1999 IEEE PES Summer Meeting

Retuning Stabilizers for the North-South Brazilian Interconnection

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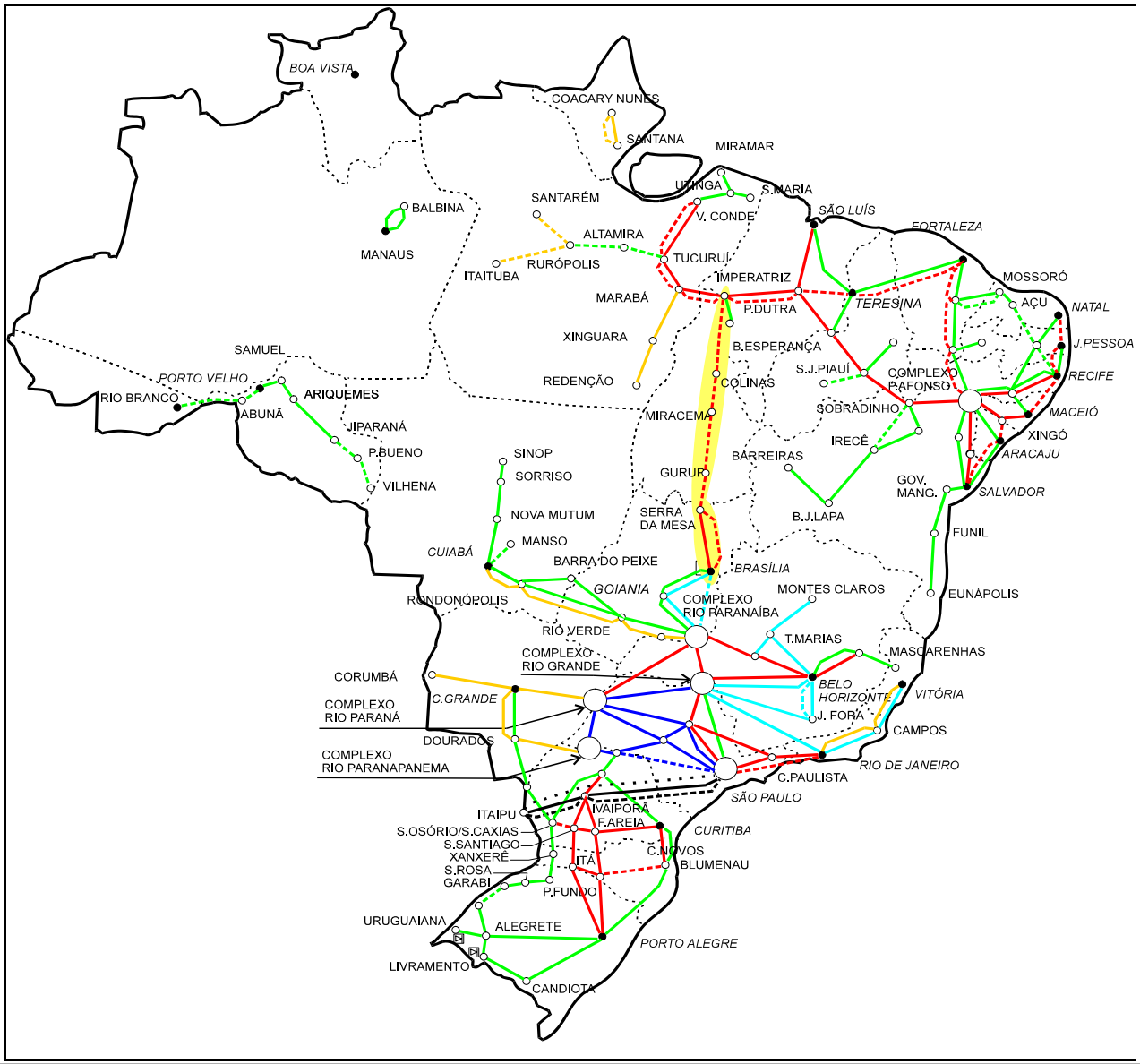
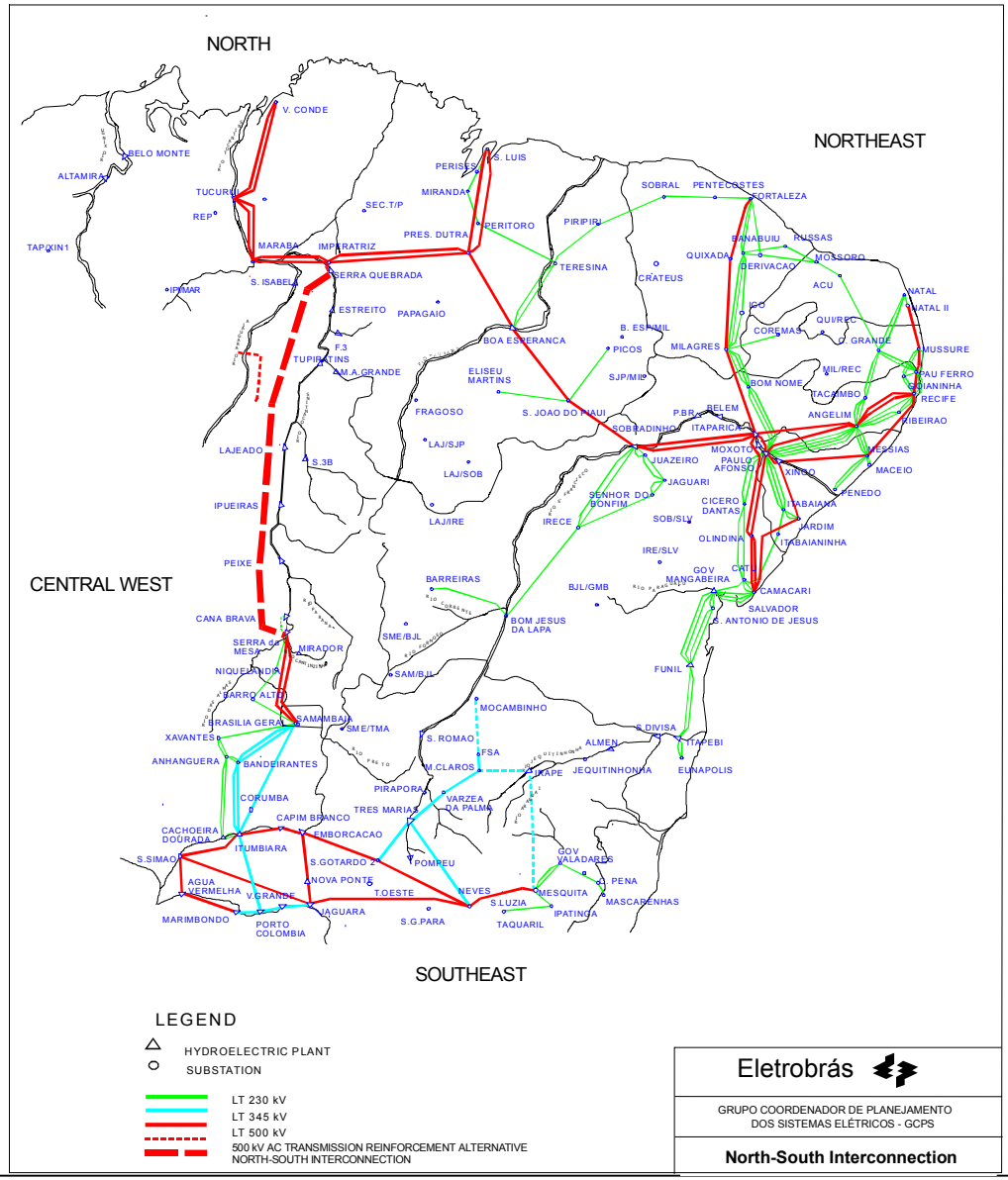
Brazilian North-South Interconnection



Brazilian North-South Interconnection - Detail



Retuning Stabilizers for the Brazilian North-South Interconnection

- Carried out by the Eletrobrás/GCOI task force NSPRE/R
- TCSC damping controllers previously defined by Planning Division
- Various base cases and (N-1) contingency scenarios have been considered
- Integral of accelerating power PSSs

System Data

- North-South interconnection
  - 1000 km long, 1300 MW transfer, 500 kV compact line, series compensated
  - 2 TCSC's (6% compensation each)
  - 2300 bus model, 120 generators, 4 SVC's, 1 HVDC link
  - North-South mode (0.17 - 0.25 Hz) may become low damped

Retuning Procedure

- The retuning procedure comprises eight steps:
  - Step 1 – Eigenvalue and Step Disturbance Studies on Individual Generator Units
  - Step 2 – Study of Three Base Cases
  - Step 3 – Coordinated Design of TCSCs and PSSs
  - Step 4 – Robustness Assessment of the PSS and TCSC Designs for Multiple Scenarios
  - Step 5 – Benchmarking Small Signal and Transient Stability Results
  - Step 6 – Transient Stability Simulations
  - Step 7 – Stabilizer Commissioning, Retuning and Power Plant Tests
  - Step 8 – Power System Oscillation Monitoring

Exciting the North-South Mode the Most

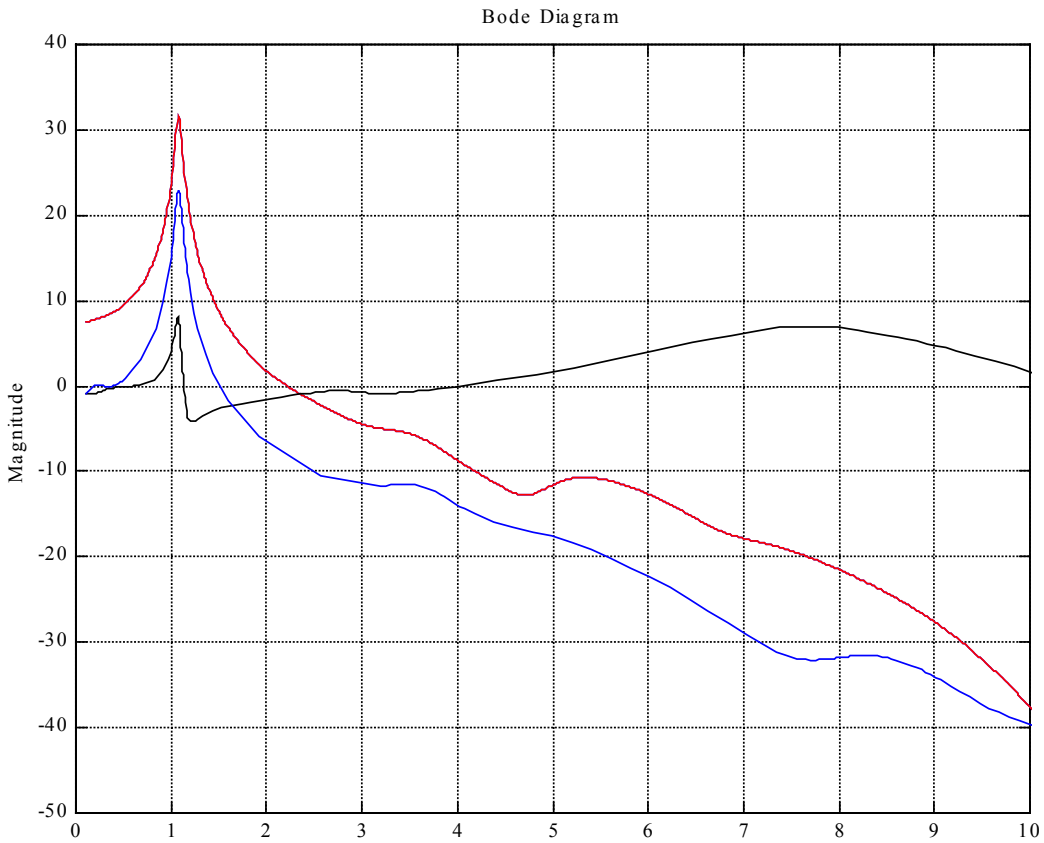
- Simultaneous disturbances of opposite polarities applied to North and South generators
- Monitor the magnitude of power transients in the North-South tie

$\lambda = -0.034 \pm j\ 1.079$

$\Delta P_{N\text{-}S\ TIE}(s) / \sum \Delta P^{i}_{MEC}(s)$

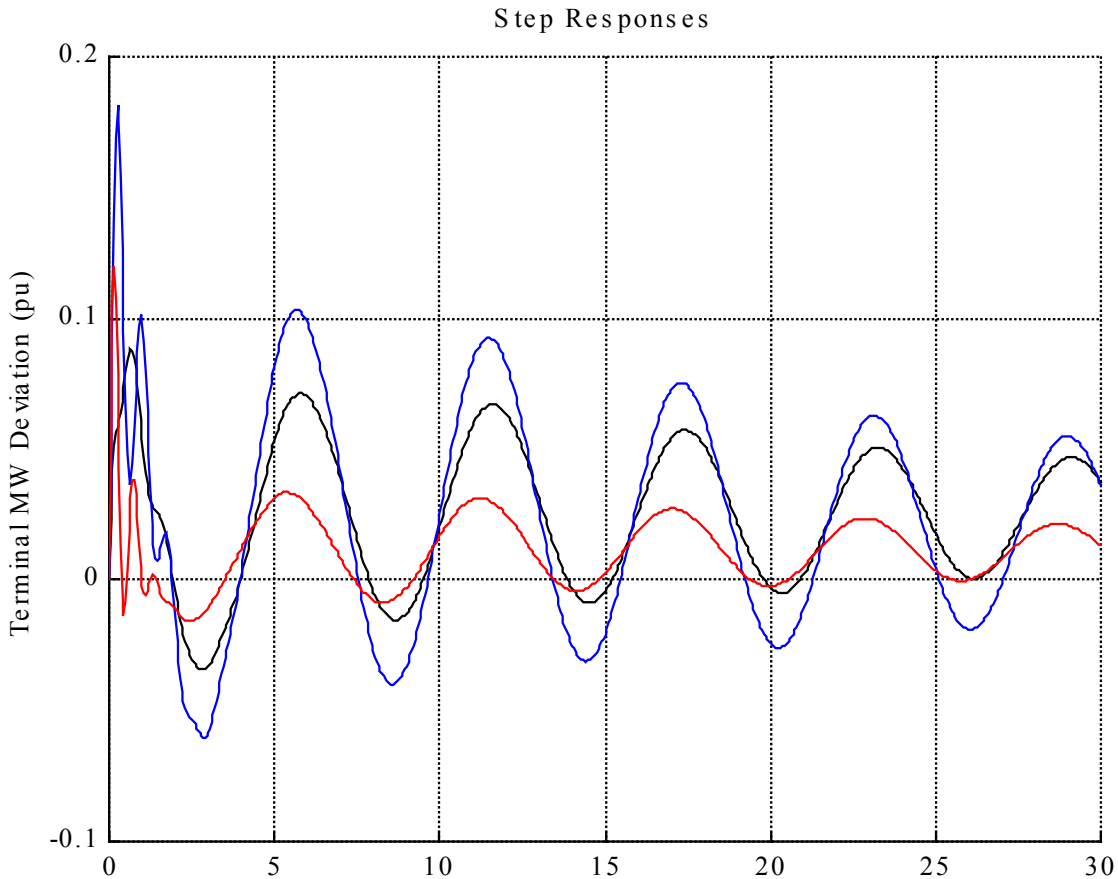
$\Delta P_{N\text{-}S\ TIE}(s) / \Delta P^{i}_{MEC}(s)$

$\Delta P^{i}_{T}(s) / \Delta P^{i}_{MEC}(s)$



Step Responses

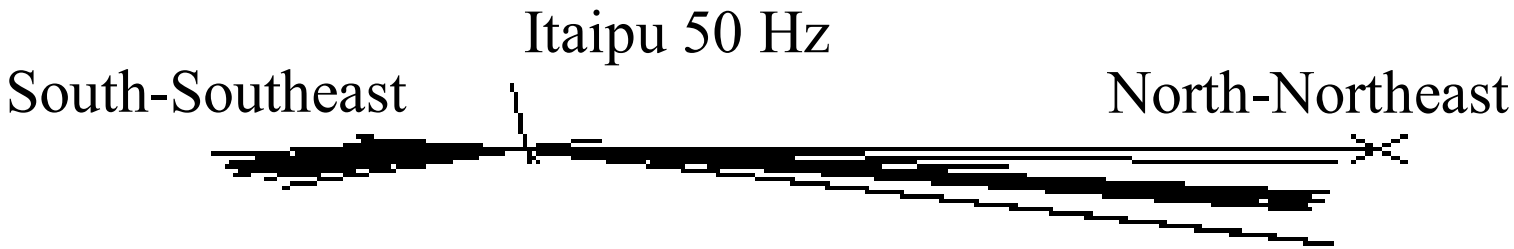
- Step responses of major system generators for scenario R (1000MW N/NE -> S/SE) with existing PSSs and without TCSC stabilizer



$\lambda = -0.034 \pm j\ 1.079$

Mode-Shape for North-South Inter-Area Mode

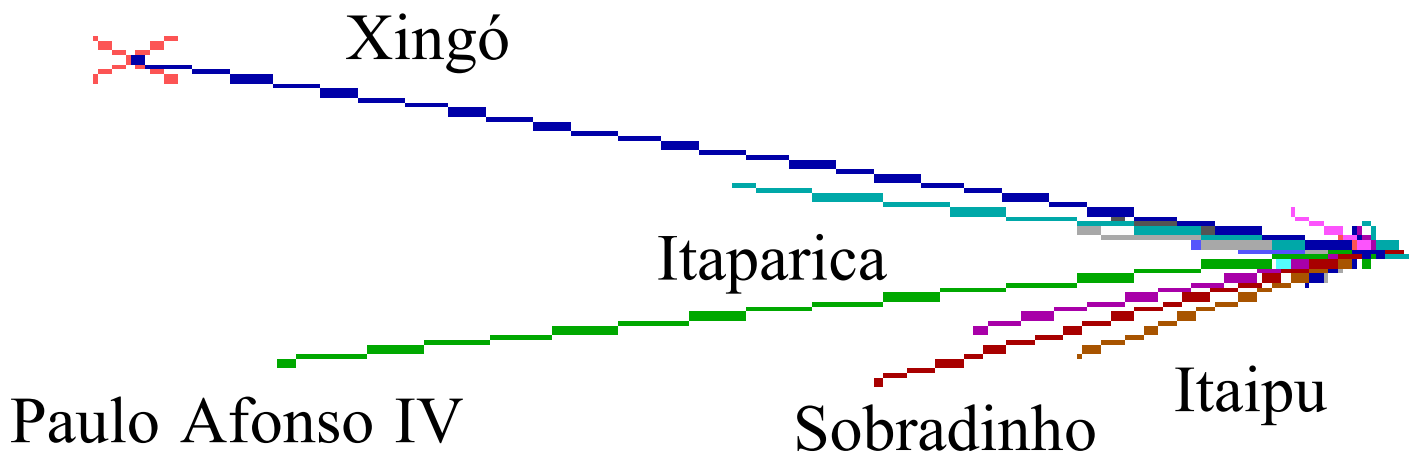
- Mode-Shape for North-South inter-area mode ($\lambda = -0.034 \pm j\ 1.079$)



Ranking the Most Effective PSS Locations Based on Transfer Function Residues

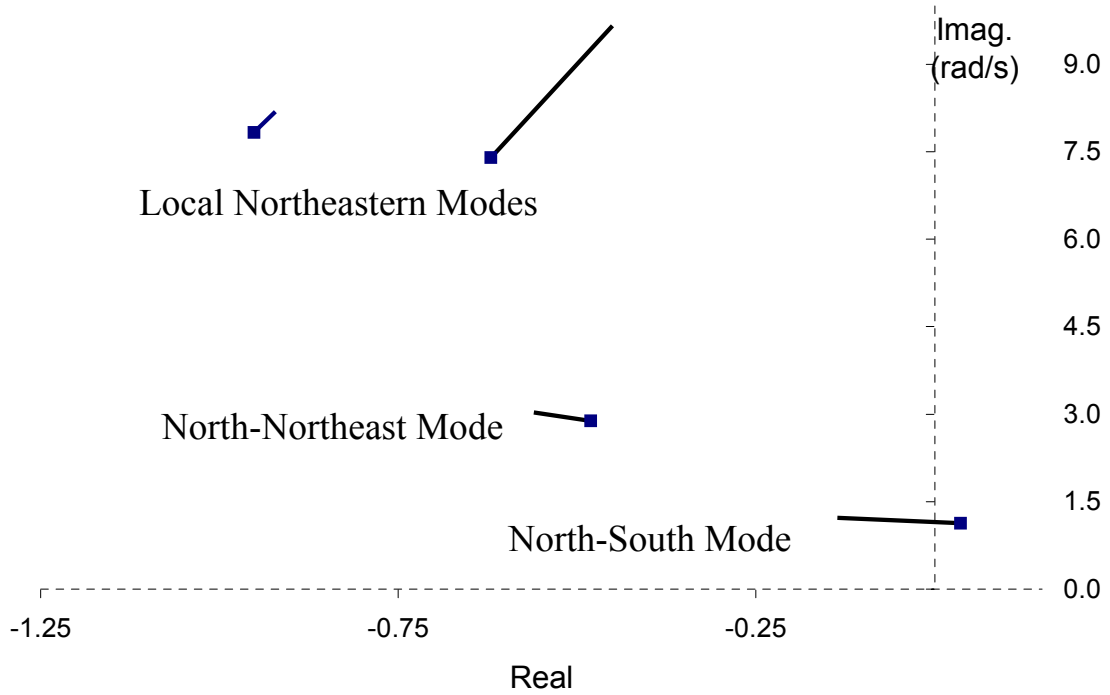
- The residue ranking list of transfer functions $\Delta\omega^i(\lambda)/\Delta V_{ref}^i(\lambda)$, $i = 1, \ldots, N_g$ helps locating the most effective generators for installing or retuning existing PSS for damping the inter-area mode

$$\lambda = -0.034 \pm j\ 1.079$$



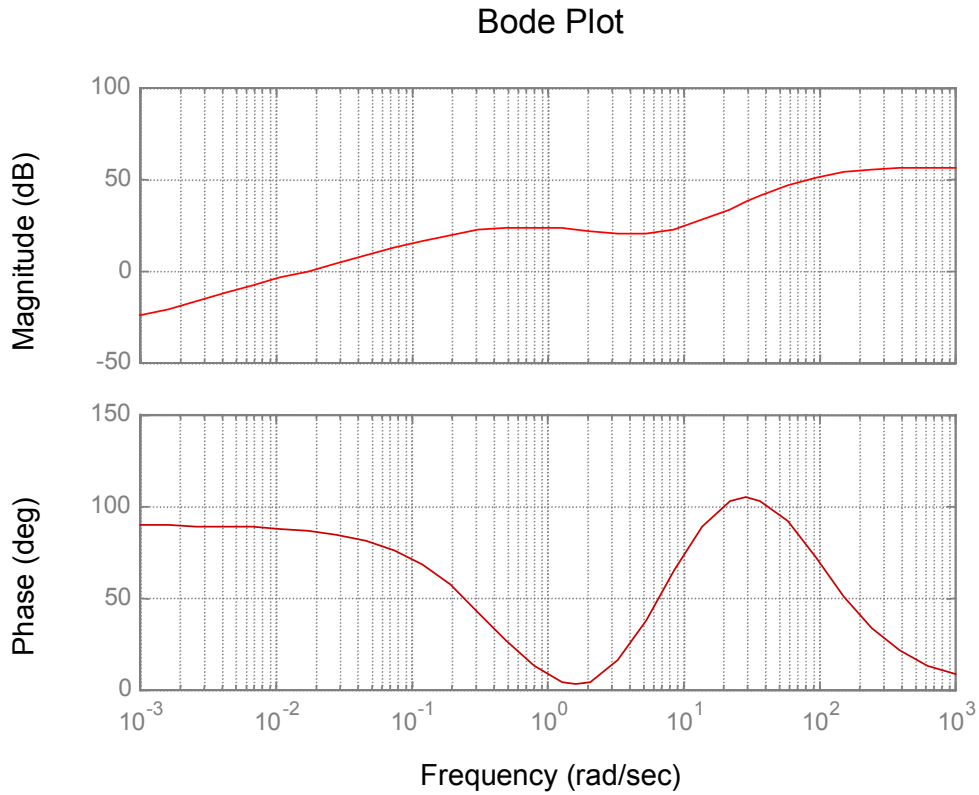
PSS Tuning and Coordination for Damping Several Dominant Modes

- Dominant pole spectrum for $\Delta\omega(s)/\Delta V_{ref}(s)$ at Xingó power plant. The complex vectors are the transfer function residues associated with the various poles. The residue magnitudes were made larger than actual for readability



PSS Tuning and Coordination for Damping Several Dominant Modes

The PSS phase characteristics are determined so that the residues associated with the multimachine modes at about 8 rad/s are advanced by about 70° while the residue associated with the North-South mode at 1 rad/s experiences no phase change.

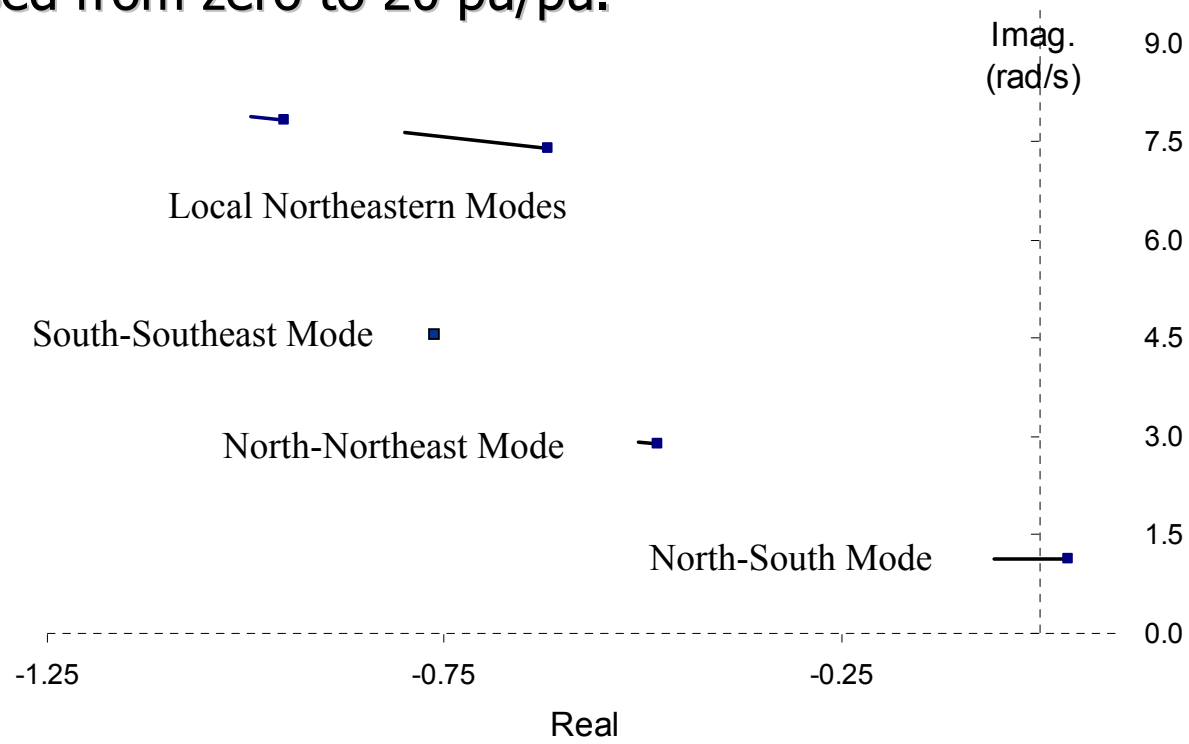


$$PSS(s) = K_{pss}\left(\frac{3s}{1+3s}\right)\left(\frac{1+0.12s}{1+0.012s}\right)^2\left(\frac{1+0.25s}{1+0.75s}\right)$$

Three Lead-Lag Blocks

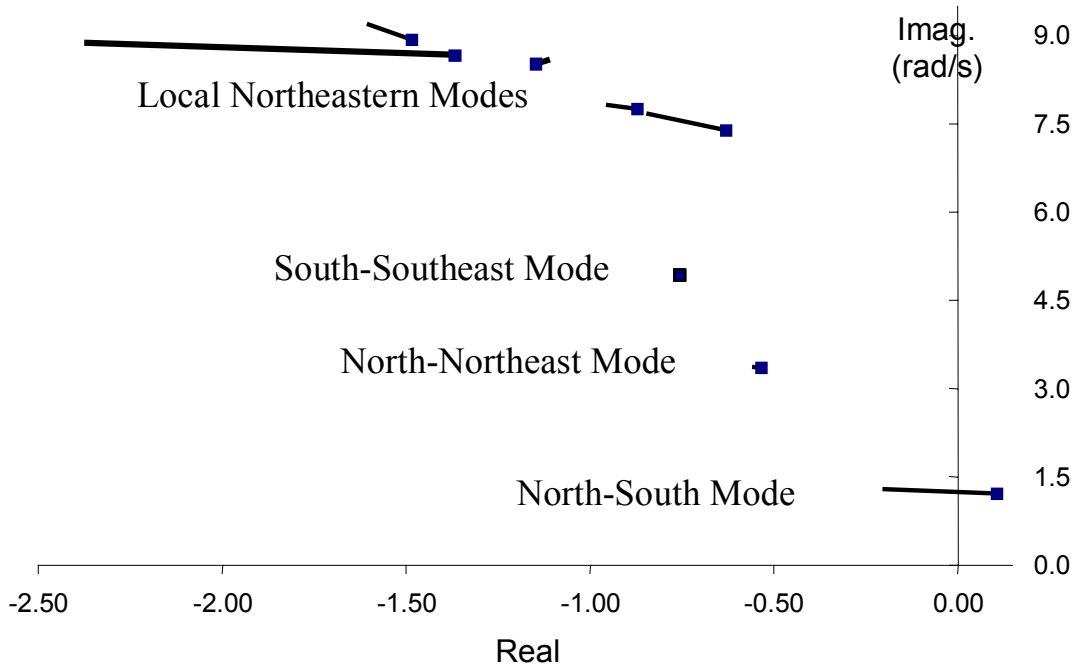
PSS Tuning and Coordination for Damping Several Dominant Modes

- This PSS tuning causes the original residues shown in to be rotated and amplified as indicated in the figure below
- Dominant pole spectrum and residues for the open-loop transfer function PSS(s).$\Delta\omega(s)/\Delta V_{ref}(s)$. These residues correspond to the first-order estimate for the Root-Locus plot, as the PSS gain at Xingó power plant is raised from zero to 20 pu/pu.



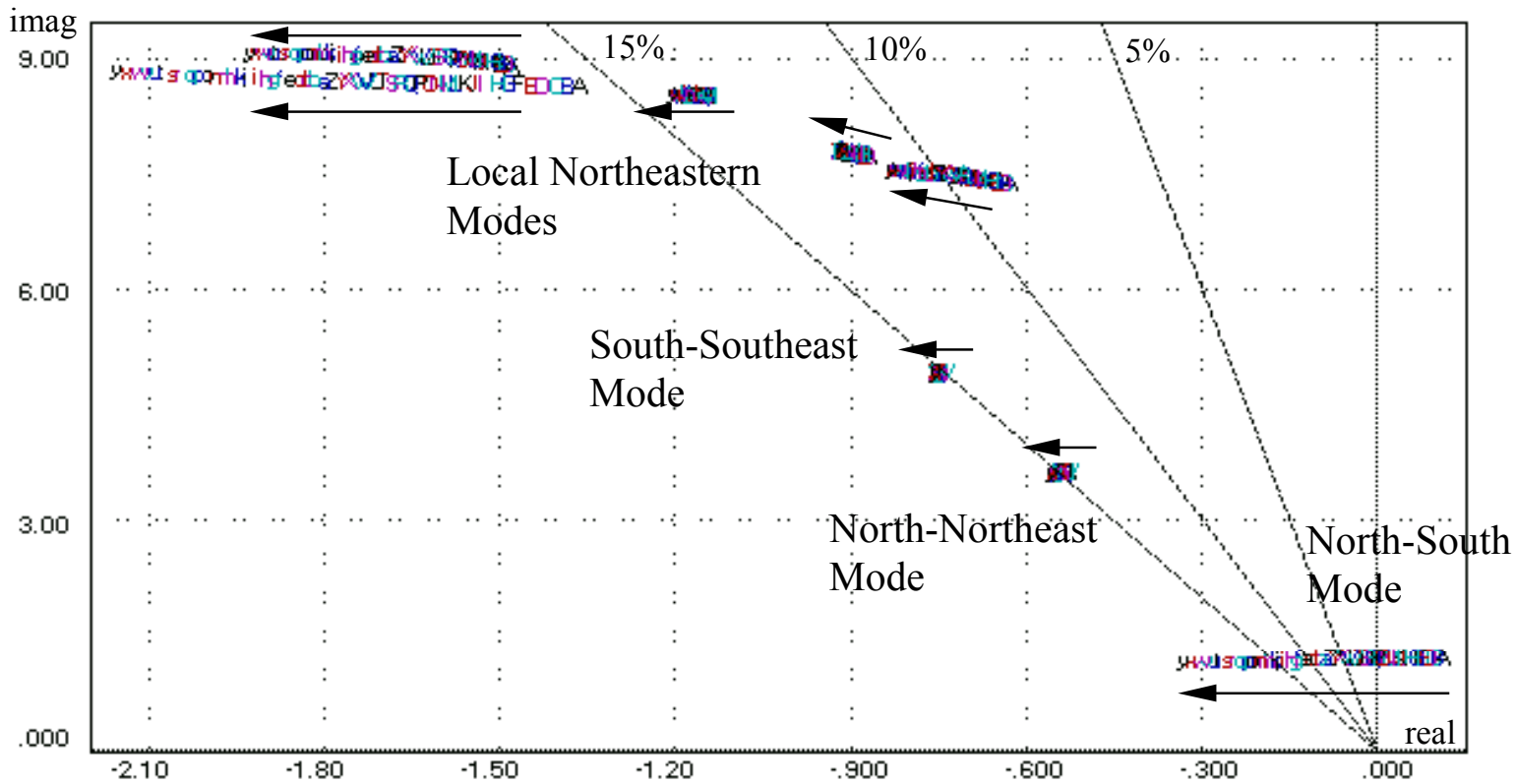
PSS Tuning and Coordination for Damping Several Dominant Modes

- First-Order estimate of the Root-Contour plot as the gains of stabilizers at Xingó, Paulo Afonso IV and Itaparica are raised from zero to 20 pu/pu



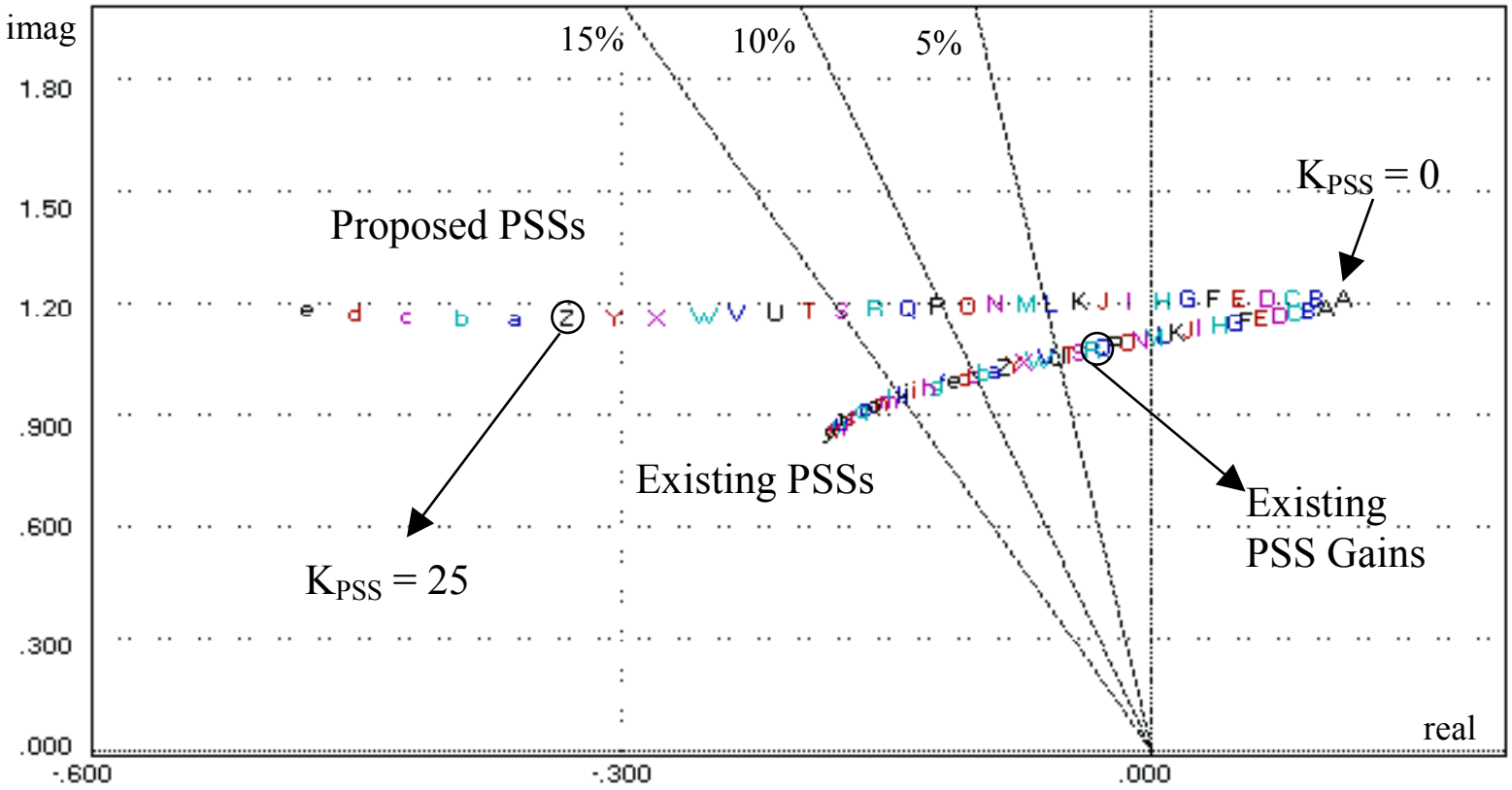
Examples of Root-Locus for Large System Models

- Root-Contour plot as the gains of the PSSs at Xingó, Paulo Afonso IV and Itaparica are raised from zero to 25 pu/pu



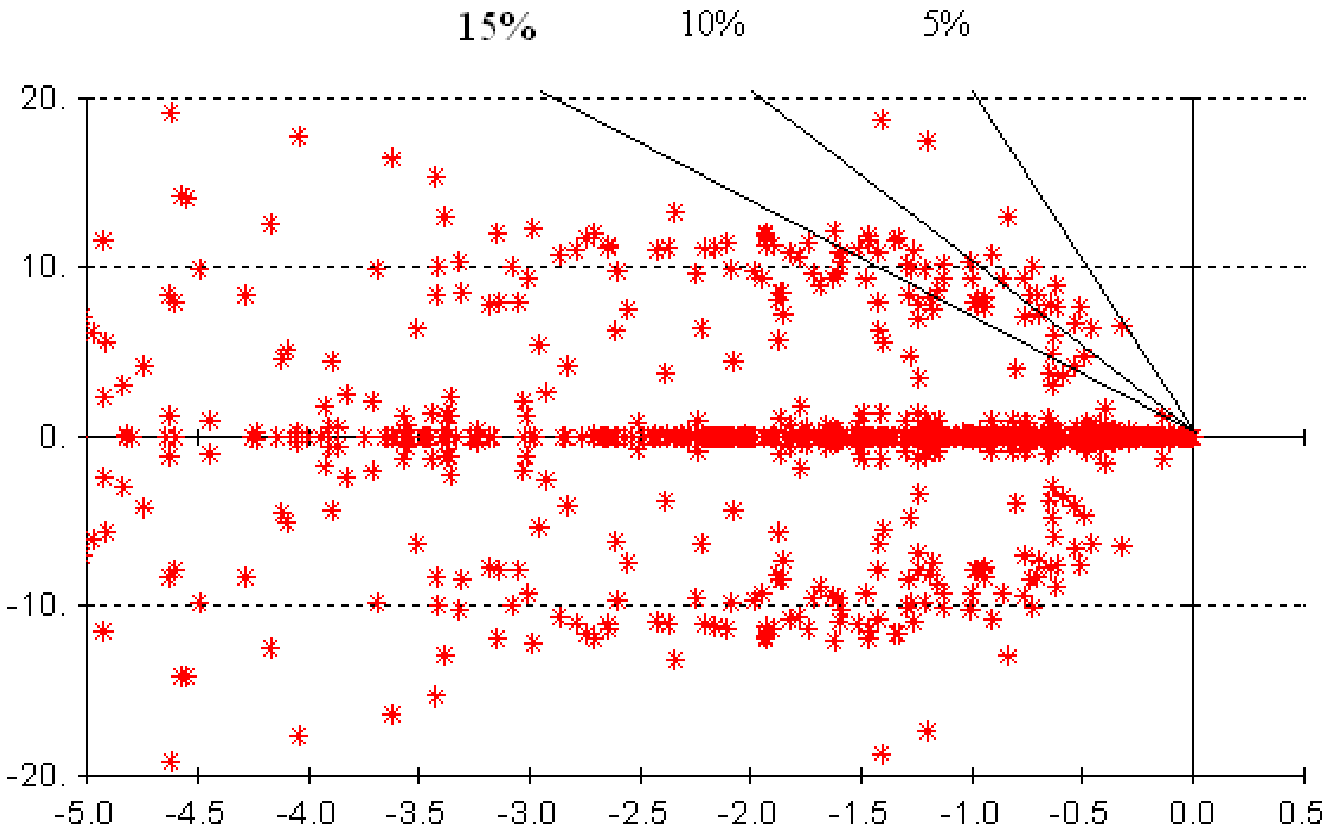
Examples of Root-Locus for Large System Models

- Locus of North-South mode following changes in the PSS gains at Xingó, Paulo Afonso IV and Itaparica power plants



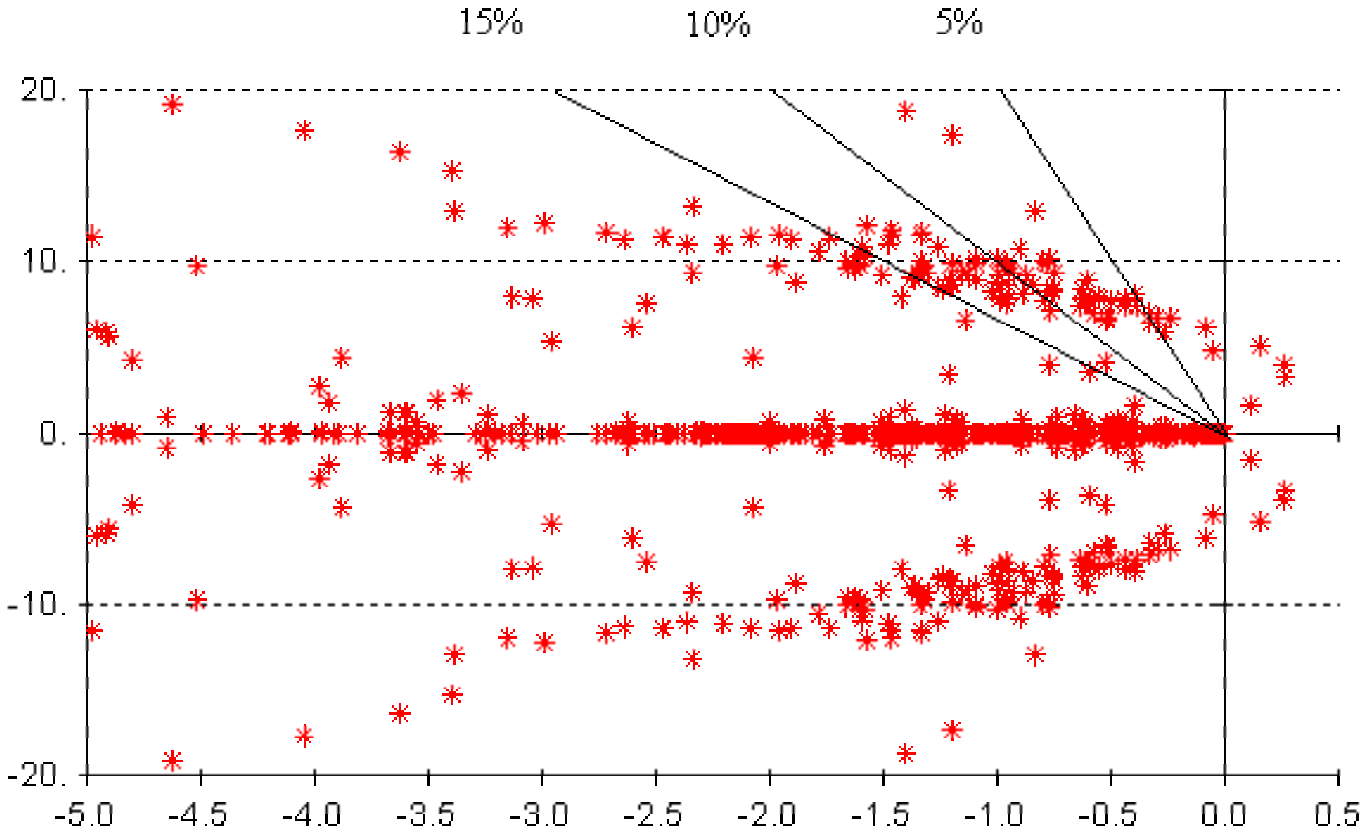
Examples of Full Eigensolution for Large Systems

- Eigenvalue spectrum of the North-South Brazilian interconnection with existing PSSs and without TCSCs (1,700 state variables). The chosen scenario is not critical



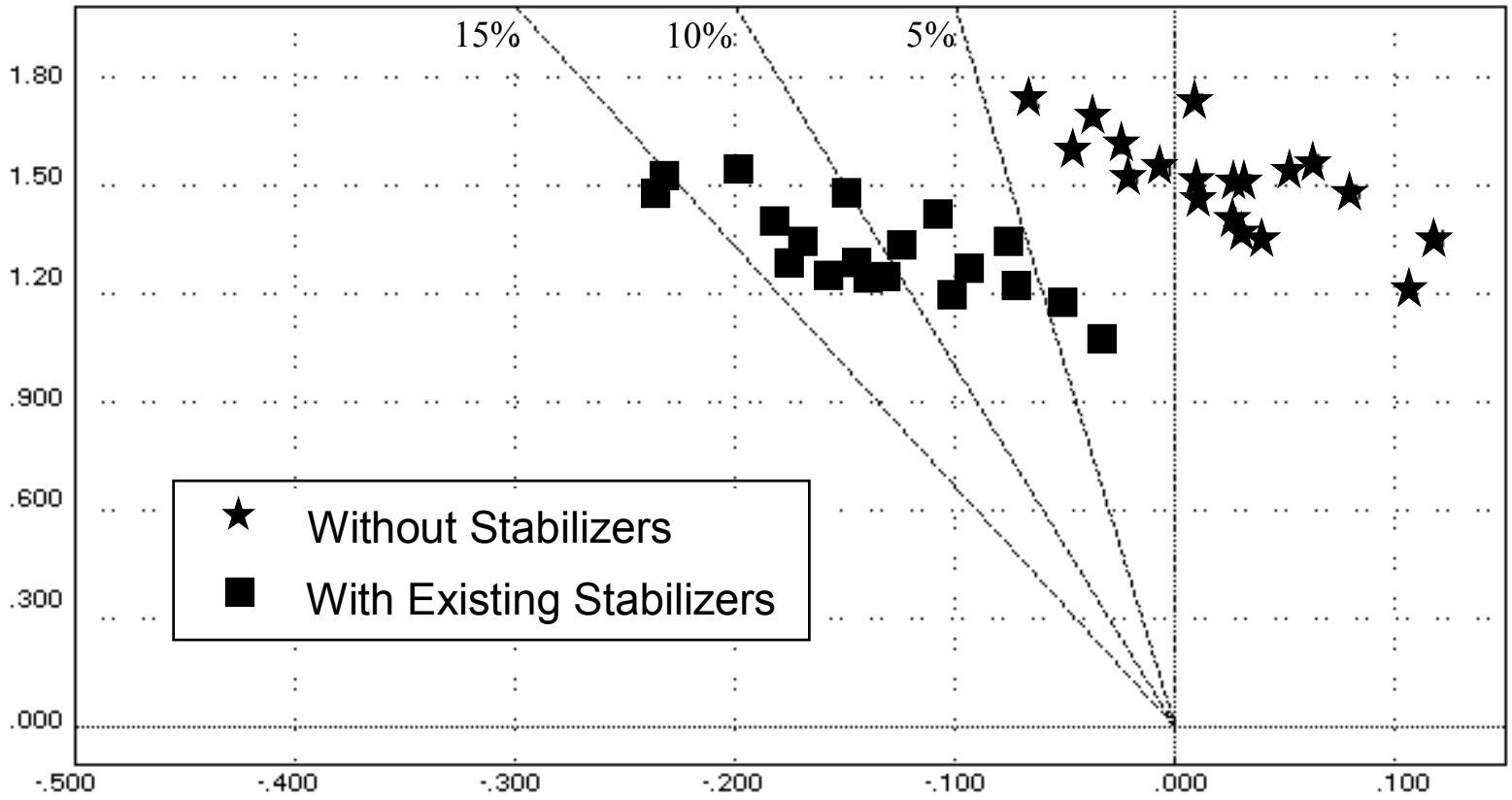
Examples of Full Eigensolution for Large Systems

- Eigenvalue spectrum for the North-South Brazilian interconnection in the absence of Power System Stabilizers and TCSC damping controllers (1,300 State Variables)



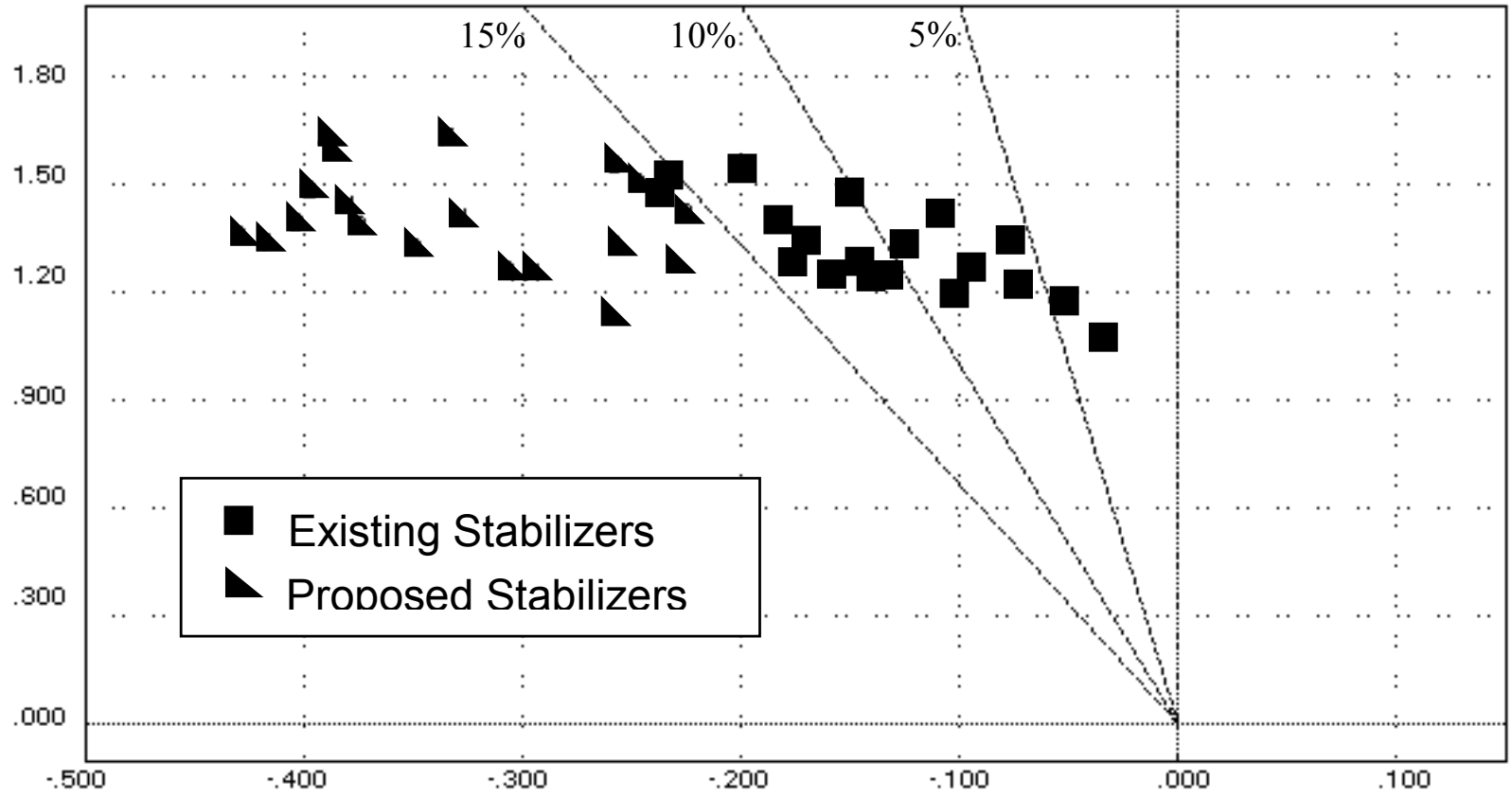
Example of Macro Functions Results for Various System Scenarios

- Location of North-South Mode, considering 19 scenarios, with and without stabilizers at Xingó, Paulo Afonso IV and Itaparica power plants



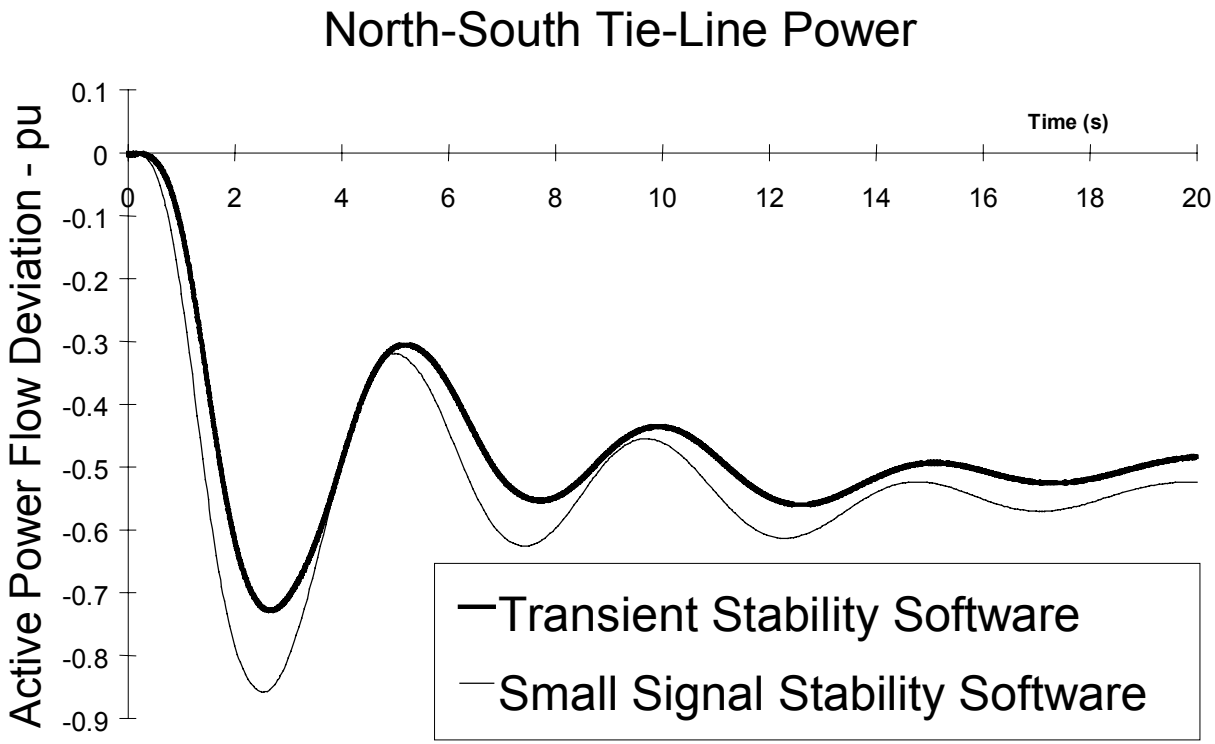
Example of Macro Functions Results for Various System Scenarios

- Location of North-South Mode, considering 19 scenarios, with existing and proposed stabilizers at Xingó, Paulo Afonso IV and Itaparica power plants



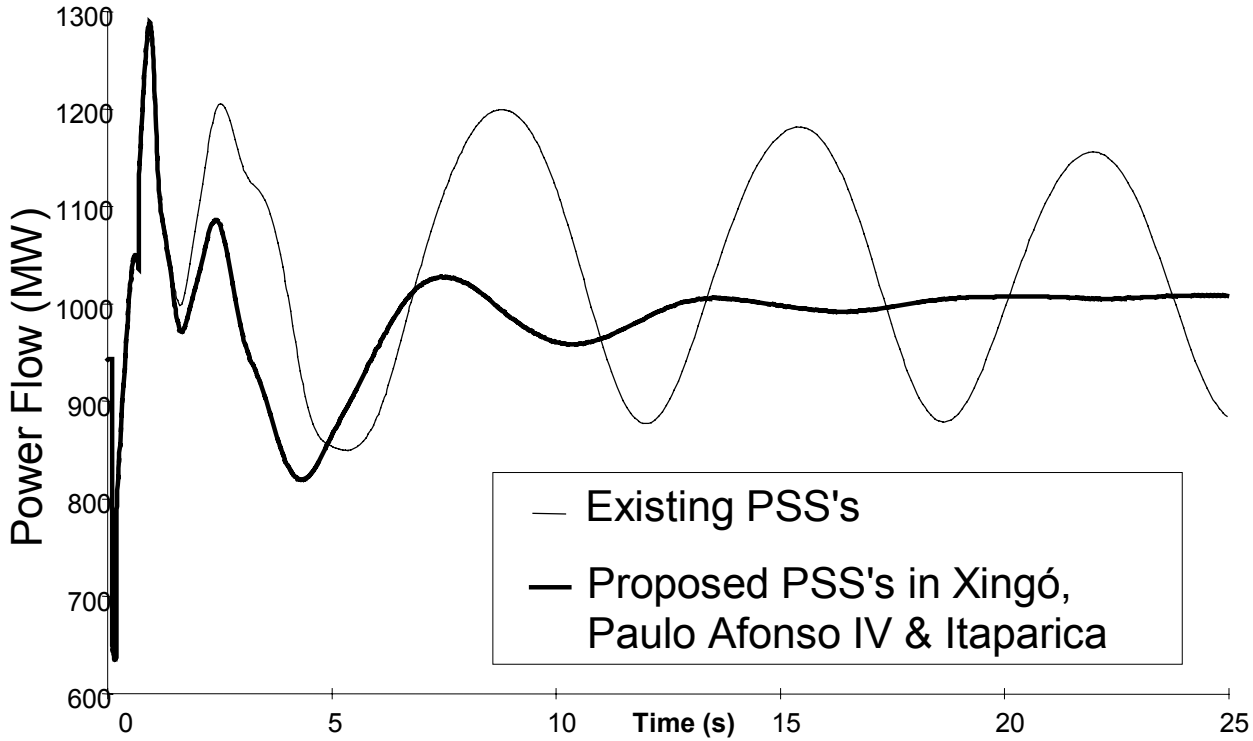
Benchmarking Small-Signal and Transient Stability Results

- Comparison of small signal and transient stability program responses for a small disturbance. System model with proposed PSSs in Paulo Afonso IV and Xingó power plants (100 MVA base)



Example of Transient Stability Simulation

- Active power flow transients in the North-South intertie, after a fault with subsequent line reclosure

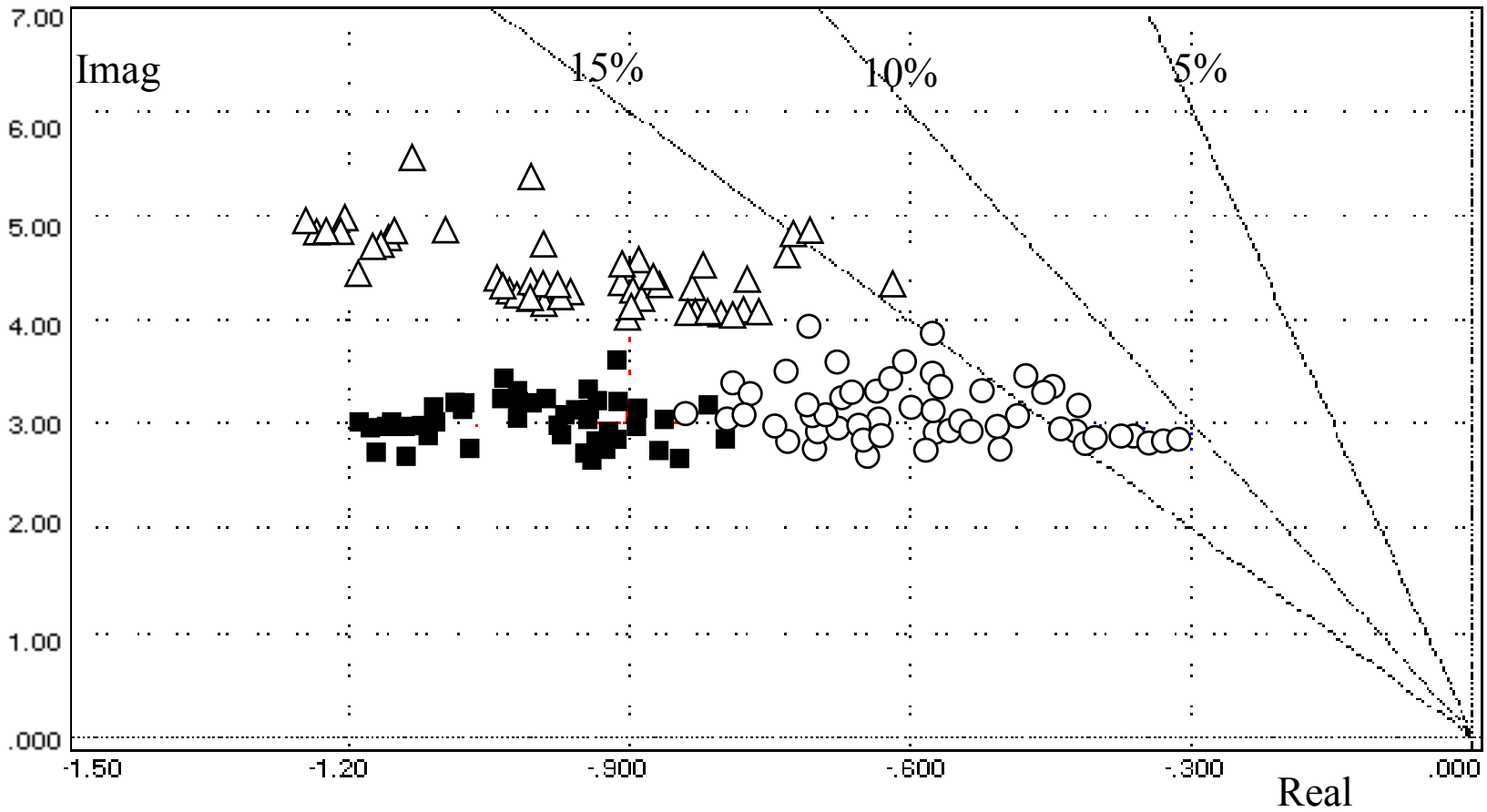


Conclusions

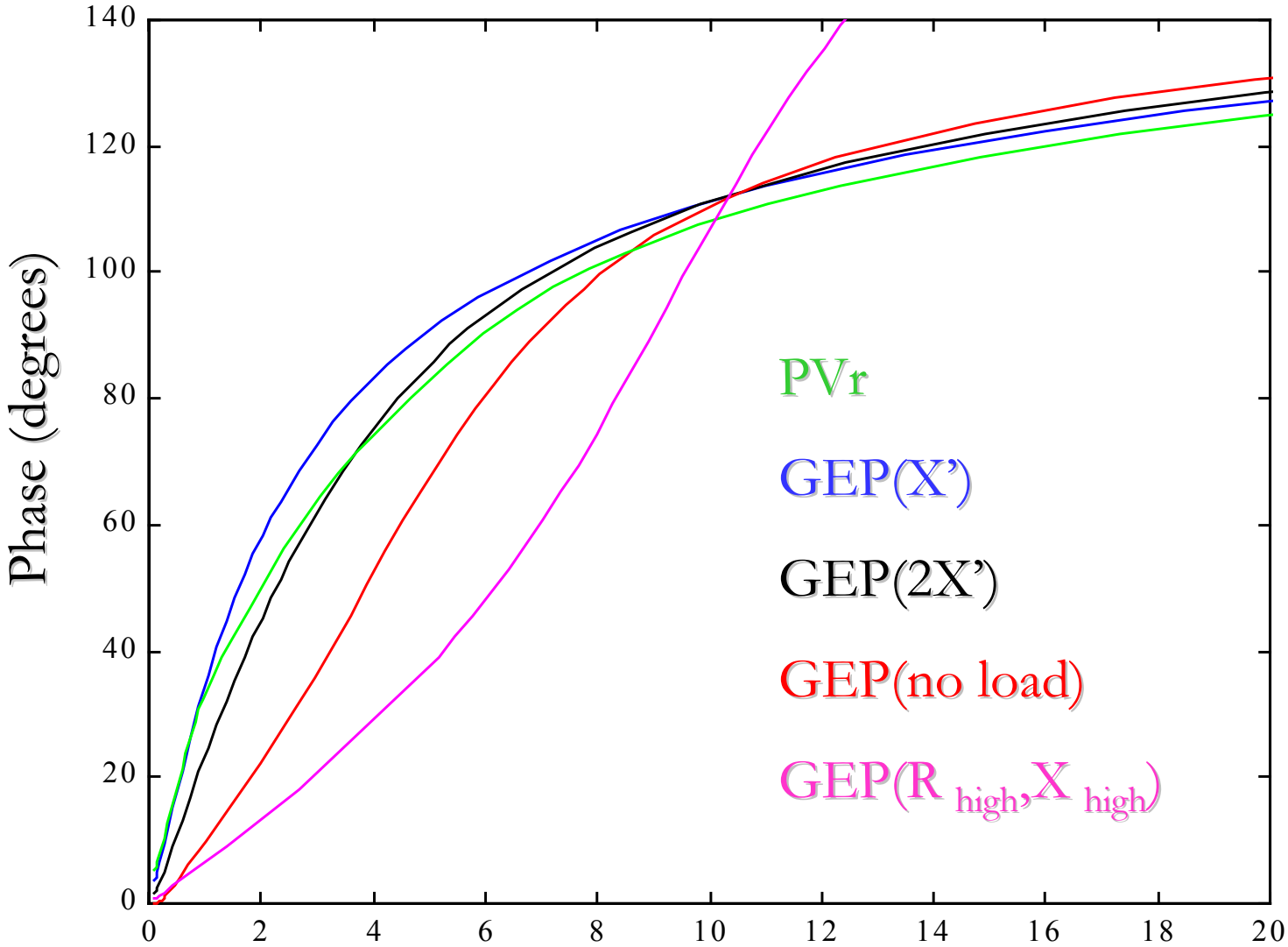
- Modified PSSs at 3 power plants plus the TCSCs provide an adequate level of redundancy in the damping sources to the critical North-South mode
- Advanced linear analysis software was instrumental to the success of the damping analysis and control study
- Very low-frequency inter-area modes call for a tighter damping criteria (ξ = 15%)
- GEP-based PSS tuning can be difficult sometimes

Example of Macro Functions Results for Various System Scenarios

- Location of three major inter-area modes for 64 N-1 contingencies in the Argentinean interconnected system



GEP(s) Phase Diagrams



Phase Diagrams for GEP(s) and PSS(s)