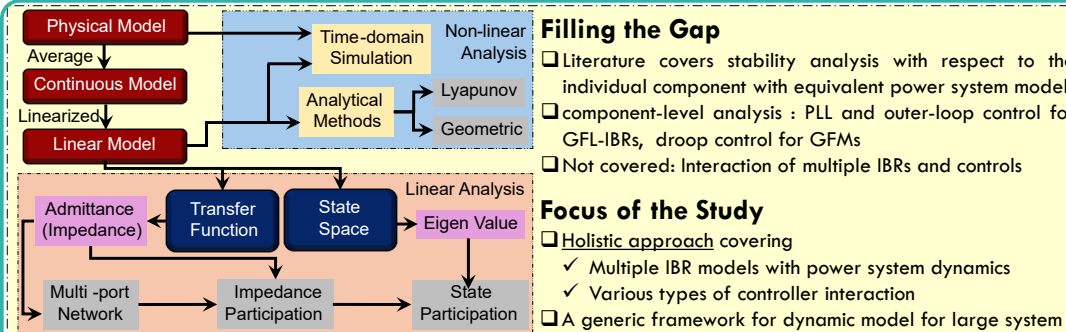


# Control Parameter Sensitivity Study for Inverter-Based-Resource Dominated Grids: A Small Signal Stability Approach and Framework

Soham Chakraborty, Bhagyashree Umathe, Jing Wang  
National Laboratory of the Rockies, Golden, Colorado 80401, USA.  
{soham.chakraborty, bhagyashree.umathe, jing.wang}@nlr.gov

NATIONAL LABORATORY OF THE ROCKIES



## Filling the Gap

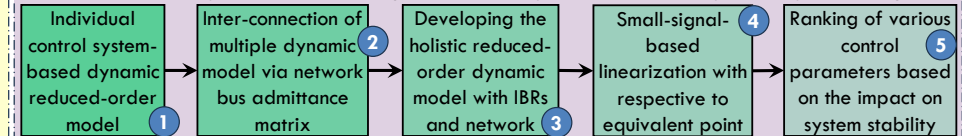
- Literature covers stability analysis with respect to the individual component with equivalent power system model
- component-level analysis : PLL and outer-loop control for GFL-IBRs, droop control for GFM
- Not covered: Interaction of multiple IBRs and controls

## Focus of the Study

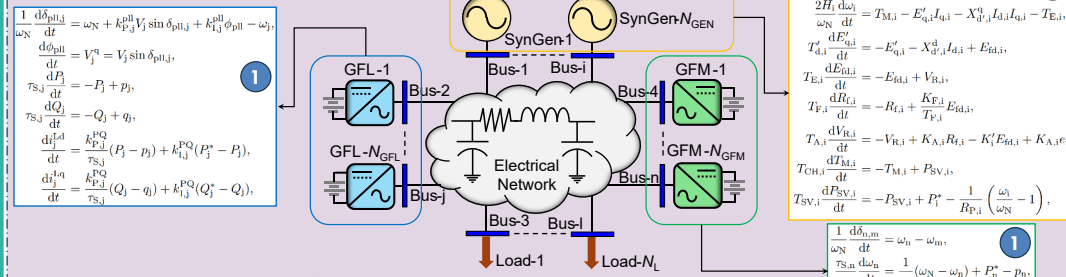
- Holistic approach covering
  - ✓ Multiple IBR models with power system dynamics
  - ✓ Various types of controller interaction
- A generic framework for dynamic model for large system

## Contribution

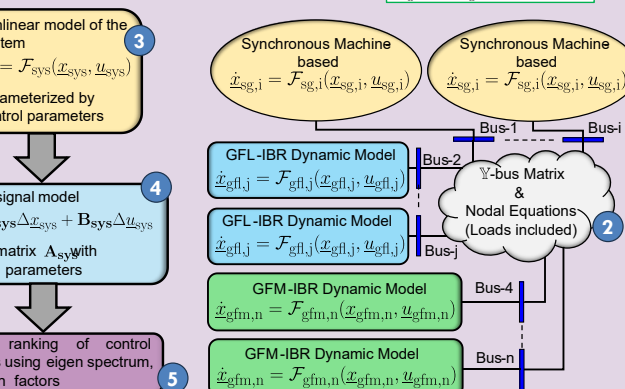
- reduced-order, dynamic model representing interactions among SGs, GFM-IBRs, GFL-IBRs, and network
- incorporating → PLL dynamics, closed-loop PQ-dispatch, droop controller, AVR, PSS, Governor.
- eigenvalue-based sensitivity analysis methodology to rank the influence of key control parameters
- offers actionable guidelines for control parameter tuning aimed at enhancing small-signal stability



## Framework and Stability Approach



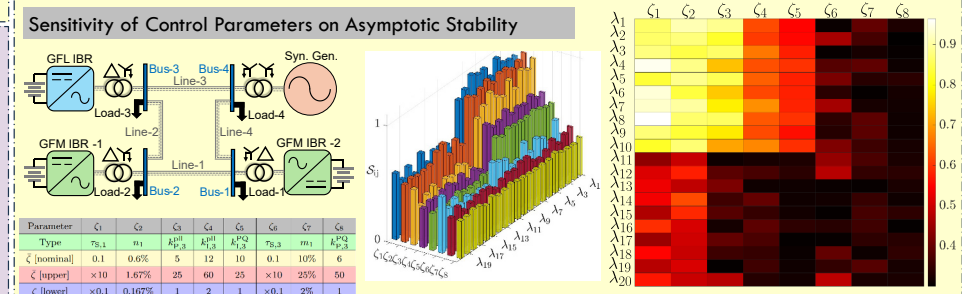
- | #  | Control Parameters of GFL -IBR       |
|----|--------------------------------------|
| 1) | bandwidth of PLL controller          |
| 2) | bandwidth of P-dispatch controller   |
| 3) | bandwidth of Q-dispatch controller   |
| 4) | bandwidth of DC link compensator     |
| 5) | droops in the plant-level controller |
- 
- | #  | Control Parameters of GFM -IBR      |
|----|-------------------------------------|
| 1) | parameters of P/f droop controller  |
| 2) | parameters of Q/V droop controller  |
| 3) | virtual inertia, damping parameters |
| 4) | bandwidth of power controller       |
| 5) | bandwidth of DC link compensator    |
- 
- | #  | Control Parameters of SGBR          |
|----|-------------------------------------|
| 1) | rotor inertia, damping              |
| 2) | droop of the governor controller    |
| 3) | Bandwidth of governor controller    |
| 4) | Bandwidth excitor controller        |
| 5) | droop of the Q/V excitor controller |



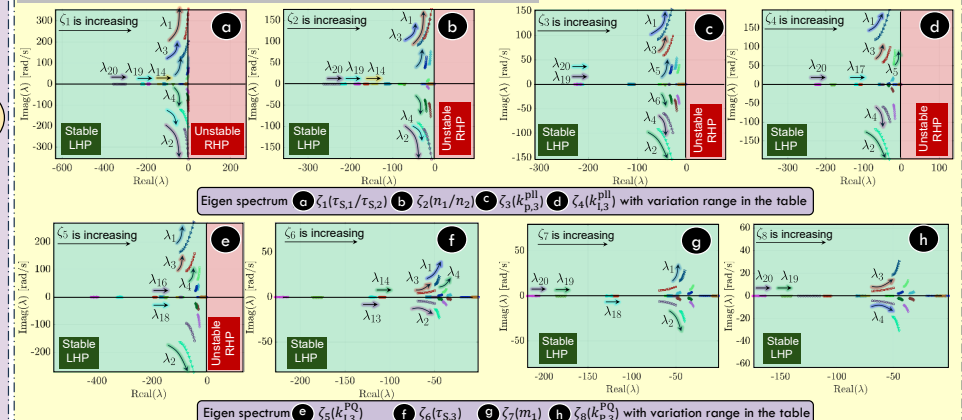
- Step-1 (first-order eigenvalue sensitivity)
- $A_{sys} v_i = \lambda_i v_i \equiv A_{sys}^T w_i = \lambda_i w_i$ , right & left eigenvectors
  - $A_{sys}$  : state matrix around the stable equilibrium point
  - $A_{sys}$  is parameterized by  $\zeta = [\zeta_1 \ \zeta_2 \ \dots \ \zeta_N]^T$

- Step-2 (Ranking based on Sensitivity)
- $S_{ij} = \partial \lambda_i / \partial \zeta_j = w_i^T (\partial A_{sys} / \partial \zeta_j) v_i$
  - first-order sensitivity of  $j^{th}$  control variable to the  $i^{th}$  eigenvalue

## Results and Validations



## Parameters on Asymptotic Stability with Varying SCR



## Observations

- PLL bw → Pf-droop → PQ controller bw →  $\tau$  of LPF
- QV-droop, PQ controller damping: least sensitive
- Low SCR increases the sensitivity
- more prone to instability

## Future Development

- framework to be generic, scalability, variety in types
- framework to be automated and open-source
- adding DC-link control, PPC, PSC and VSM control
- extension with robust stability framework