Moving Beyond SCR

Updating Our Stability Screening Methods

Matthew Richwine   Nicholas Miller

G-PST/ESIG Webinar, May 22, 2025

GridLAB

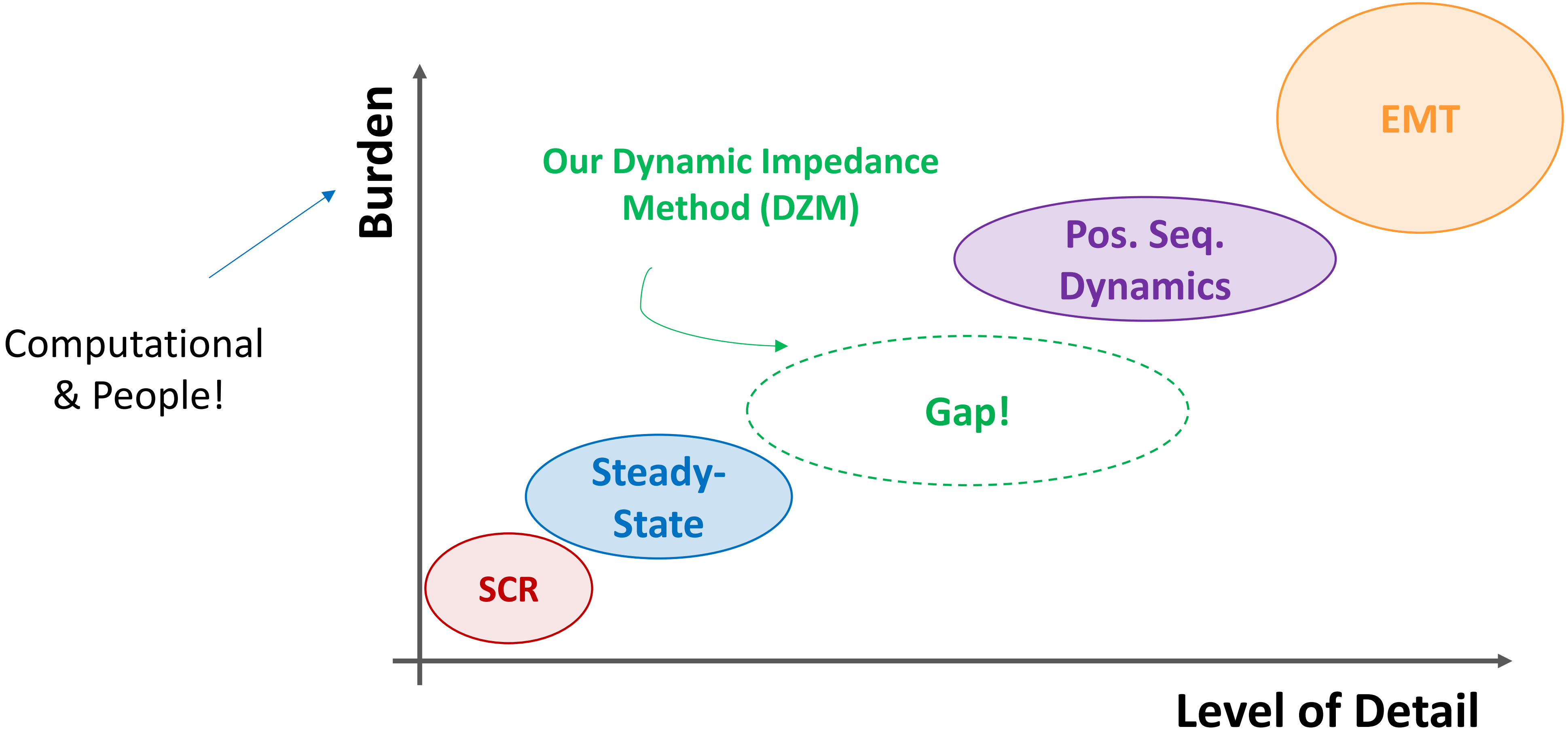
TELOS ENERGY

HickoryLedge

Screening Methods

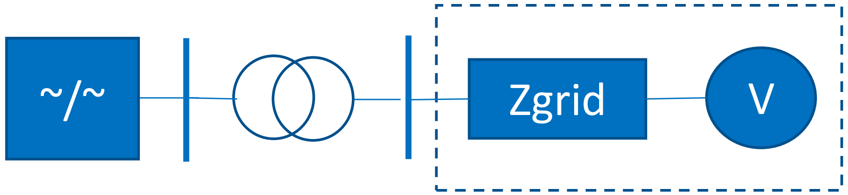
A Very Brief Overview

The Big Picture of Stability Studies



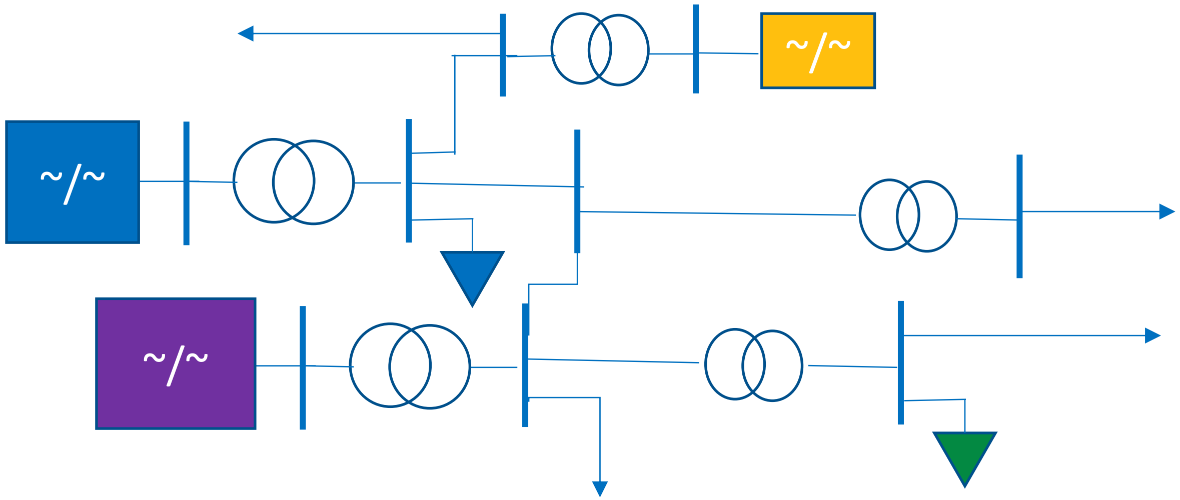
SCR-Based Methods

Simple short-circuit ratio (SCR)
Typically calculated as a single resource radially connected to an equivalent grid



However, this simple (often very useful) approach breaks down (becomes useless) in today's practice:

- It does not differentiate IBR technology or quality (GFL, GFM)
- It does not handle complex topologies with multiple resources (aggregation ambiguity - how close is "nearby"??)



While there are many variants of SCR (ESCR, eSCR, WSCR, CSCR, SDSCR, MIESCR, etc), they share these flaws

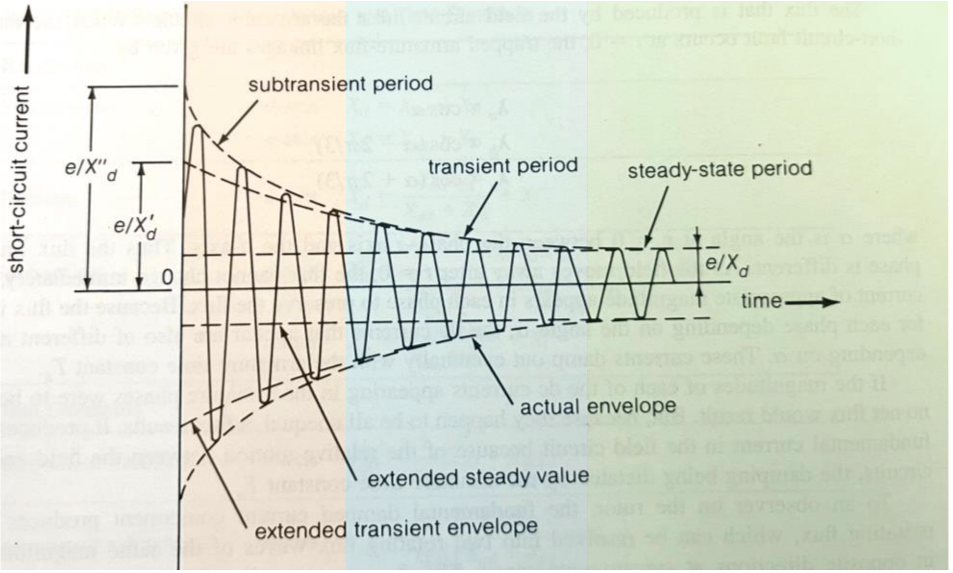
The Dynamic Impedance Method

A Very Brief Overview

Timeframes & Synchronous Machine Theory

Synchronous Machine Dynamic

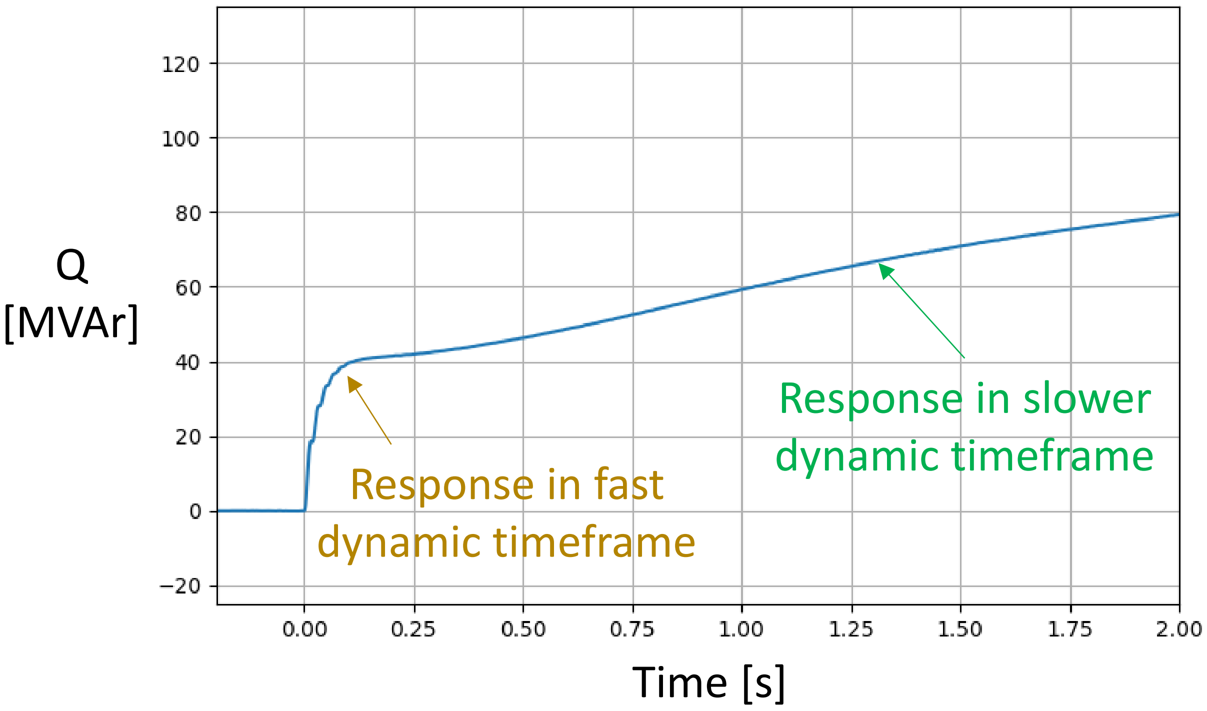
- Concept of a time-dependent impedance from synchronous machine theory
- Subtransient, transient, and steady-state (synchronous) periods



Sarma, M., Electric Machines Steady-State Theory and Dynamic Performance, 2nd Ed. 1994

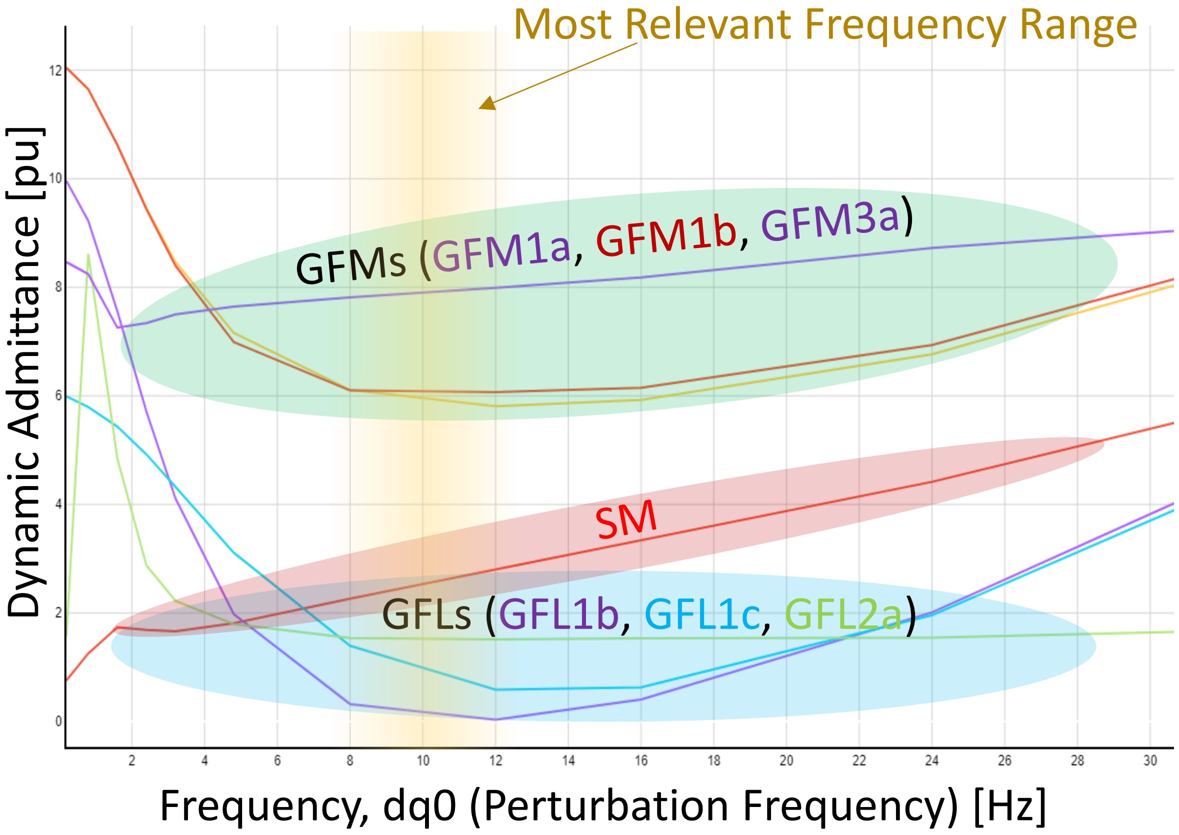
IBR Voltage Regulation Dynamics

- IBR exhibit different levels of response in different timeframes following a voltage disturbance



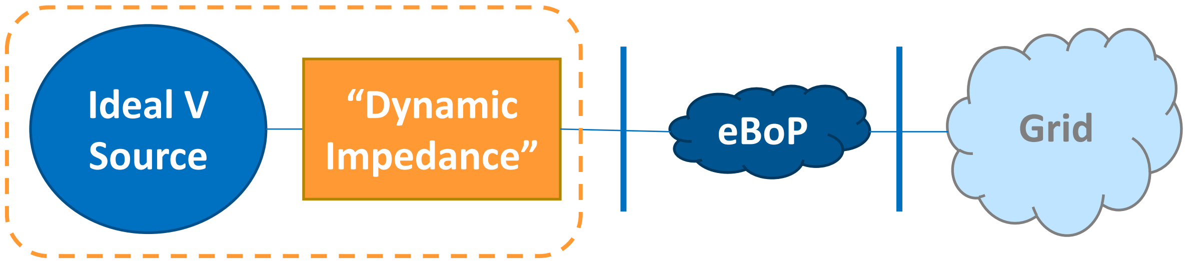
Brief Overview of the Dynamic Impedance Method

Core Finding: Quality of voltage regulation is critical to voltage stability



Our work on the Dynamic Impedance Method (DZM) was published in 2023 and shared in: ESIG, NERC IRPS, WSIS/IEEE White Paper

Admittance of the resource at 10Hz is applied as an impedance behind the terminals



Analysis Framework (Briefly)

Data Inputs

Analysis

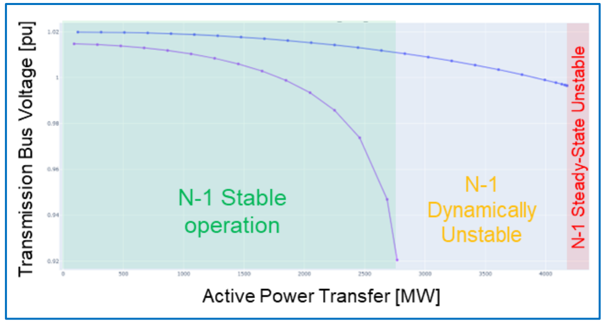
Network Topology

Scenarios & Resource Mixes

Contingency List

Steady-State (P-V) Analysis

Tractable for Large Systems

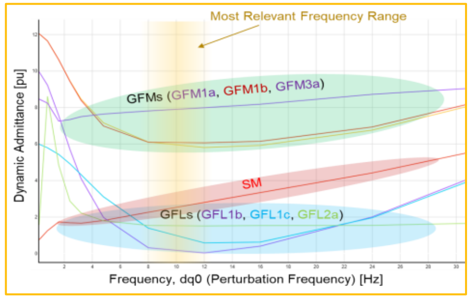


Steady-State Analysis
Augmented with Resources'
Dynamic Characteristics

Detailed (EMT) Resource Models

Impedance Analysis

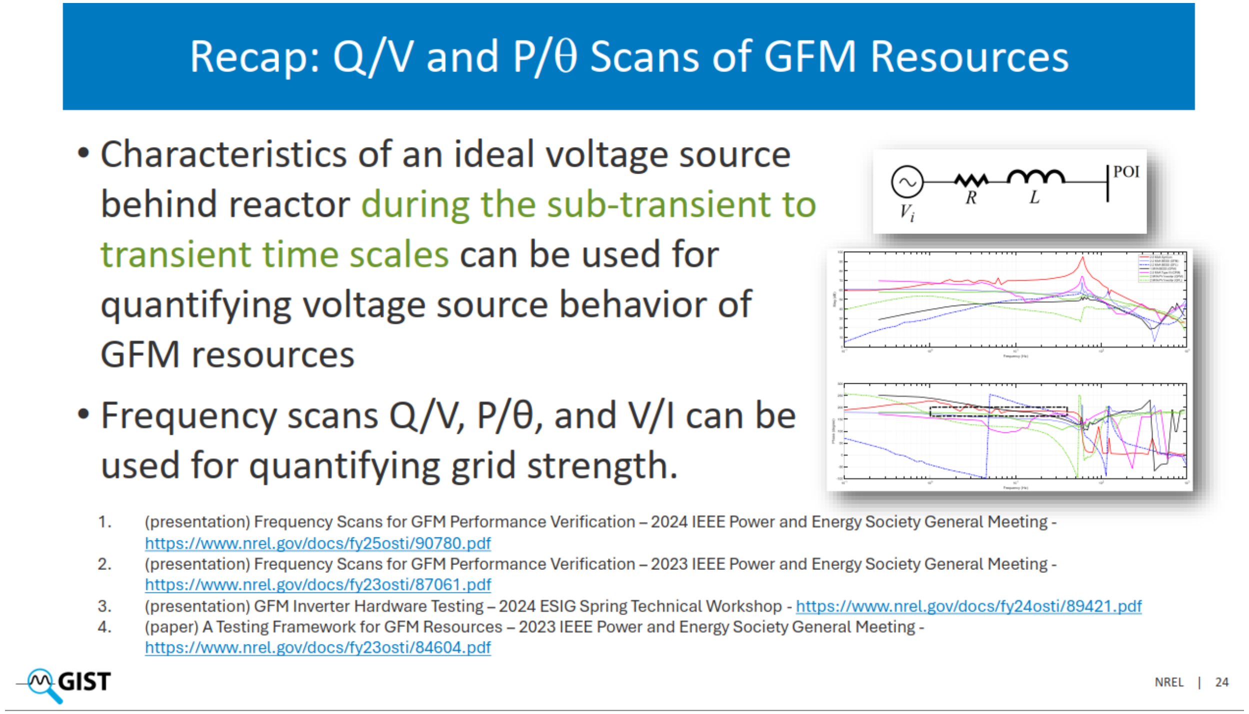
Resource-Specific Characteristics



Suitable for screening **large systems + large contingency** sets over **many possible futures**

Convergence of Approaches in Industry

- **Shahil Shah** (NREL) is using frequency-domain analysis of the Q/V relationship with a focus on relevant time frames as a means of characterizing IBR
- He has independently used this approach to quantify the support provided by different IBR technologies
- Also finds that this approach provides insight to stability limits without large EMT studies



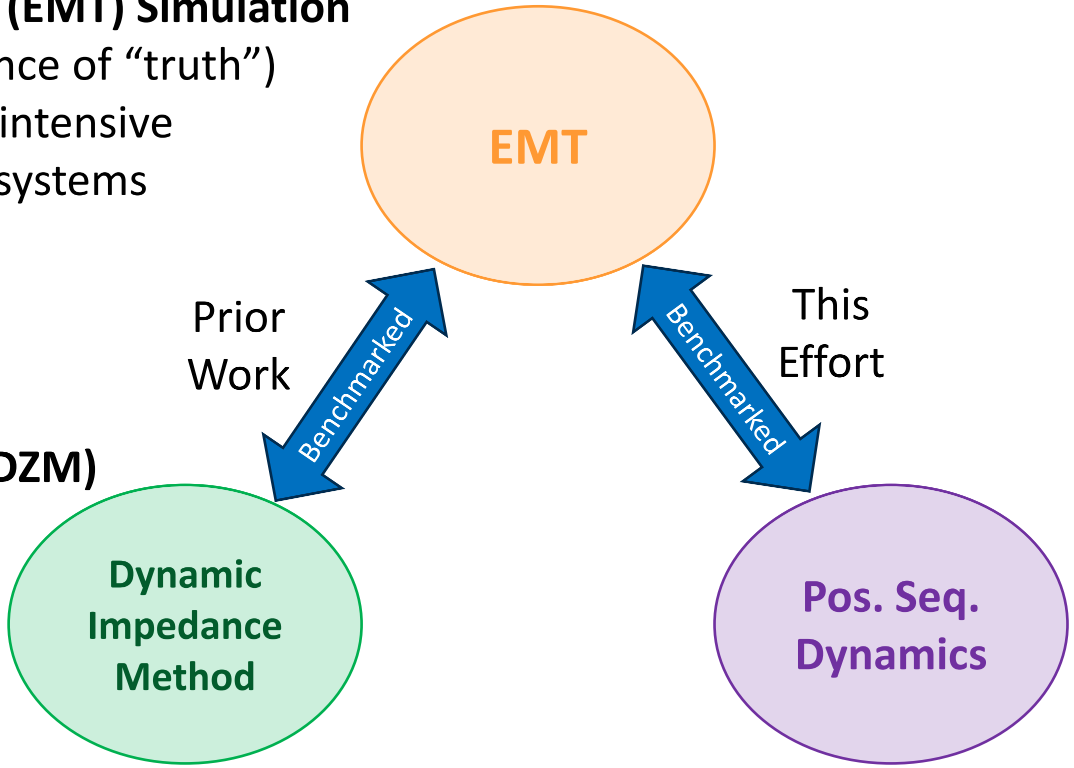
Source: Analysis of IBR-driven Oscillations in the Australian Grid [ESIG Webinar](), Feb 18, 2025

Benchmarking the Methods

EMT v. PSDS v. DZM

3 Approaches for Finding Stability Limits

Electromagnetic Transient (EMT) Simulation
- Best fidelity (our reference of “truth”)
- Most difficult and data-intensive
- Does not scale to large systems

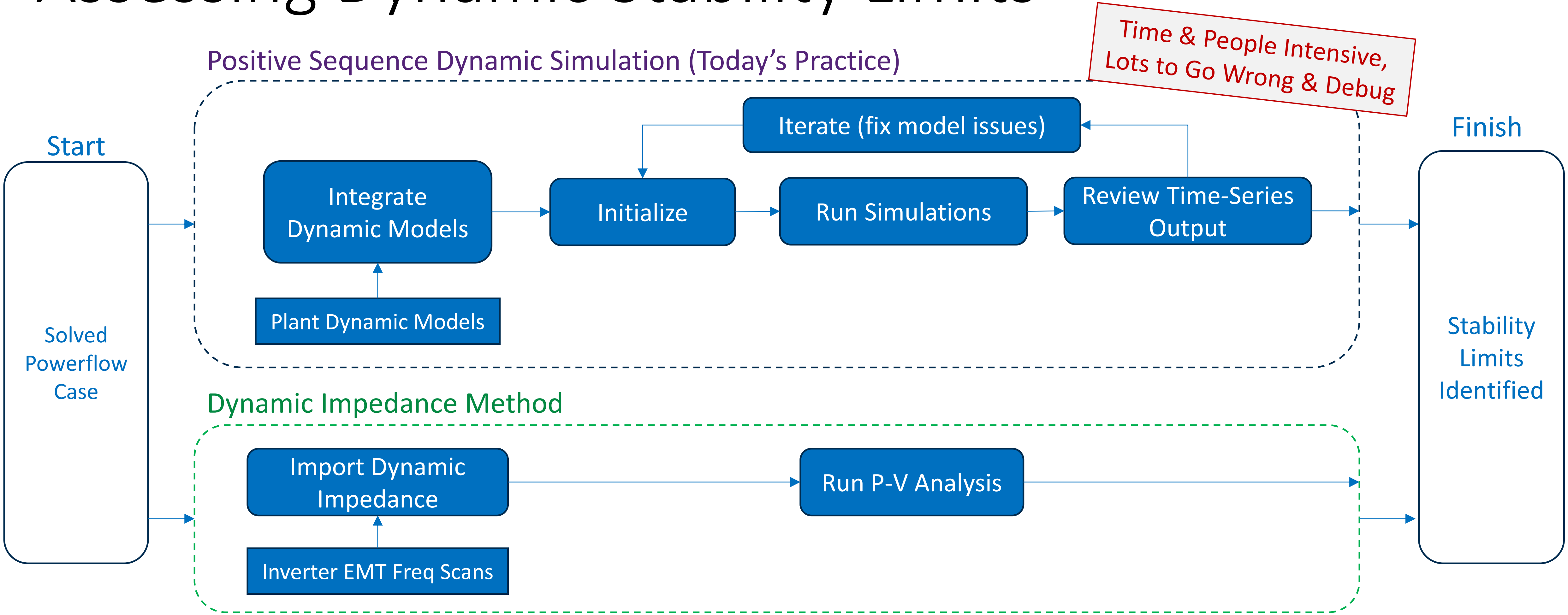


Dynamic Impedance Method (DZM)
- Greatly simplified dynamics
- Utilizes steady-state (P-V) analysis + some EMT
- Fastest – scales up well

Positive Sequence Dynamics Simulation (PSDS)
- Simplified dynamics
- Runs for large systems, but laborious

Developed in 2023 and shared in:
ESIG, NERC IRPS, WSIS/IEEE White Paper

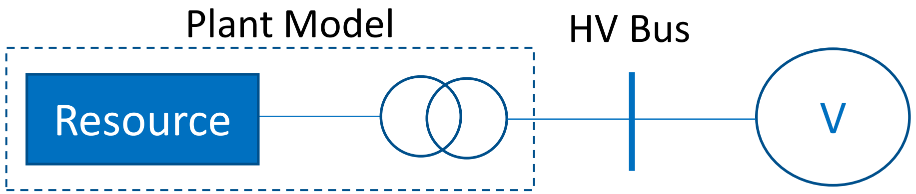
Assessing Dynamic Stability Limits



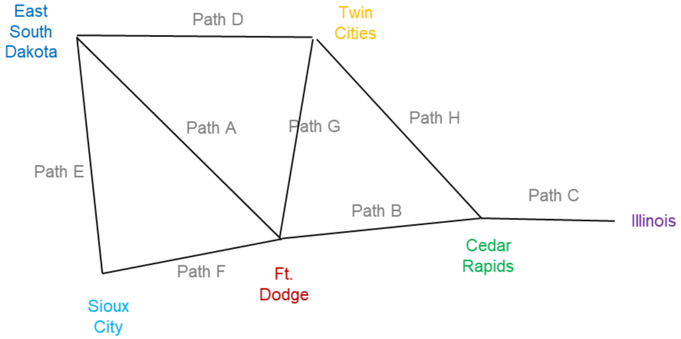
Comparing Approaches: EMT & PSDS

1 **Variety of Equipment**
SM, GFL (2 OEMs), GFM (2 OEMs)

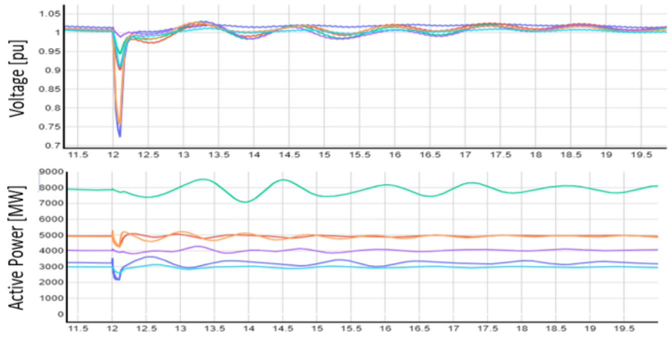
2 **Plant Model Benchmarking**
To ensure agreement of EMT and PSDS Models



3 **Simulations on a Representative Transmission System**



4 **Evaluate Stability Limits**
Using identical criteria



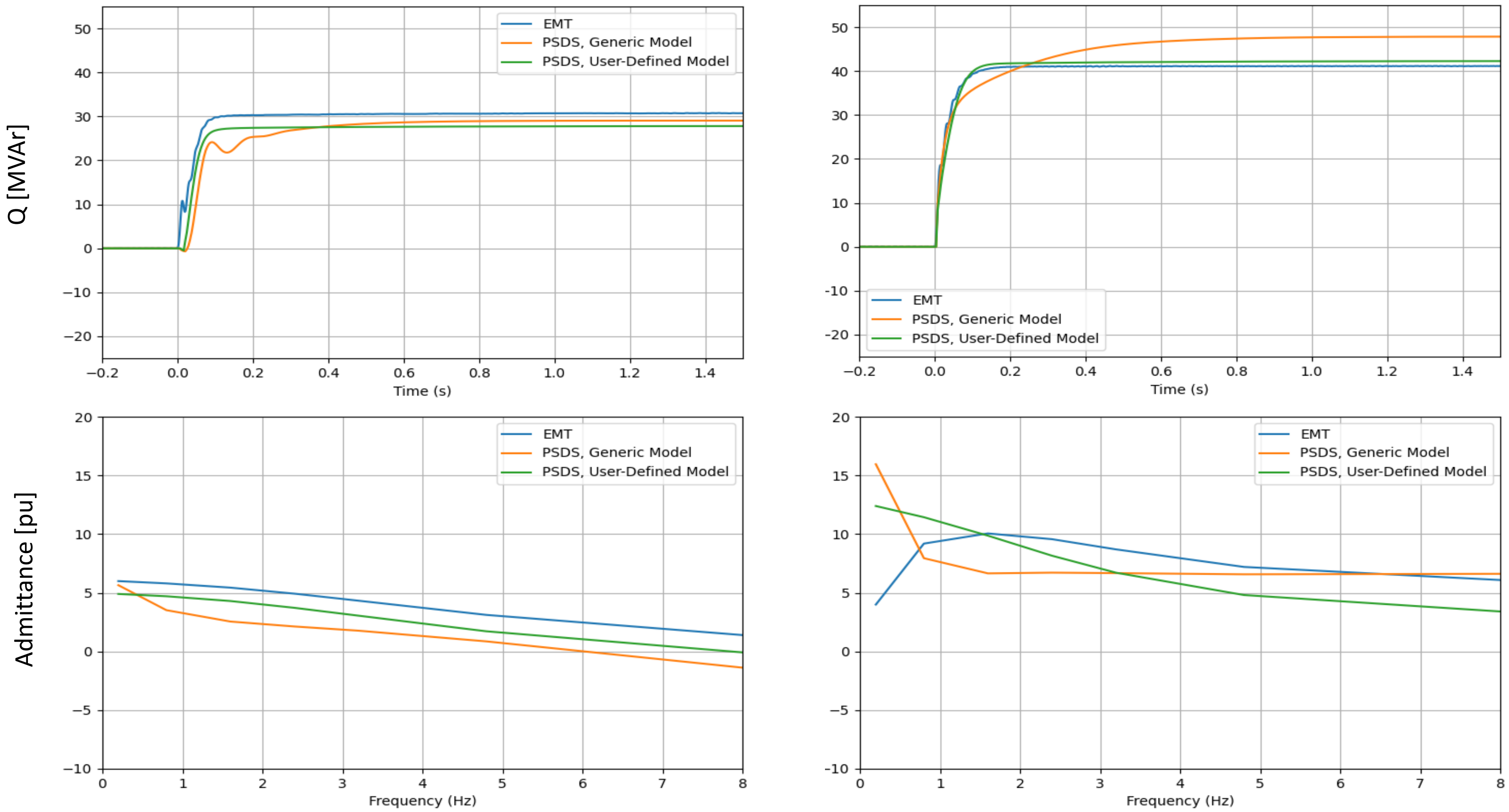
Resource Model Benchmarking

Traces Legend
EMT Model
PSDS, Generic
PSDS, UDM

GFL Inverter | **GFM Inverter**

Time-Domain

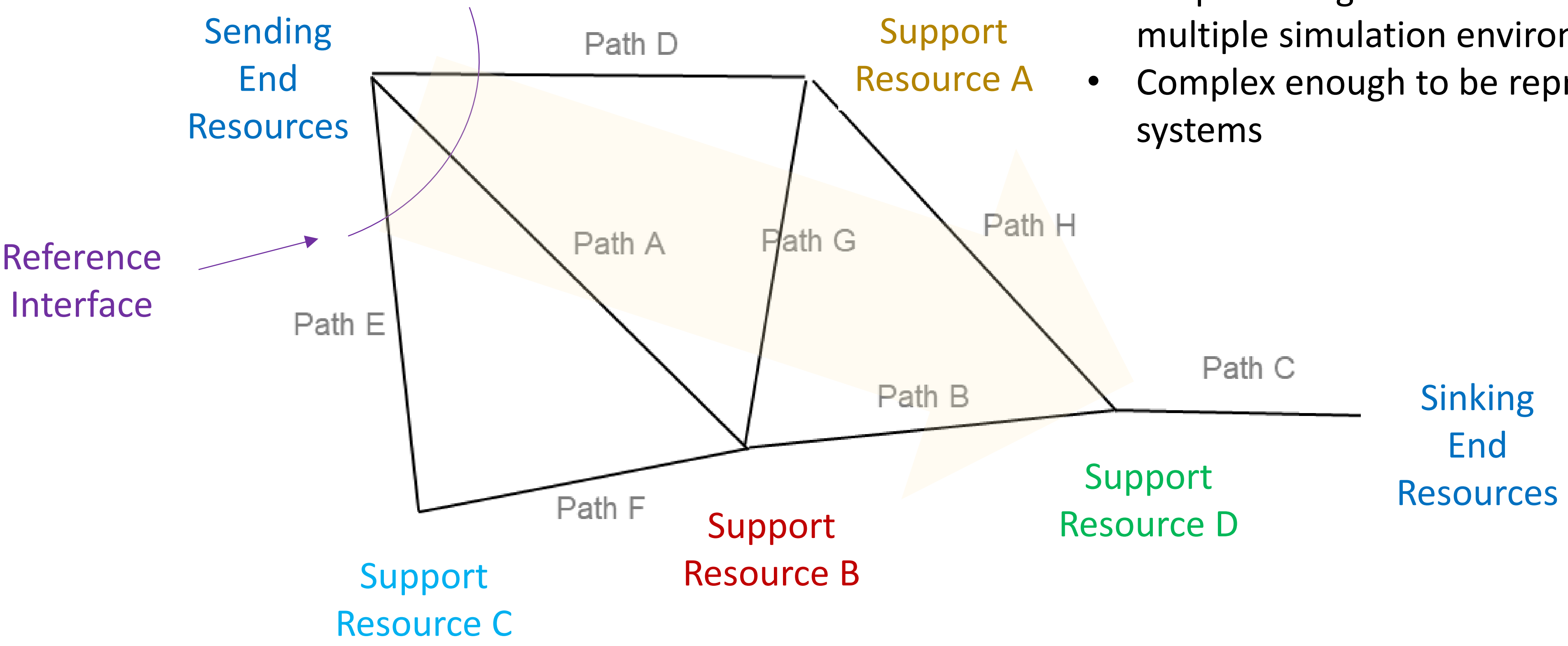
Frequency-Domain



1% grid voltage step at POI

Frequency in dq0 reference frame

A Simplified System for Testing



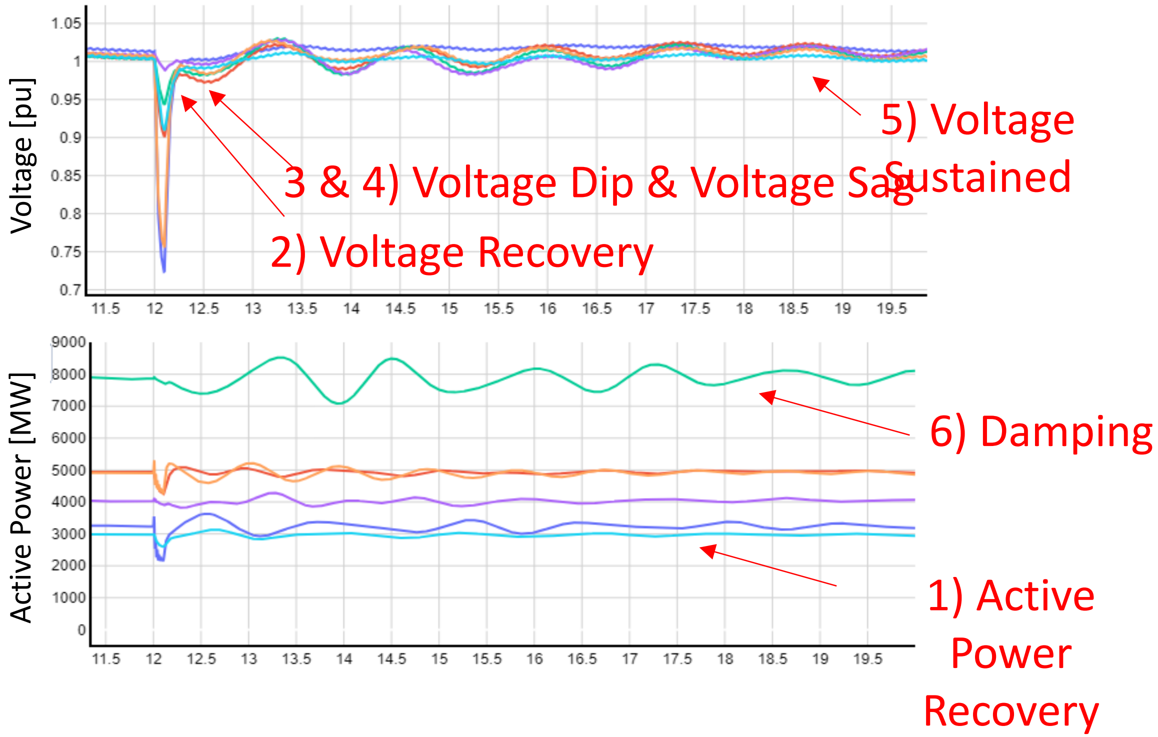
- High-Voltage, Networked Transmission System
- Simple enough to be manageable for testing in multiple simulation environments
- Complex enough to be representative of large systems

Stability Criteria Time-Domain Simulations

- For each simulation, measure stability criteria
- Interpolate between the 70%, 90%, 105%, and 130% runs to estimate the maximum stable power transfer level

<u>Stability Criteria:</u>

1. **Power Recovery** – Active power > 80% of its pre-disturbance value
2. **Voltage Recovery** –Voltage > 70% at 6 cycles following the disturbance
3. **Voltage Dip** – Voltage dip on the first transient swing > 70%
4. **Voltage Sag** – Voltage must not be below 80% for > 0.6 sec
5. **Voltage Sustained** – Voltage > 90% 6-8 seconds after event
6. **Damping Ratio** – Damping ratio > 0.4 for all buses?



Comparisons – In Practice

For each combination of resource mix & disturbance:

- Find the transfer limit using the Dynamic Impedance Method
- Run four simulations in each platform (70%, 90%, 105%, and 130% of DZM transfer limit)

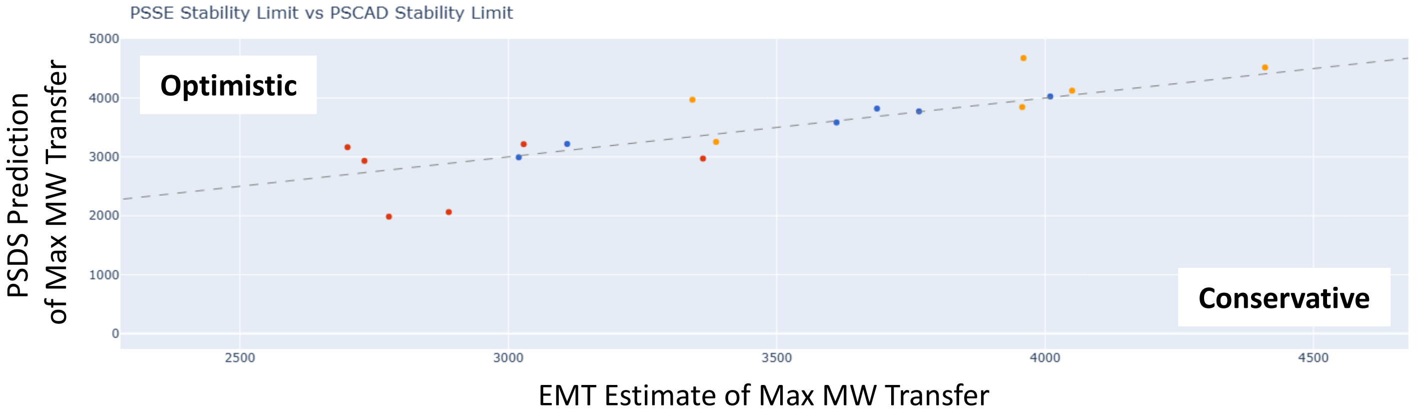
Sending	SM	GFL	GFM	GFL	GFM	GFL	GFM	GFL	GFM	GFL	GFL2	GFM2	GFM	GFL2
Grid Support	SM	SM	SM	GFM	GFM	GFL	GFL	GFM	GFM	GFL	GFM2	GFM2	GFL2	SM
Disturbances	**mix0**	**mix1**	**mix2**	**mix3**	**mix4**	**mix5**	**mix6**	**mix7**	**mix8**	**mix9**	**mix10**	**mix11**	**mix12**	**mix13**
pathD_1ckt_LineSw														
pathD_1ckt_FltClr														
pathD_2ckt_LineSw														
pathD_2ckt_FltClr														
pathA_1ckt_LineSw														
pathA_1ckt_FltClr														
pathA_2ckt_LineSw														
pathA_2ckt_FltClr														
pathB_1ckt_LineSw														
pathB_1ckt_FltClr														
pathB_2ckt_LineSw														
pathB_2ckt_FltClr														

(14 resources mixes) x (12 disturbances) x (4 MW transfer levels) = **672 simulations per platform (EMT and PSDS)**

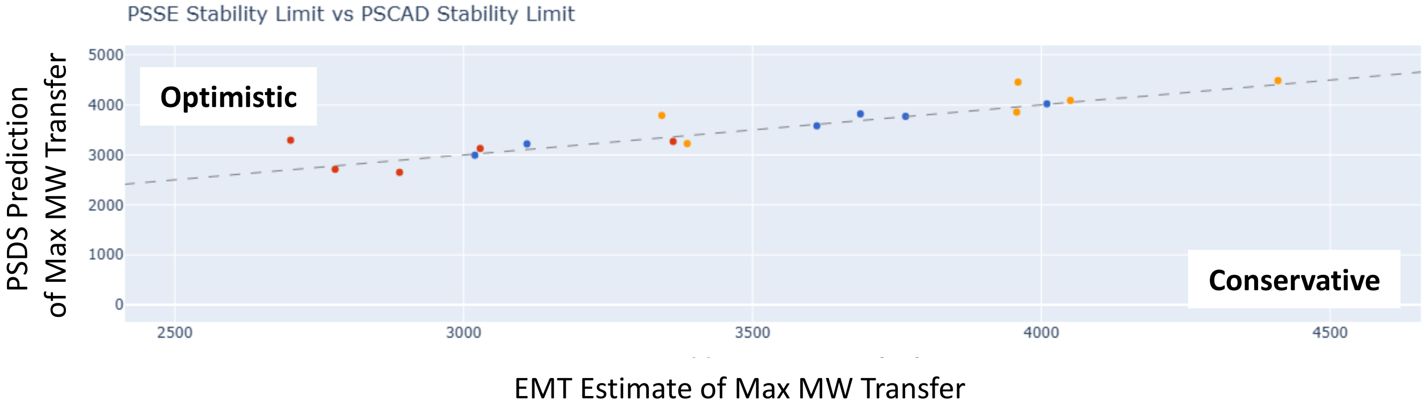
Stability Limit Comparisons, PSDS - EMT

- Focusing only on the fault & clear disturbances (most limiting events)
- SM-dominant cases match very well
- GFM-dominant cases match well
- GFL-dominant cases have the most error, but correspond reasonably well

PSDS, Generic Models



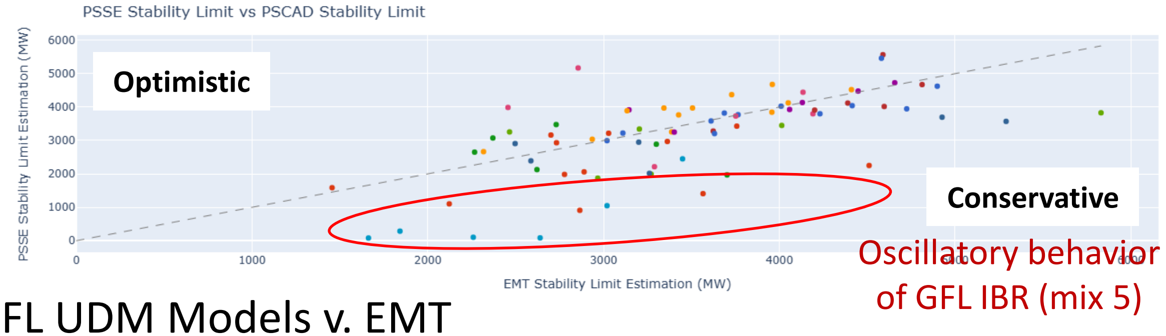
PSDS, IBR UDM Models



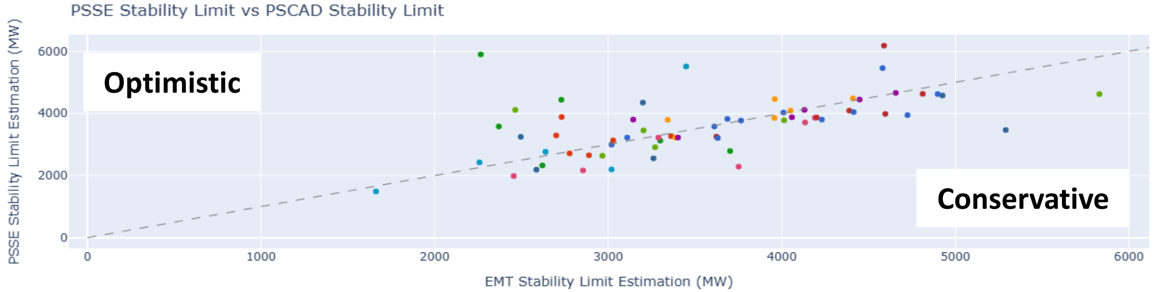
Stability Limit Comparisons to EMT

- Fault & Clear disturbances only
- Colors coded by resource mix
- Outliers from PSDS are GFL-dominant resource mixes
- Oscillatory behavior in PSDS exhibited for cases that are stable in EMT
- This is observed with both generic PSDS and user-defined PSDS models

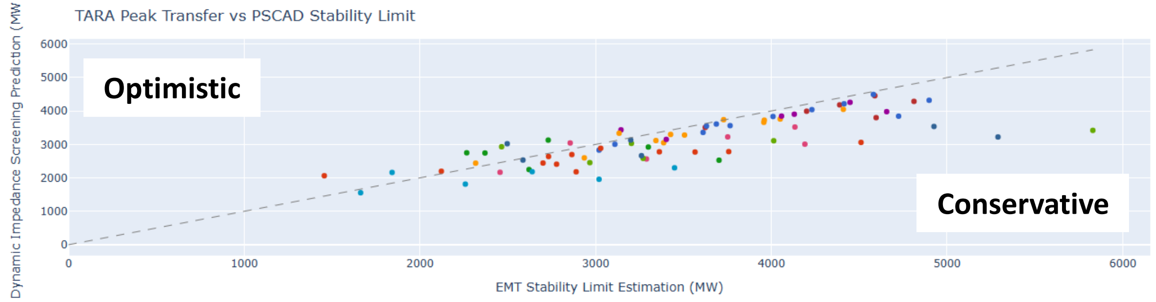
PSDS Generic Models v. EMT



GFL UDM Models v. EMT

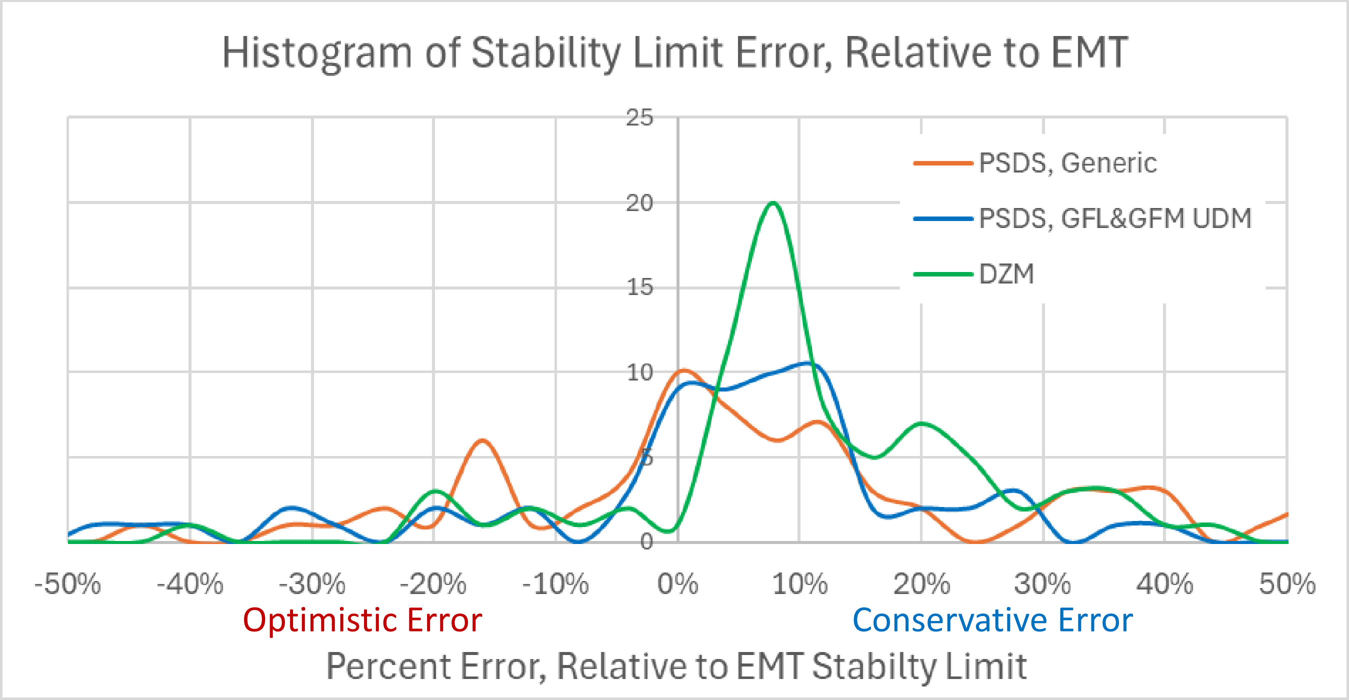


Dynamic Impedance Method v. EMT



Key Findings

- Stability limits from EMT and PSDS compare well for most disturbances (slight conservative bias)
- SM and GFM models compare particularly well, GFL models show more spread



The Dynamic Impedance Method (DZM) Estimates Stability Limits Well, while being Simpler & Faster

Conclusions

Big Picture

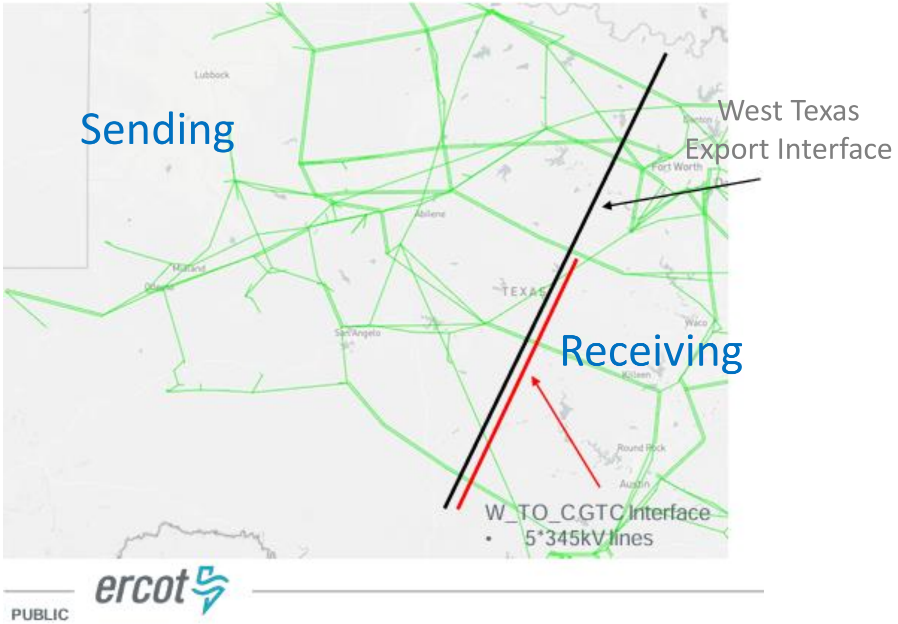
Applying the DZM

Setting it up

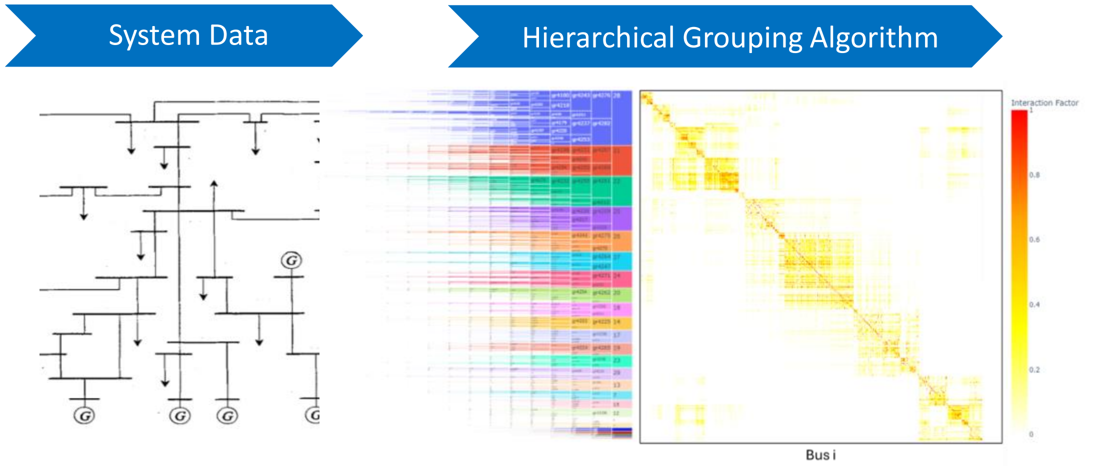
- Evaluating transfer limits requires defining sending & receiving subsystems
- Major interfaces / cut-planes are already defined, but…

…these will evolve with the grid (changes in transmission & resources)

A hierarchical clustering method can be used to systematically identify new interfaces (see our [ESIG Stability Services work](#))



West Texas Export GTC, Transmission Operations Planning ROS Meeting, 10/08/2020



Why Simulate?

System Level, at Scale

Scenarios
- Resource mixes
  - Where
  - What
  - When
  - Weather
- Transmission investments

Contingency List
- Generation
- Transmission

Screening → Focus →

A subset of cases can be examined with more detailed tools

What's it worth?
Limits provide boundary conditions for 8760 cost tools

Detailed IBR Models (EMT)
- GFL
- GFM
- SVC, HVDC
- IBR loads

DZM Analytical Methodology

TELOS ENERGY
HickoryLedge

To Make Better Decisions!

THIS: 

NOT: 

Conclusions

- Many of today's analysis practices are hitting limits (or soon will)
  - The range of planning and operating scenarios is getting bigger
  - Transmission stability analysis is getting more complex
- Screening methods are increasingly important
  - Not all screening methods are the same – some have major limitations
- DZM addresses key limitations of SCR methods
  - Differentiate by resource technologies
  - Handles large systems with mixed resources
  - Applications in planning horizon and operating horizon

Apply effort where it is needed most – make better decisions faster!

Thank You! Questions?

Matt Richwine, Andrew Siler, Eva Mailhot

Matthew.Richwine@telos.energy

TELOS ENERGY

Nick Miller

Nicholas.Miller@hickoryledge.com

HickoryLedge

Casey Baker, Ric O'Connell

casey@gridlab.org

GridLAB