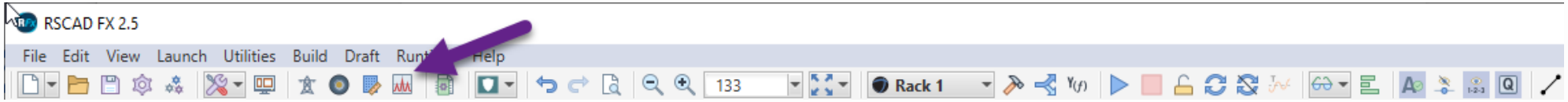
ANALYTICAL METHOD

- Determine the +/-/0 zero sequence of a frequency dependent transmission line



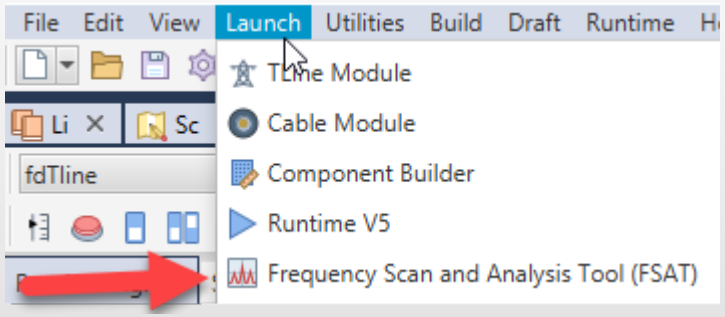


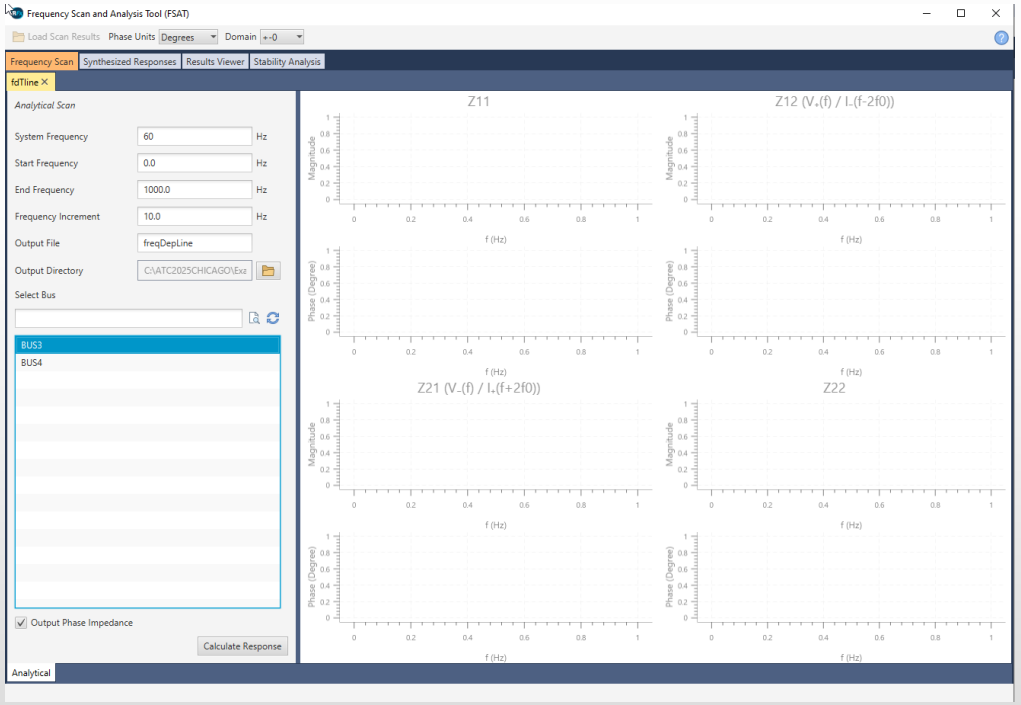
ANALYTICAL METHOD



- Select ‘Open FSAT’ icon from toolbar

- Select ‘Open FSAT’ from the menu

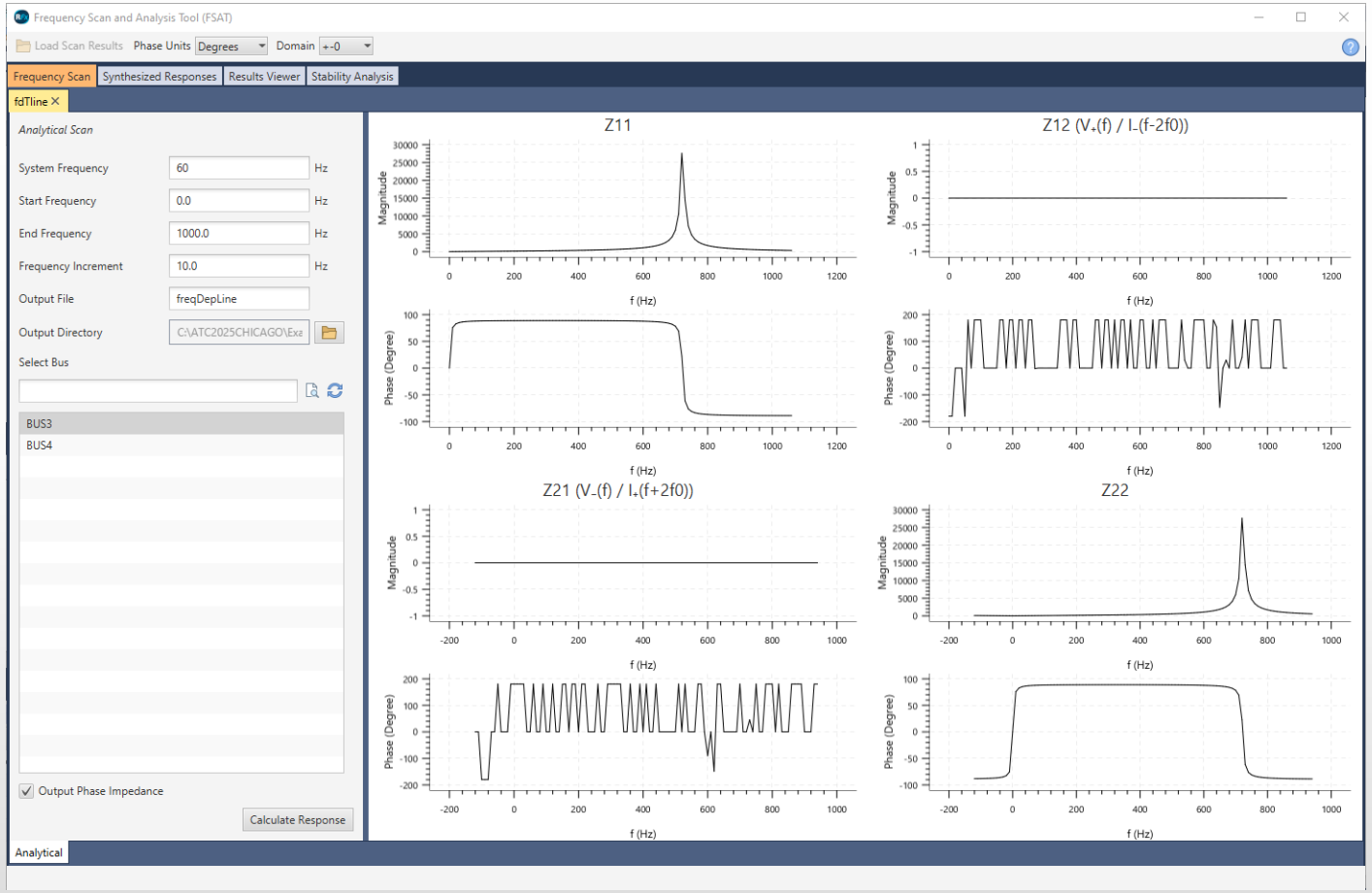




Simulation does not need to be running

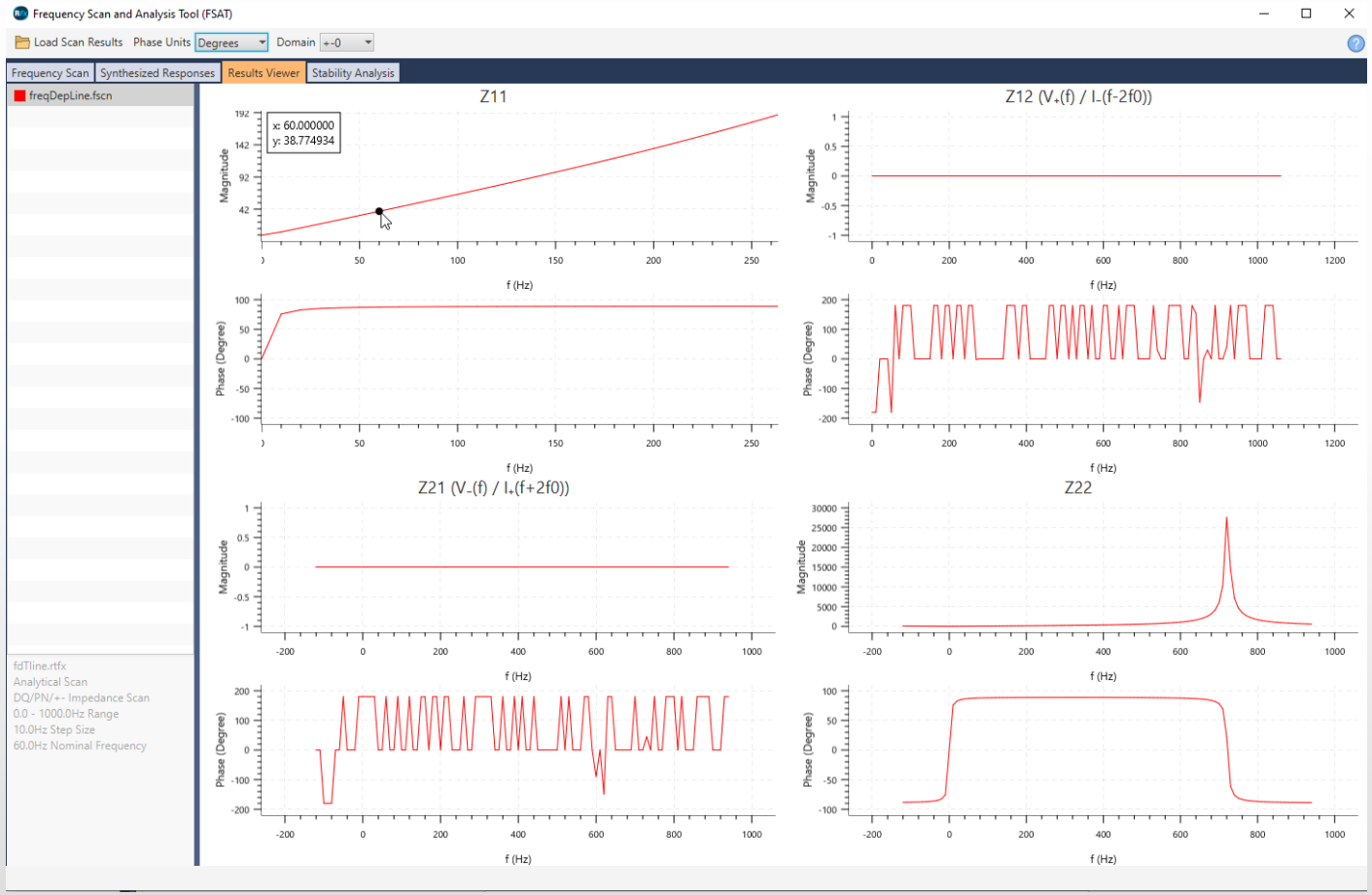
ANALYTICAL METHOD

- Run the Frequency Scan
  - Select Bus
  - Frequency range
  - Output file name
  - Calculate Response
- Calculations
  - Admittance matrix of the network YBUS
  - Kron reduction technique used to solve
  - Compute impedance as seen from BUS
  - Select domain
  - Select to output phase impedance



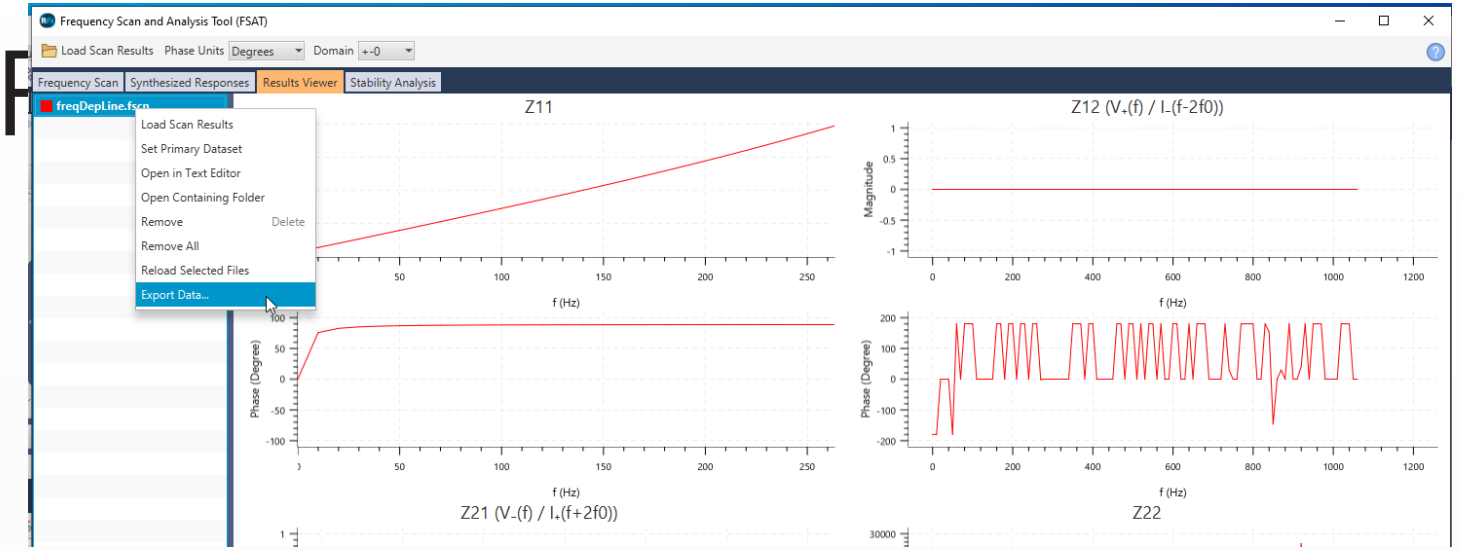
ANALYTICAL METHOD

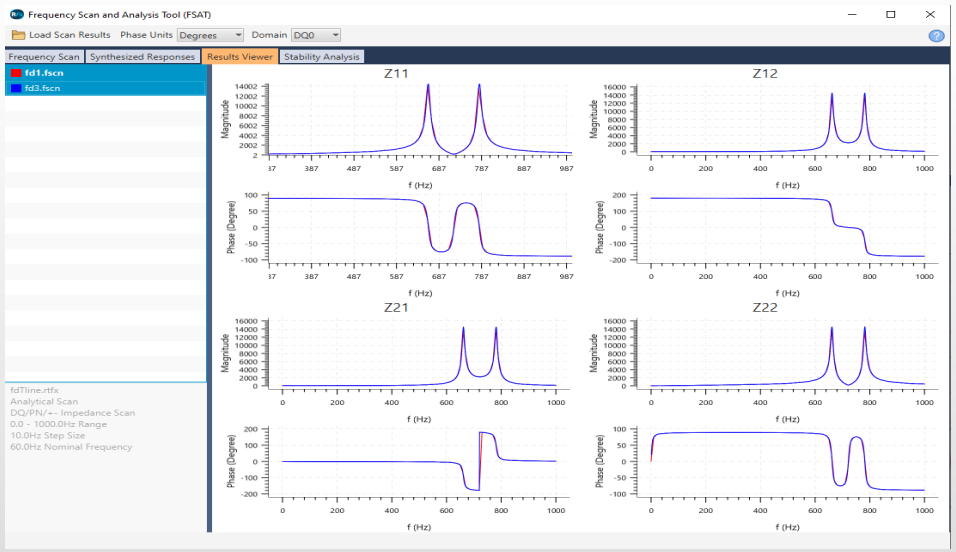
- Results Viewer
  - Select the output filename
  - Zoom in



RESULTS VIEWER

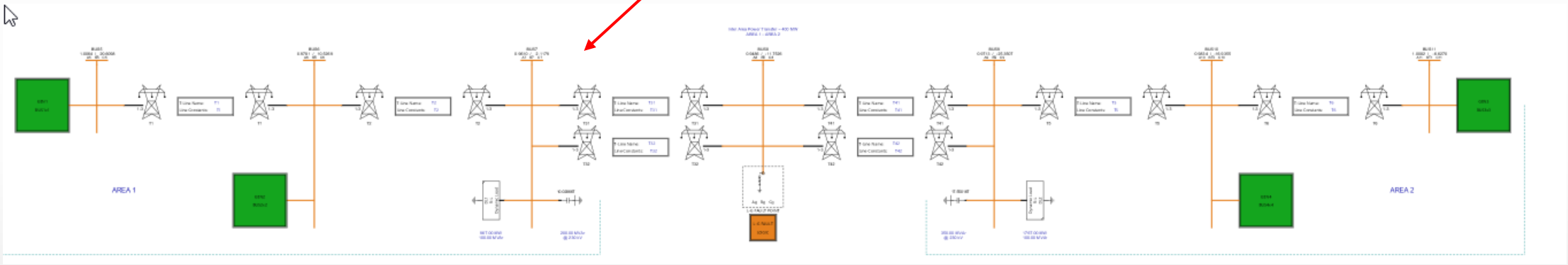
- .fscn file contains the data as shown on the GUI in DQ format
- Click on the name of the frequency scan file, additional menu options
- Export Data to different file formats and different domains
- Load other scan results and compare



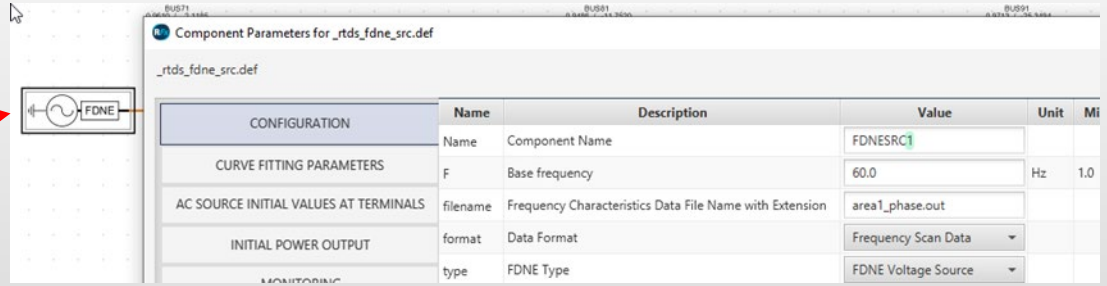


ANALYTICAL METHOD

Scan of the network at this bus



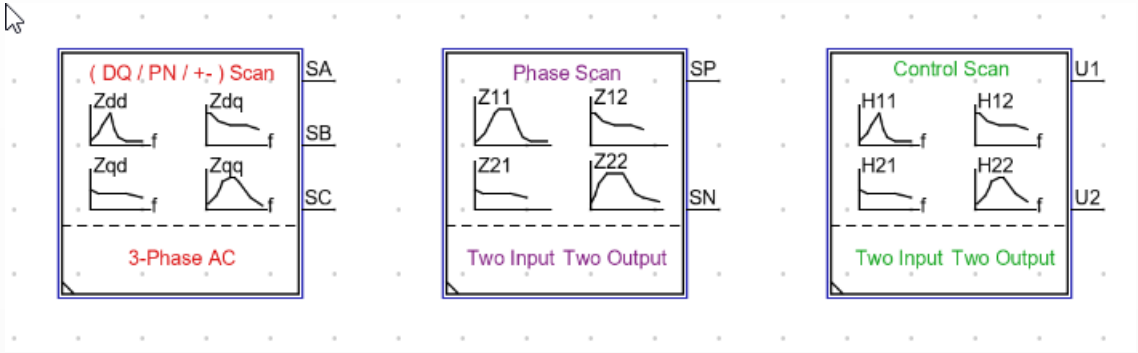
Replaced with FDNE source



MEASUREMENT BASED METHOD

- Analytical scan does not take into account operating conditions such as controls or states of power electronic switches
- Black boxed controls
- Measure voltage and current at different frequencies
- Calculate impedance Z=V/I
- For efficiency, the frequency bandwidth of interest can be split up into sub-ranges and a harmonically rich signal injected (multi-sine)
- DFT used to extract the frequency response

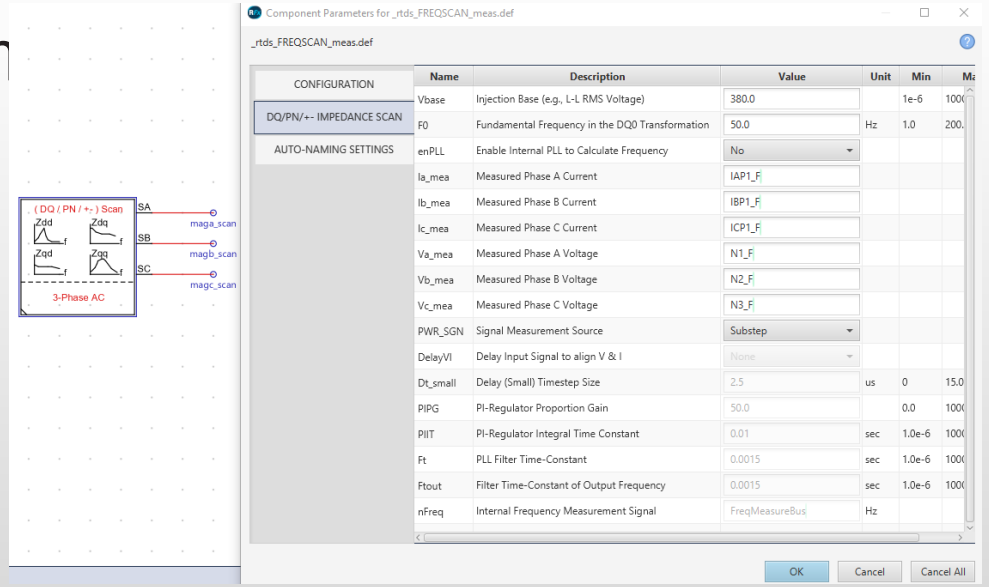
MEASUREMENT BASED METHOD



- Component named _rtds_FREQSCAN_meas.def generates the perturbation signal
- Three types of frequency scan supported
  - 3Phase AC (DQ0,PN0,+/-/0)
  - Two Phase AC/DC networks
  - Controls

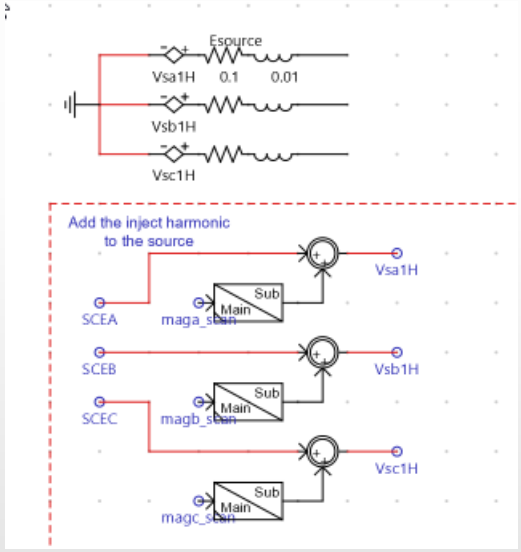
MEASUREMENT BASED METHOD

- Component must reside in main step
- Select where the perturbation signal is being applied
- Enter the voltage and current at the bus
- Frequency accurately match system

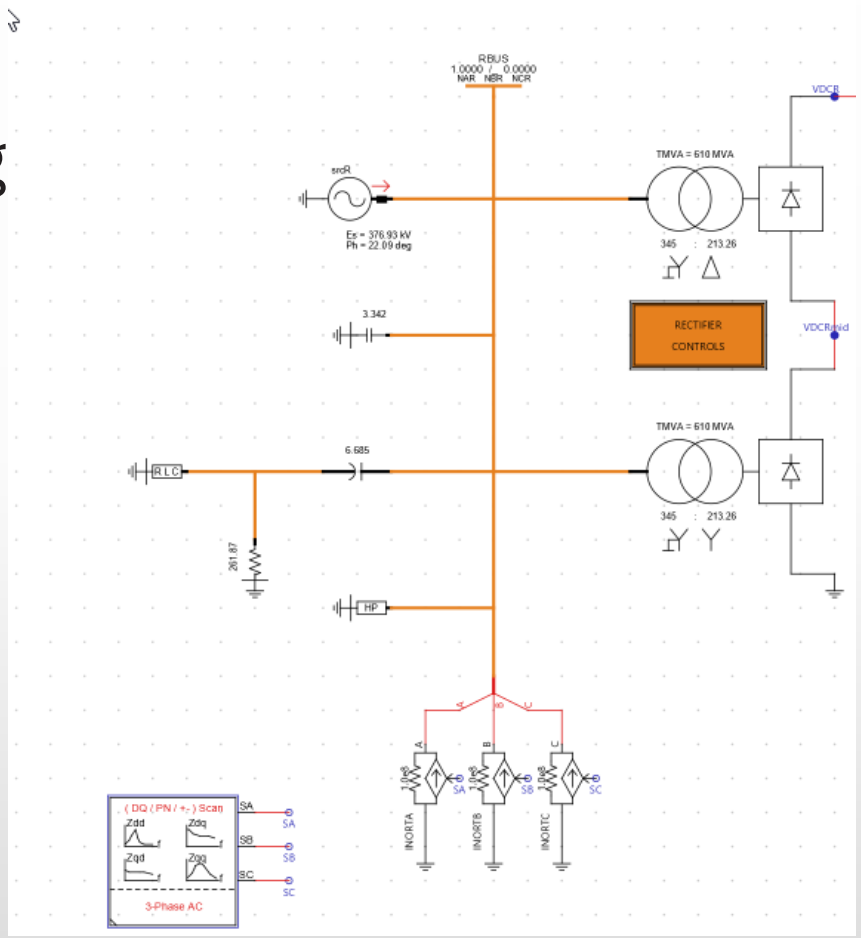


MEASUREMENT BASED METHOD

- Inject either current or voltag



Substep

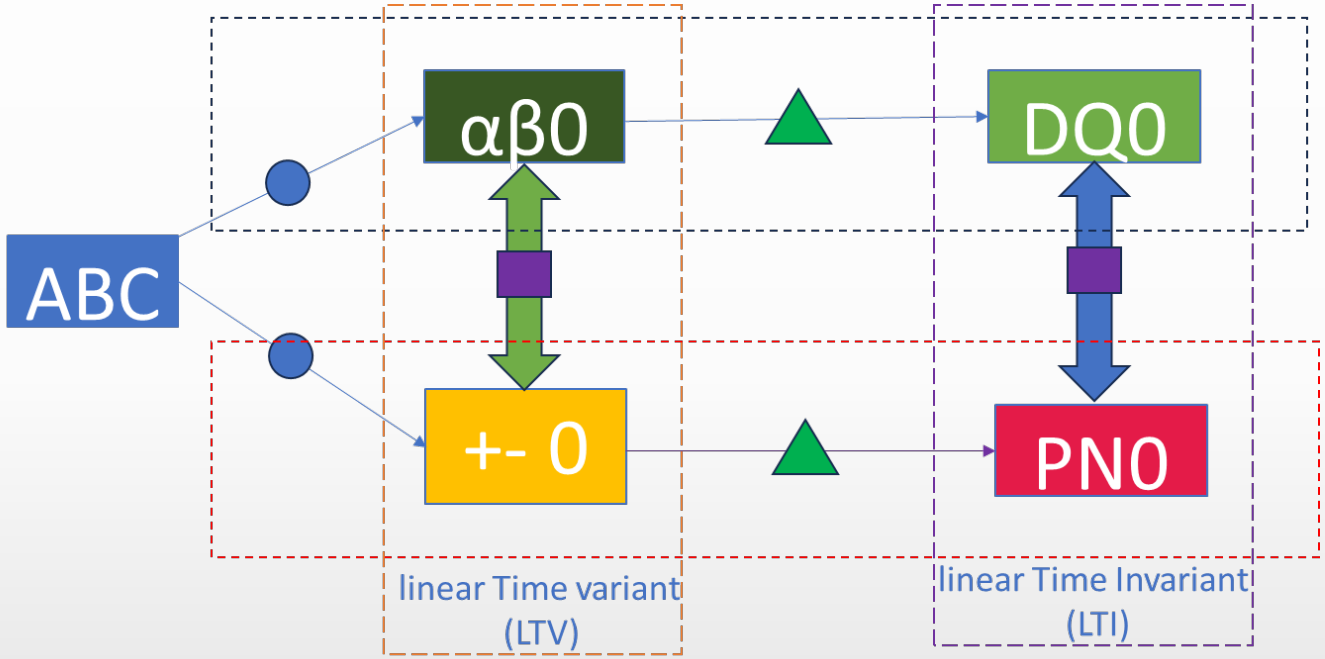


MEASUREMENT BASED METHOD

- 3Phase AC scan
  - Pertubation signals DQ
  - Transformed to phase
  - Sampled
  - Transformed DQ
  - DFT

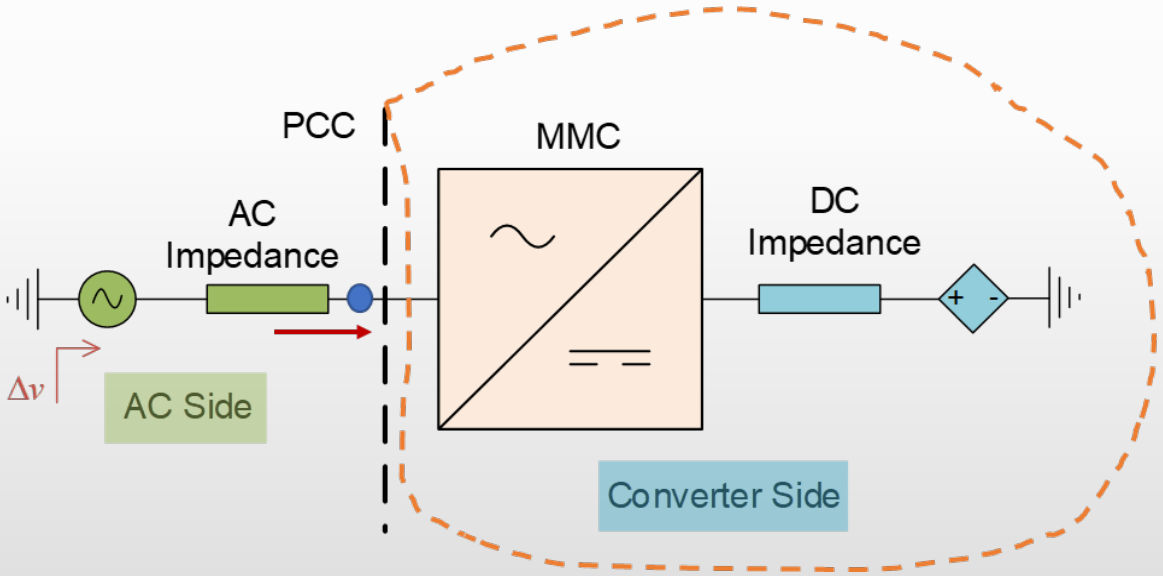
$$Z_{dq0} = \begin{bmatrix} Z_{dd} & Z_{dq} & 0 \\ Z_{qd} & Z_{qq} & 0 \\ 0 & 0 & Z_0 \end{bmatrix}$$

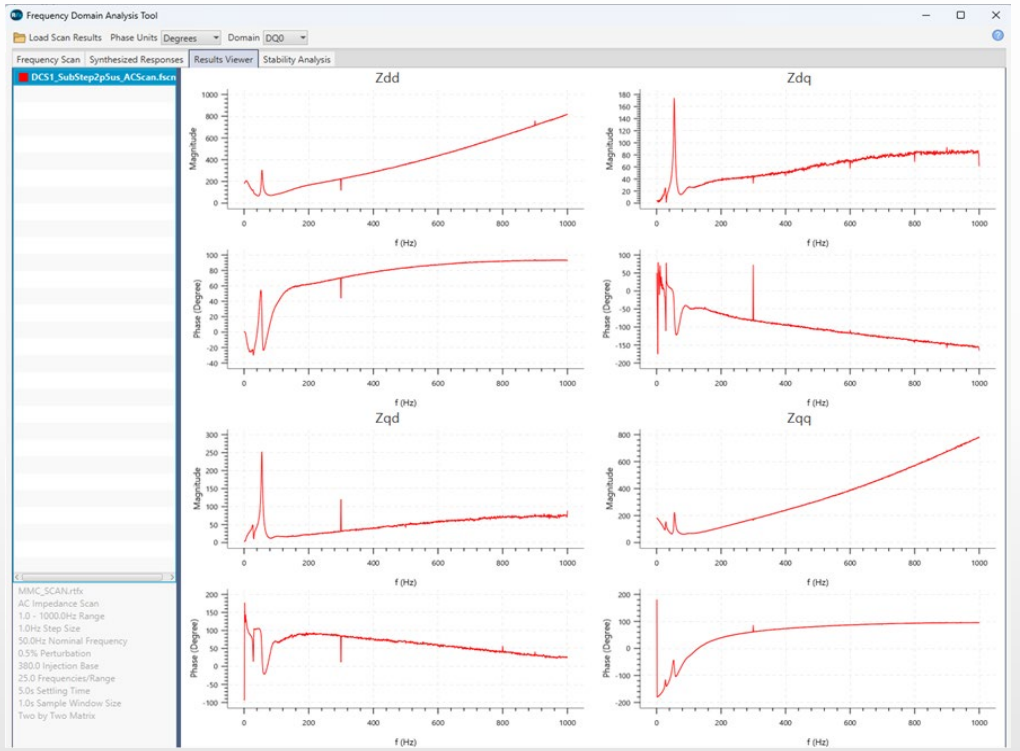
Impedance Matrix Form



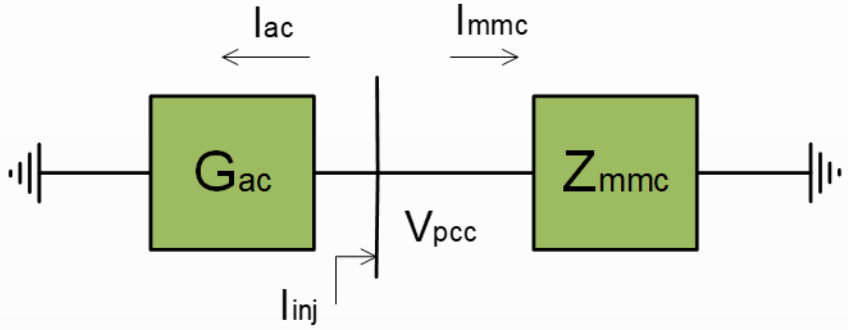
MEASUREMENT BASED METHOD

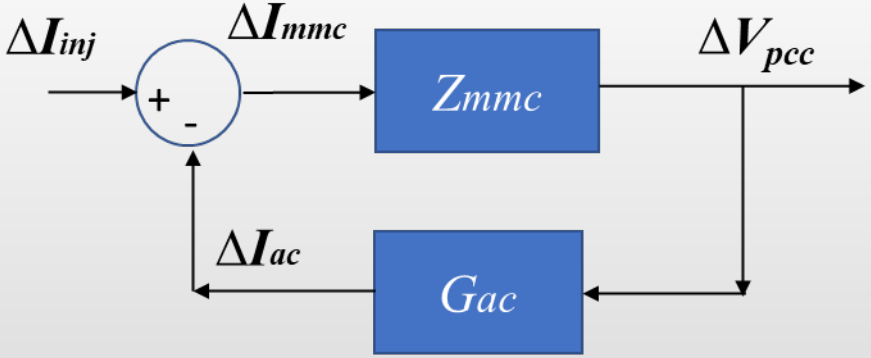
- Perturbation: AC source
- Input: Current into the MMC
- Output: PCC voltage
- Calculated: Impedance of the MMC (dq0 domain)





STABILITY ANALYSIS





Closed-loop transfer function

$$\frac{y(\omega)}{x(\omega)} = \frac{Zmmc(\omega)}{I + Gac(\omega) * Zmmc}$$

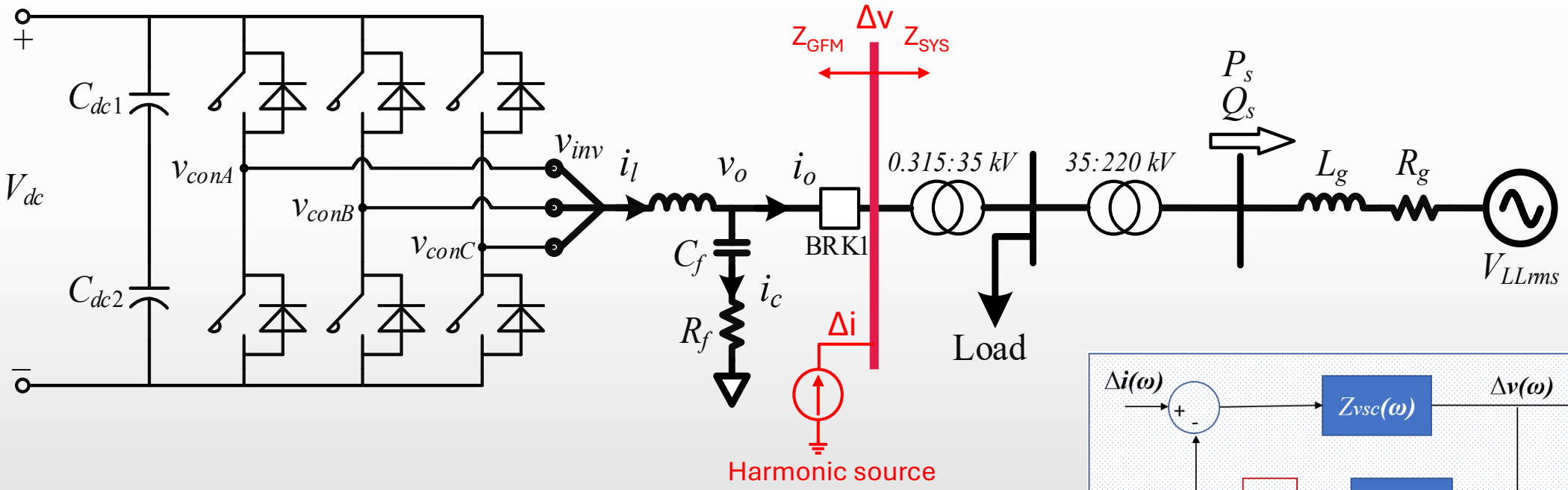
Open-loop transfer function

$$Tf(\omega) = Gac(\omega) * Zmmc$$

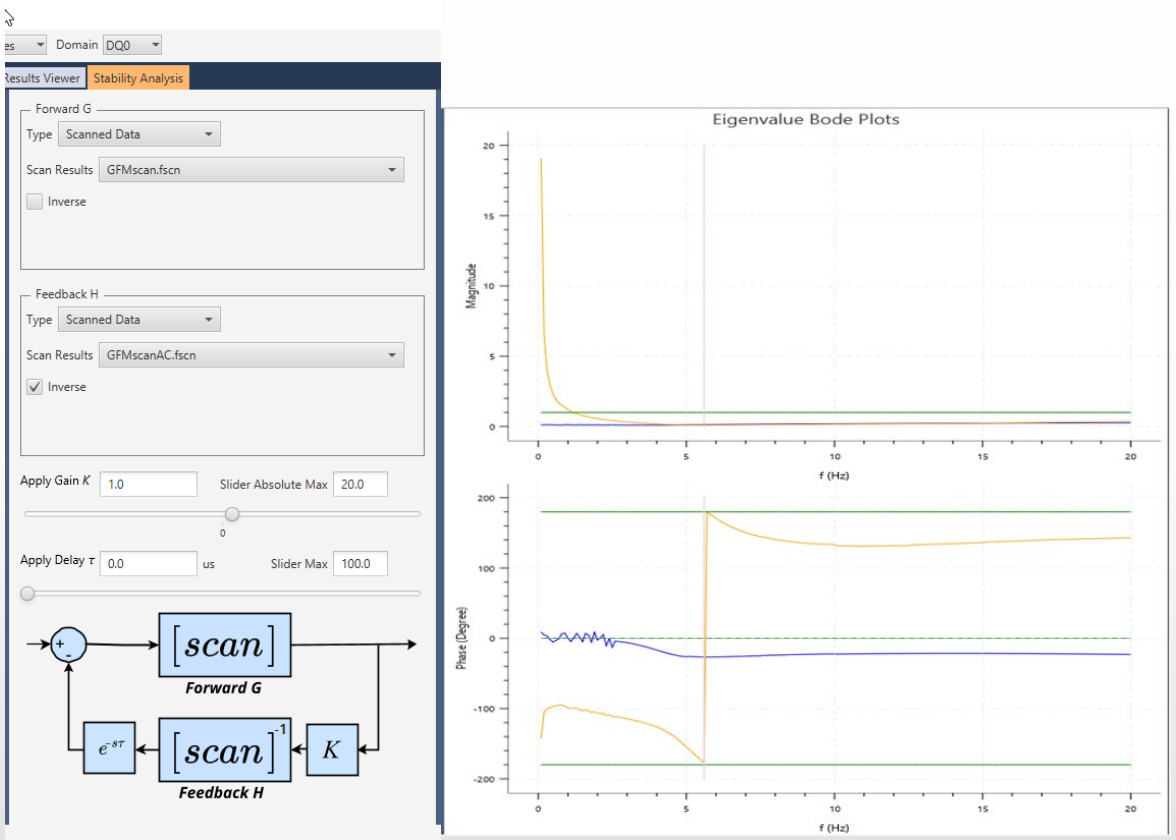
At frequency ω_1, open loop eigenvalue $\lambda c\ (\omega_1)$

STABILITY ANALYSIS

Current injection 0.1hz step, size 0.02% (base 230 kA), 25 per subrange

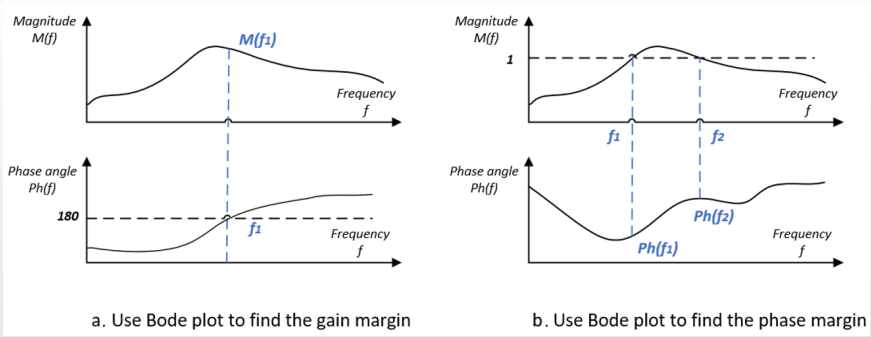


STABILITY ANALYSIS

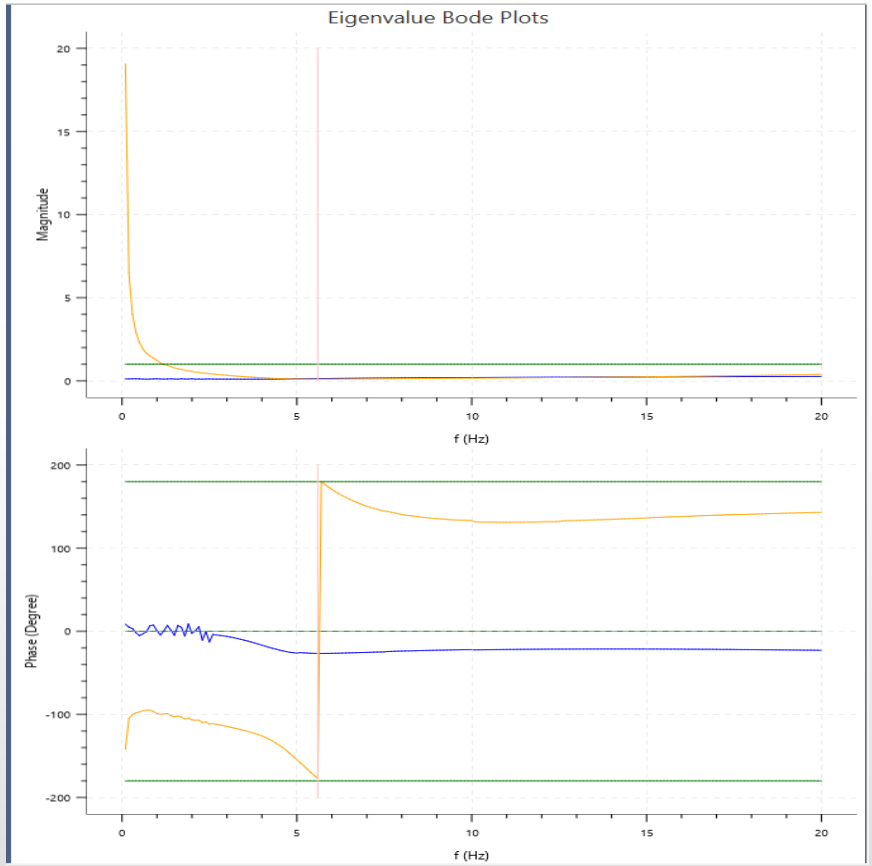


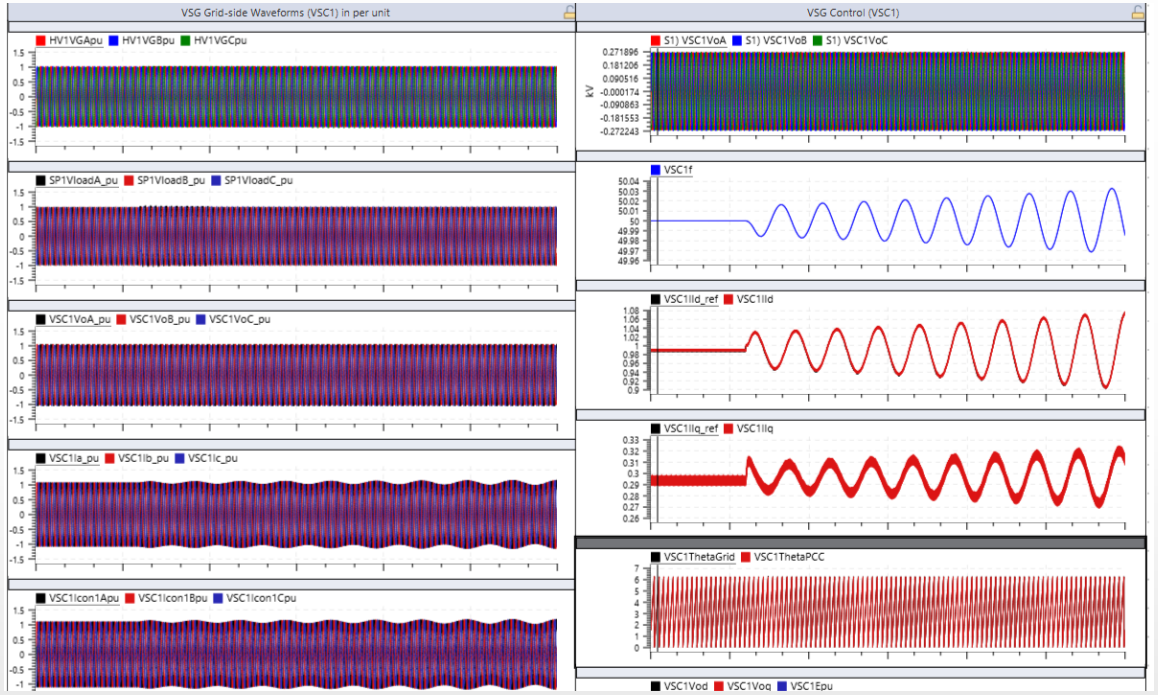
Stability Boundary

- $Mag[\lambda c(\omega_1)] = 1$ → *Phase Margin*
- $Phase[\lambda c(\omega_1)] = 180\text{Deg}$ → *Magnitude Margin*



STABILITY ANALYSIS

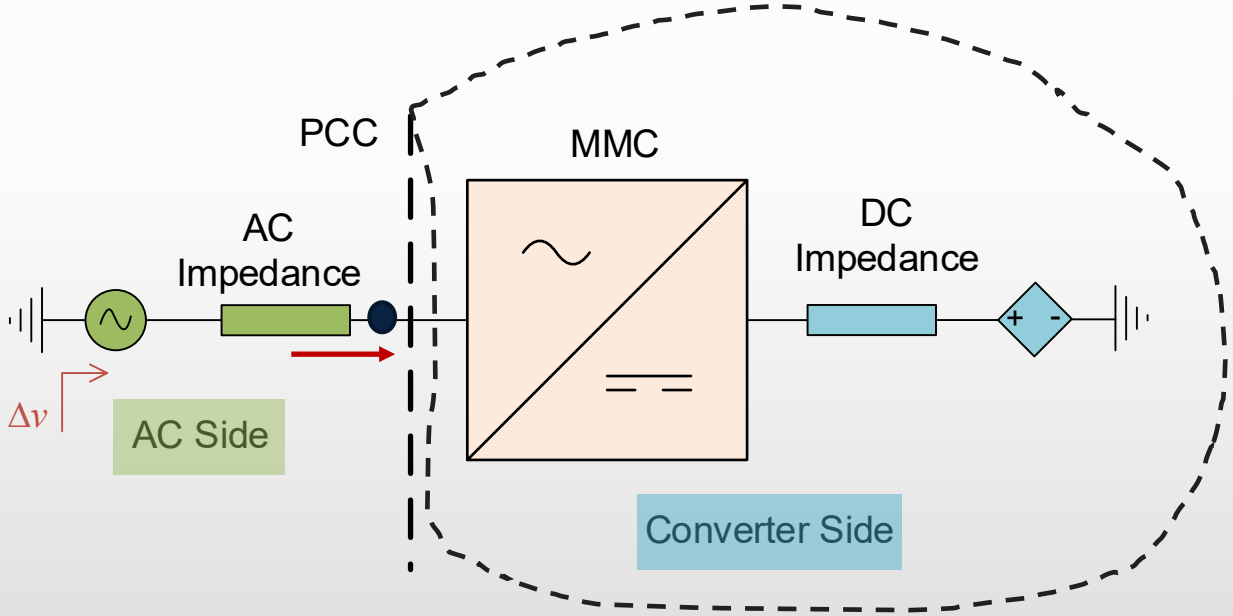


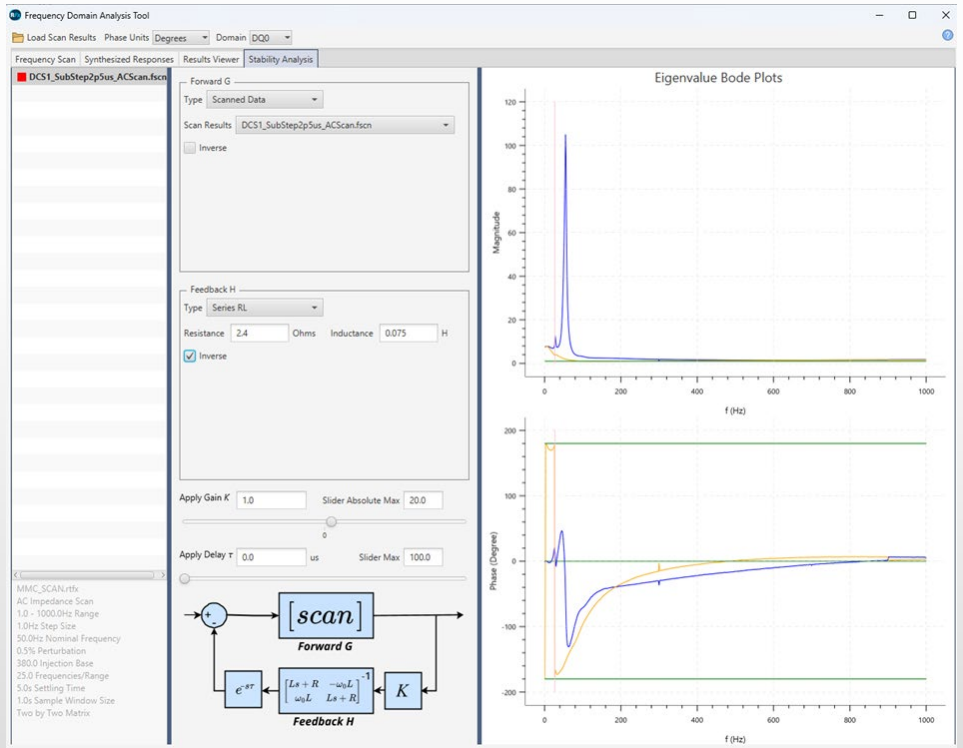


@5.6hz. gain margin = 9.79

STABILITY ANALYSIS

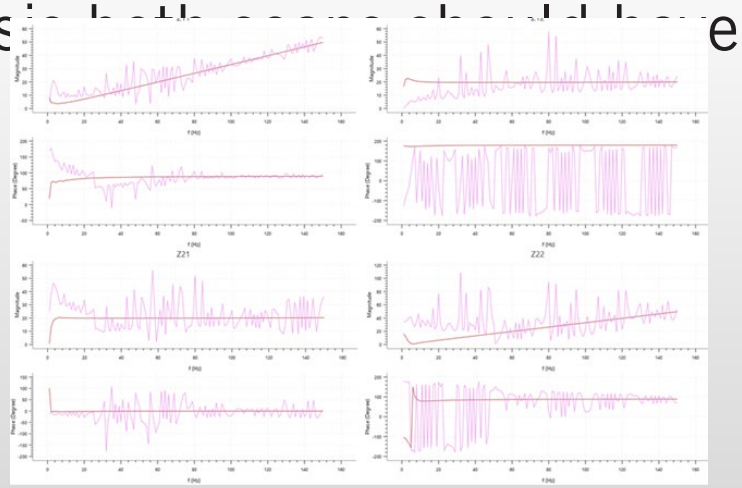
- Type (Scanned Data/Series RL / Transfer Function)





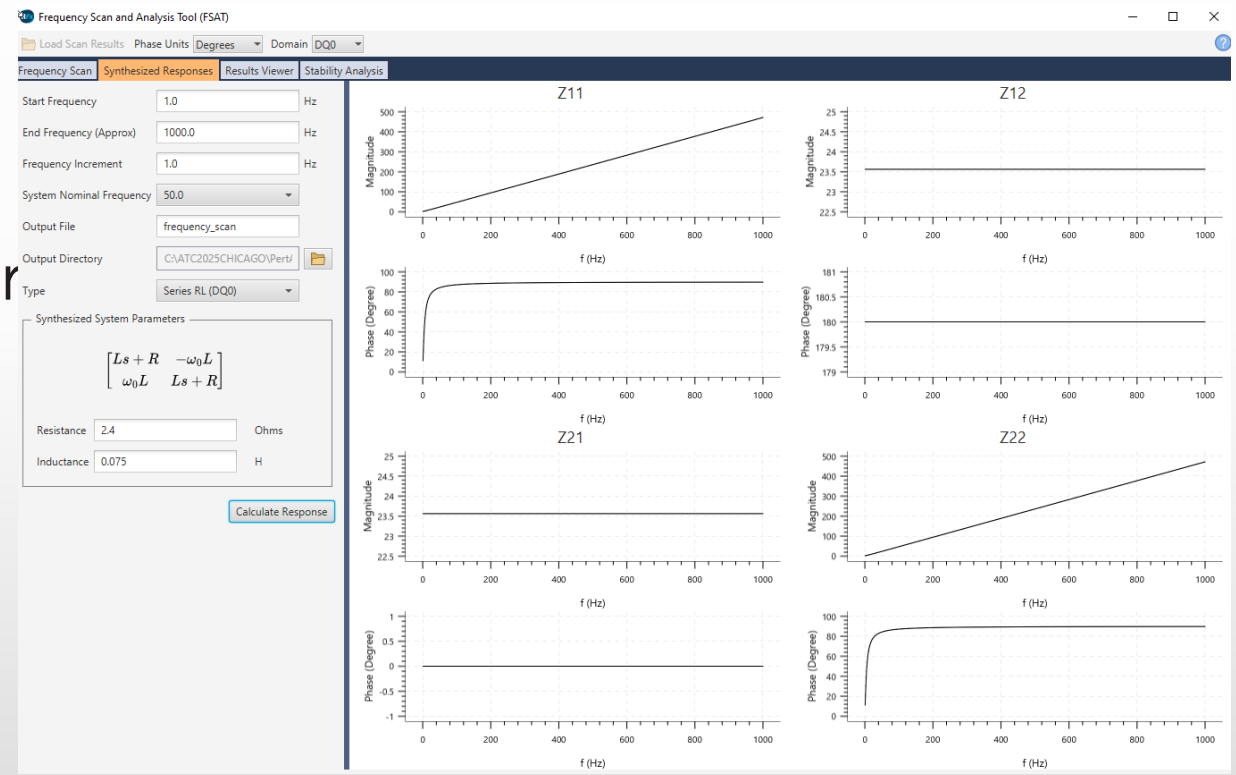
FSAT Tool

- Important Points
  - Ensure the simulation is running at desired operating point
  - Plot the voltage and current at the PCC bus observe any instabilities or noise
  - Adjust scan parameters if required
  - Stability analysis both scans should have the same frequency range and increment



FSAT Tool

- Synthesized Responses tab
  - Verifying network equivalents
  - Scan network equivalent
  - Load scan results and compar



FSAT Tool

- Future Developments
  - Automation

- Example Casesl14 Impedance Scan
  - Frequency Scan (analytical)
  - Harmonic Scan (measured)