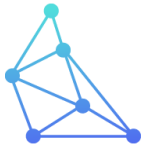
Stability Screening Methods

Comparing EMT, Phasor Domain, and the Dynamic Impedance Method

Matthew Richwine Nicholas Miller

ESIG Spring Technical Workshop, March 2025

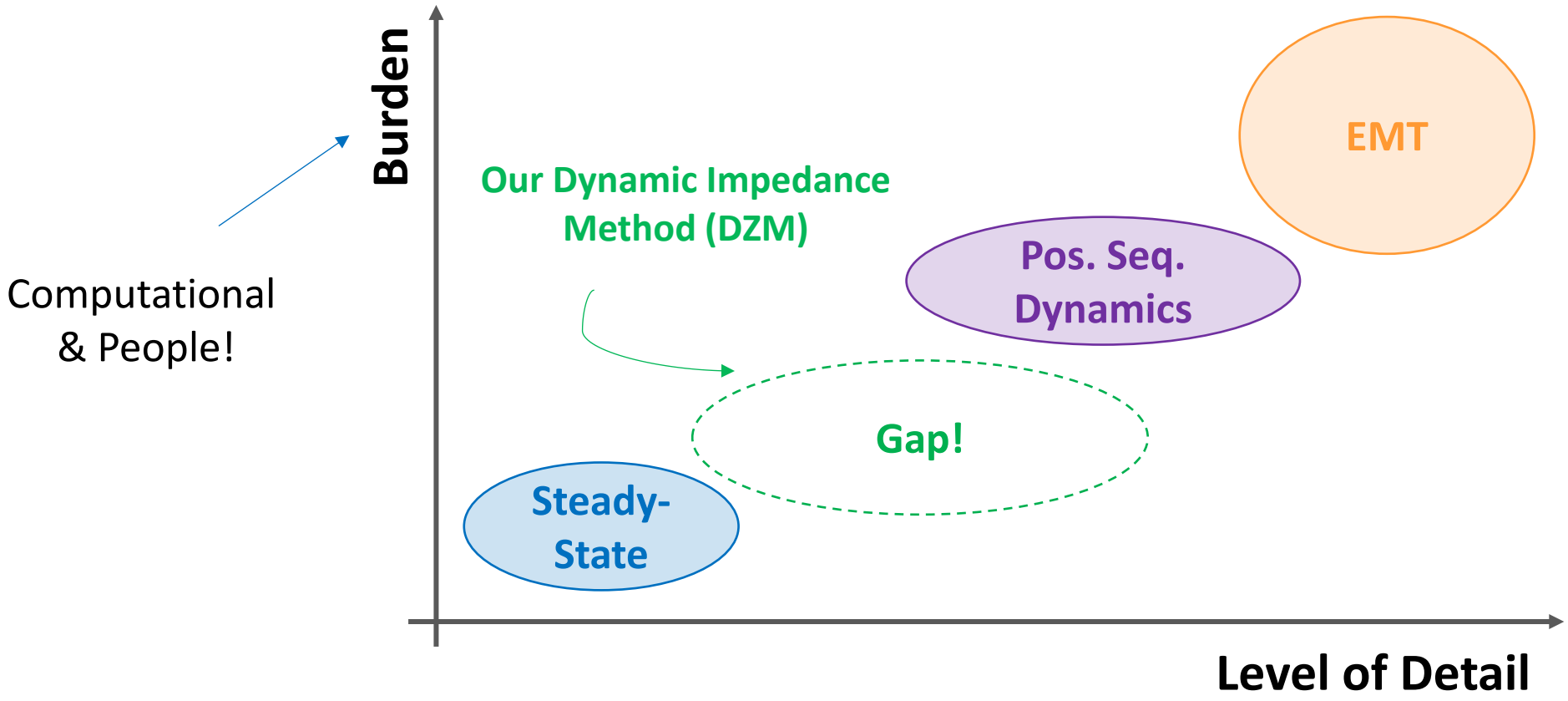
GridLAB



TELOS ENERGY

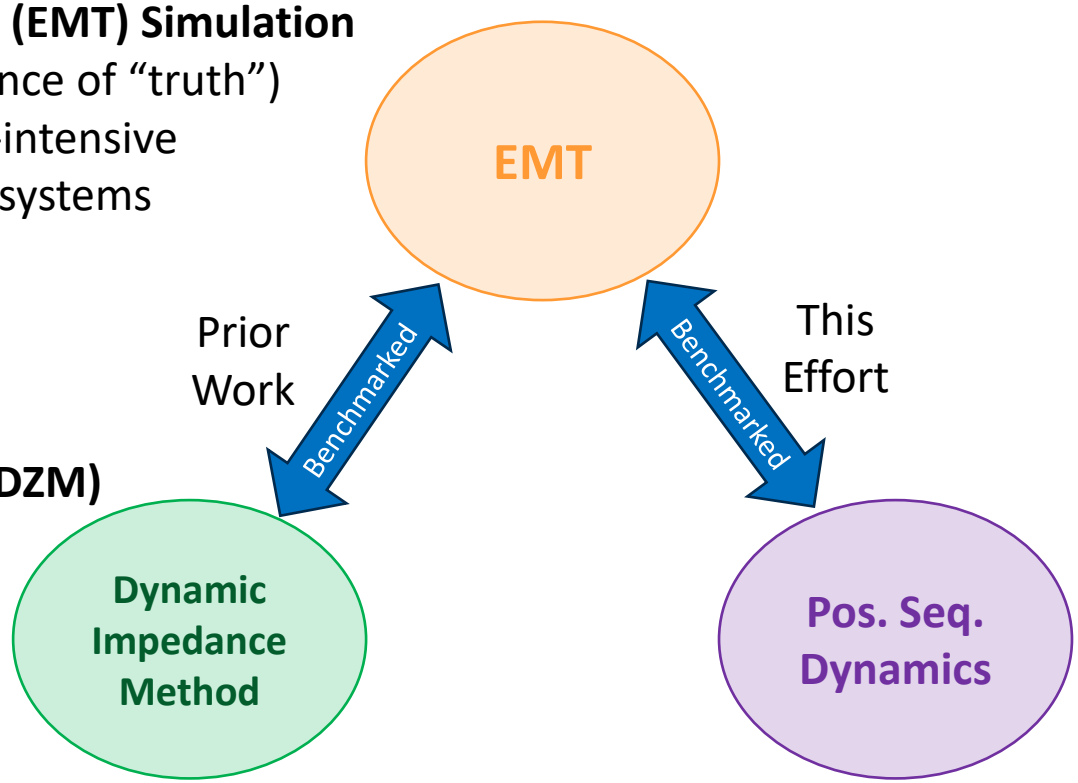
HickoryLedge

The Big Picture of Stability Studies



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

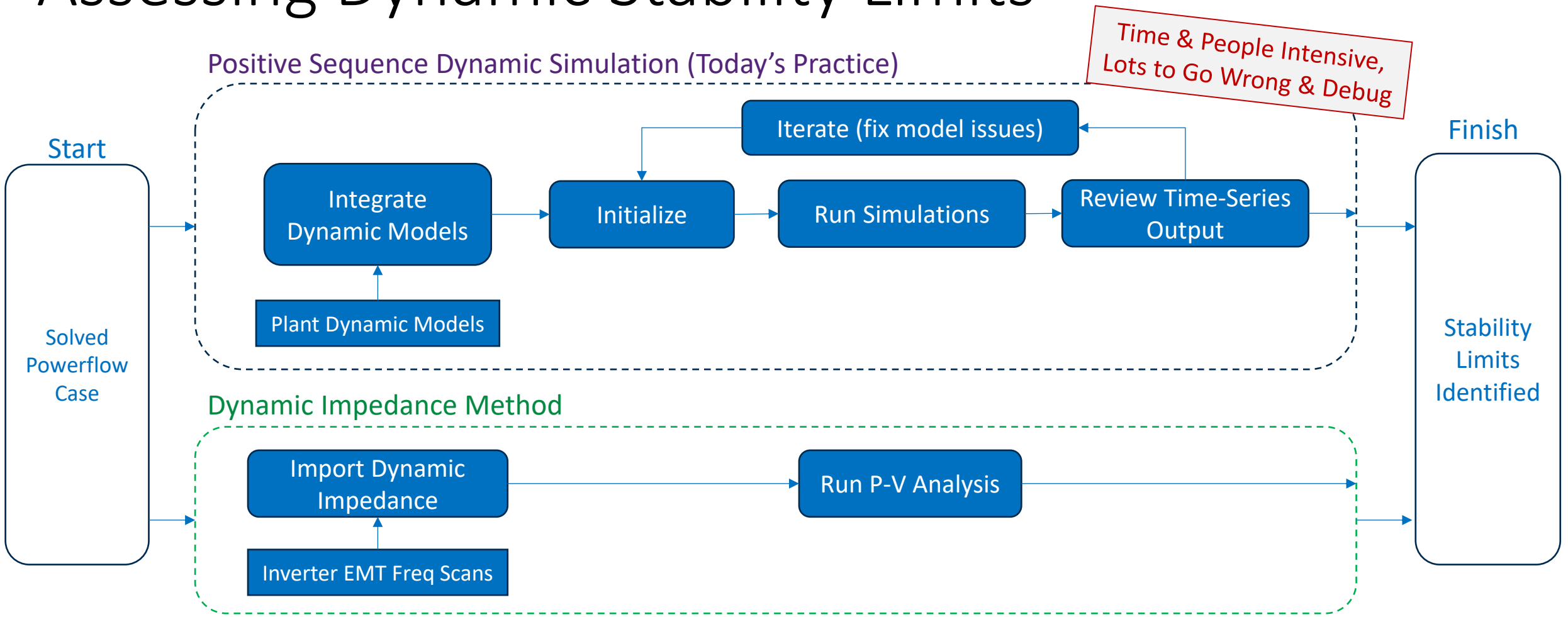


Dynamic Impedance Method (DZM)
- Greatly simplified dynamics
- Utilizes steady-state (P-V) analysis + some EMT
- Fastest – scales up well

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

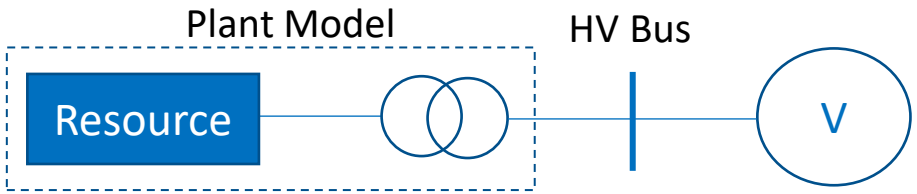
Assessing Dynamic Stability Limits



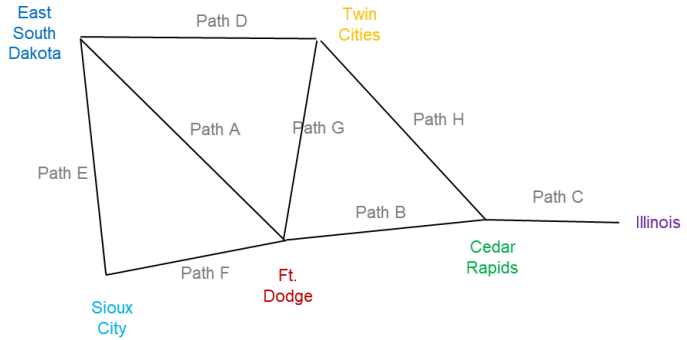
Comparing Approaches: EMT & PSDS

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

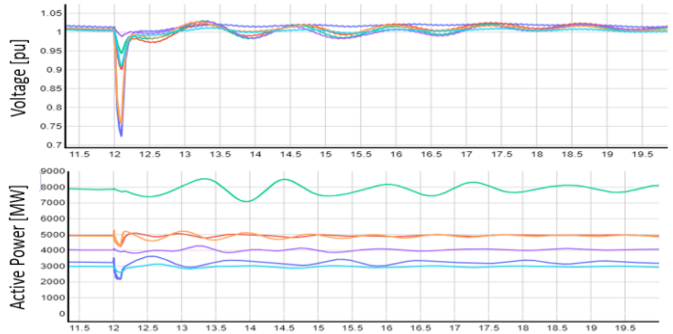
2 **Plant Model Benchmarking**
To ensure agreement of EMT and PSDS Models



3 **Simulations on a Representative Transmission System**



4 **Evaluate Stability Limits**
Using identical criteria



Resource Model Benchmarking

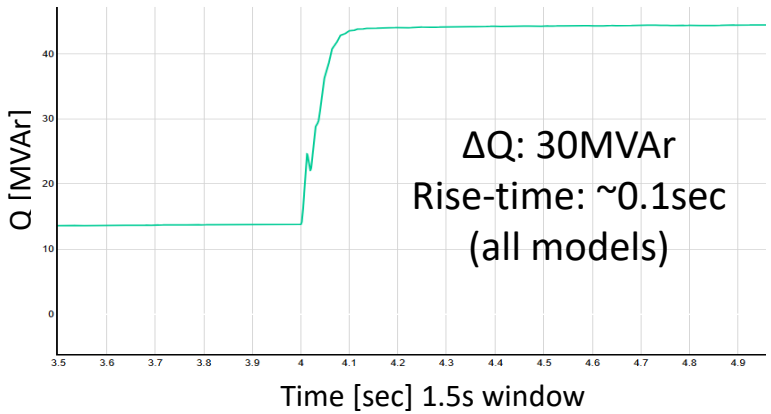
- Example shown for a GFL Resource for Volt/VAr response; 1% voltage step applied.
- Benchmarking performed for all models, including for Power/angle response.

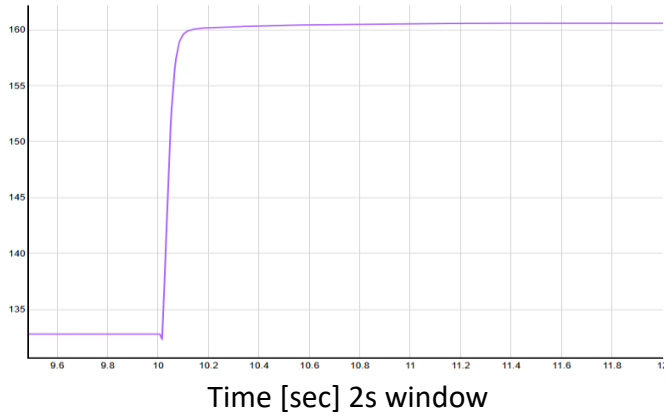
EMT Model

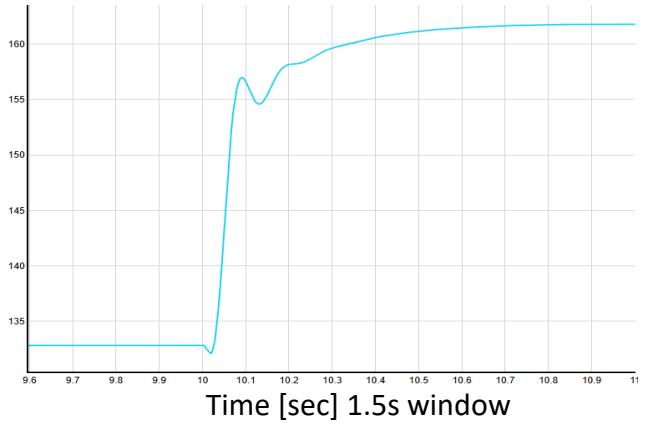
PSDS, User-Defined Model

PSDS, Generic Model

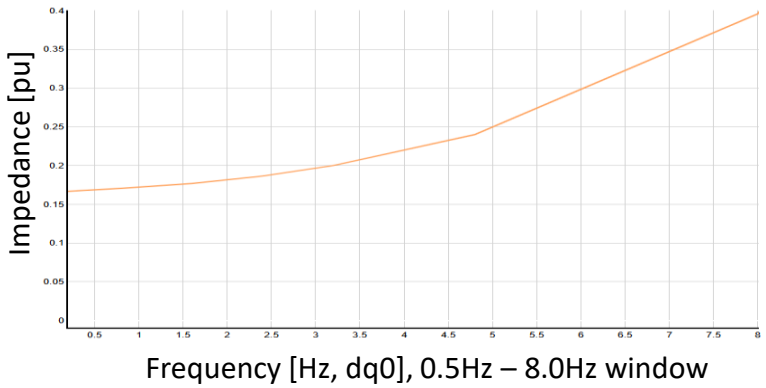
Time-Domain

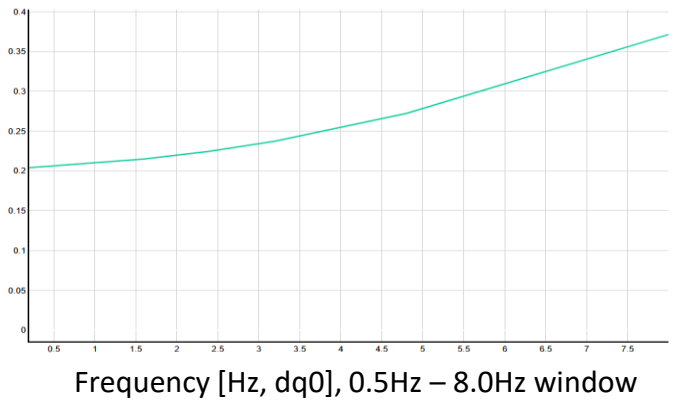


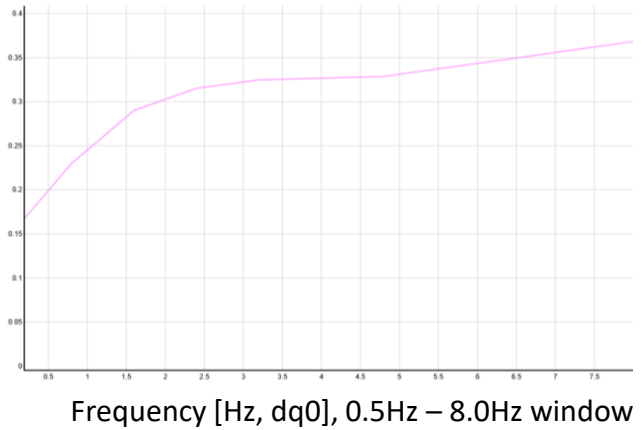




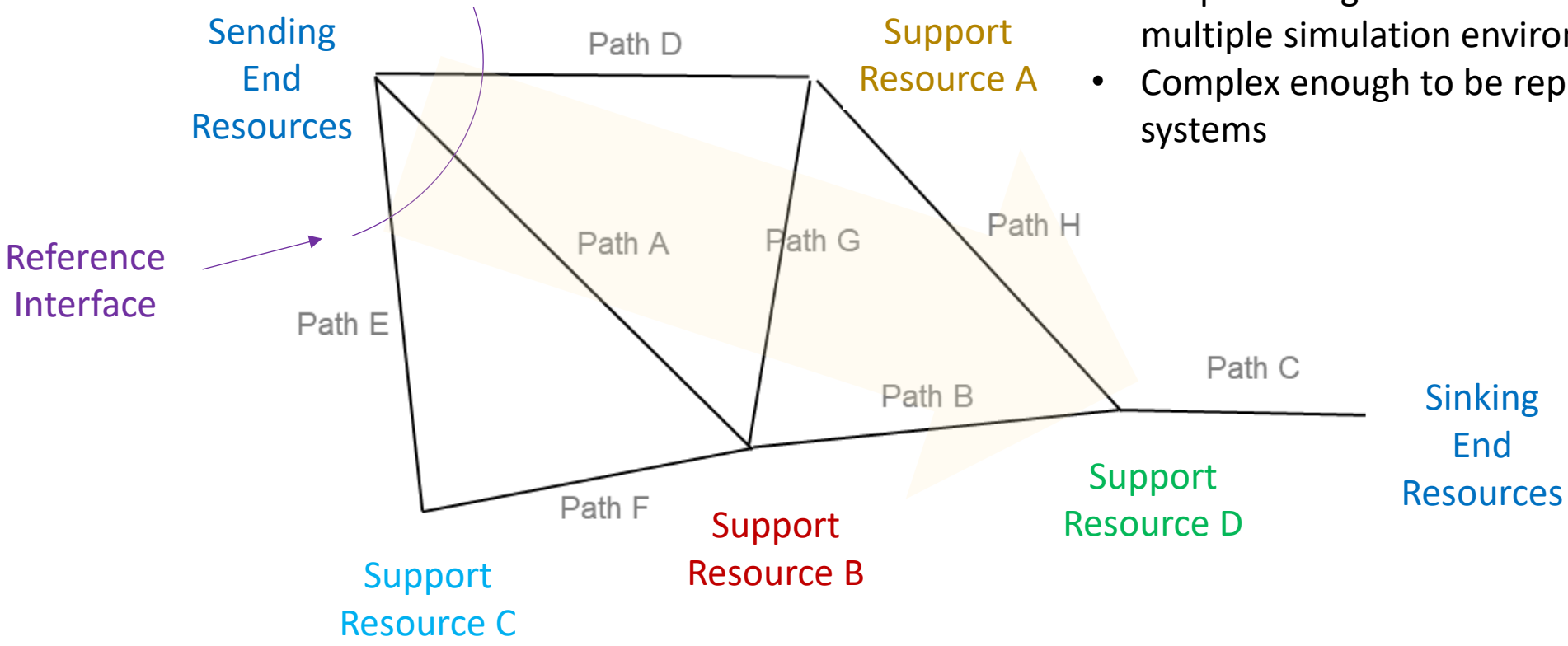
Frequency-Domain







A Simplified System for Testing



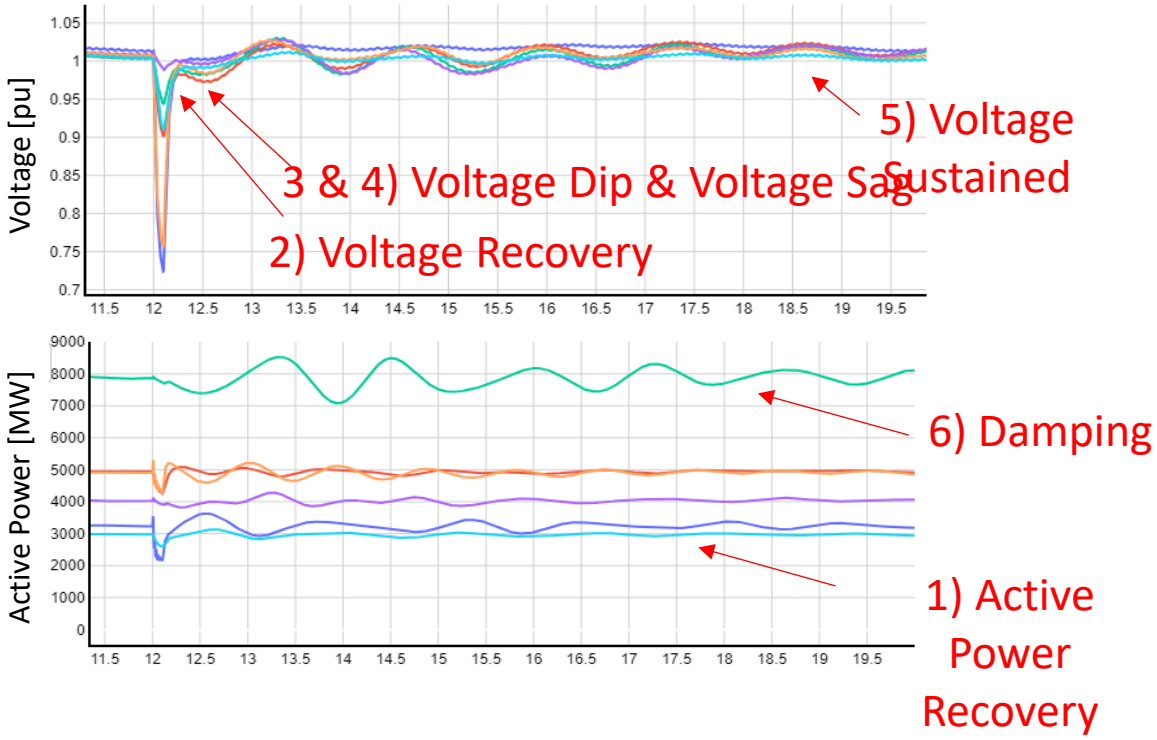
- High-Voltage, Networked Transmission System
- Simple enough to be manageable for testing in multiple simulation environments
- Complex enough to be representative of large systems

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

Stability Criteria:

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)

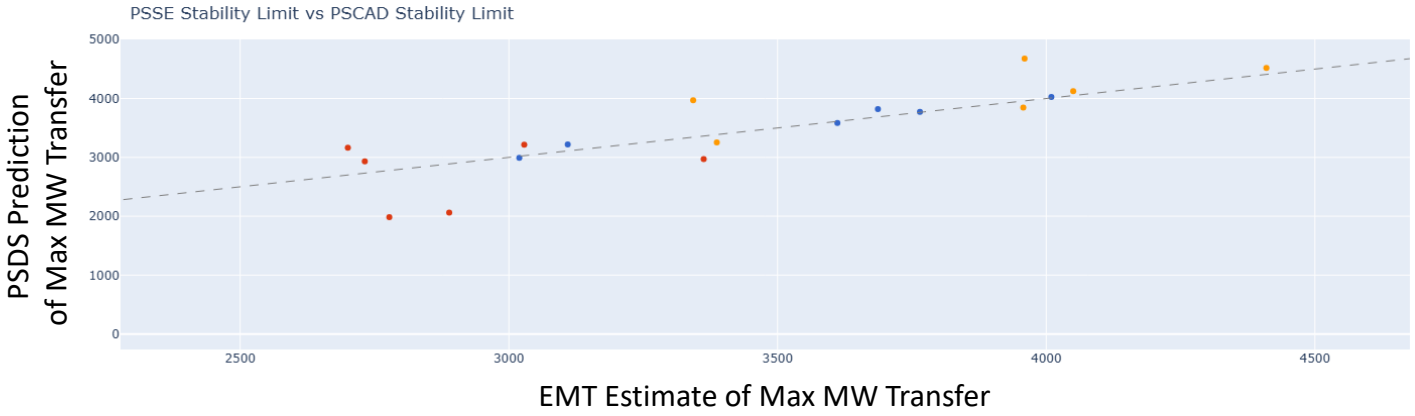
Sending	SM	GFL	GFM	GFL	GFM	GFL	GFM	GFL	GFM	GFL	GFL2	GFM2	GFM	GFL2
Grid Support	SM	SM	SM	GFM	GFM	GFL	GFL	GFM	GFM	GFL	GFM2	GFM2	GFL2	SM
Disturbances	mix0	mix1	mix2	mix3	mix4	mix5	mix6	mix7	mix8	mix9	mix10	mix11	mix12	mix13
pathD_1ckt_LineSw														
pathD_1ckt_FltClr														
pathD_2ckt_LineSw														
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)**

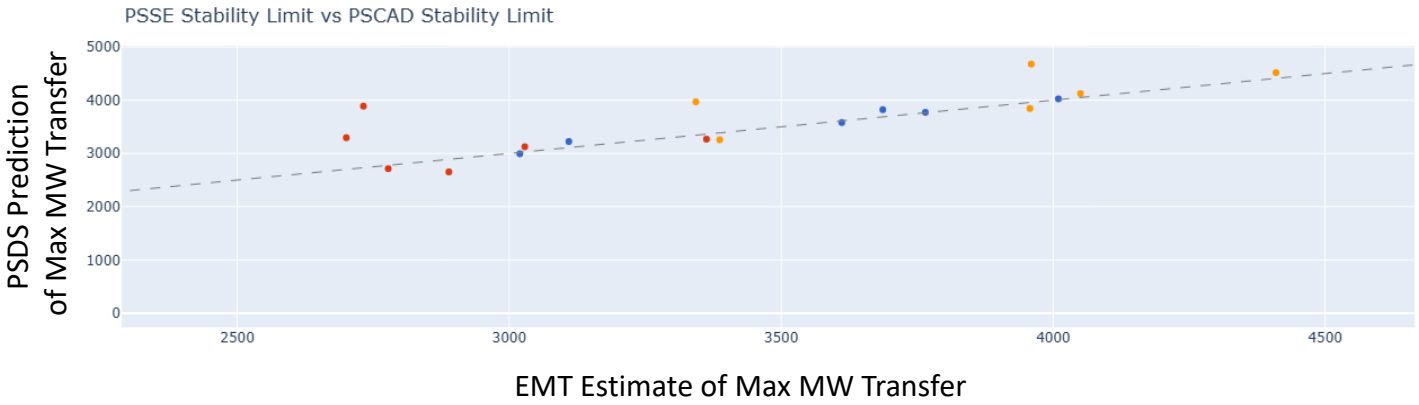
Stability Limit Comparisons, PSDS - EMT

- 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



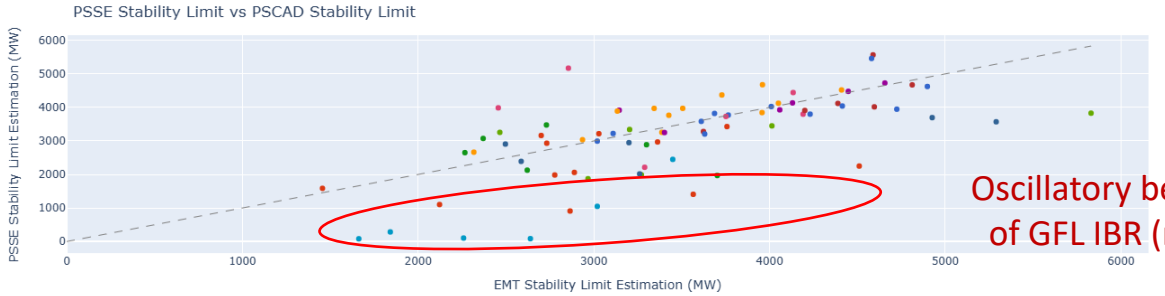
PSDS, GFL UDM Models



Stability Limit Comparisons to EMT

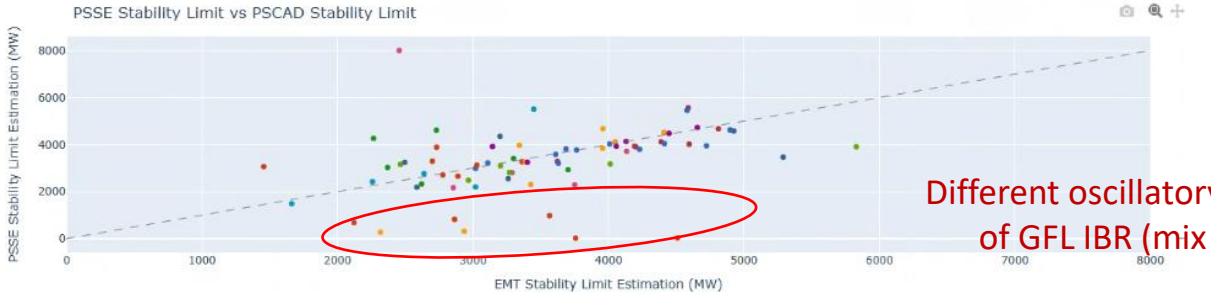
- Fault & Clear disturbances only
- Colors coded by resource mix
- Outliers from PSDS are GFL-dominant resource mixes
- Oscillatory behavior in PSDS exhibited for cases that are stable in EMT
- This is observed with both generic PSDS and user-defined PSDS models

PSDS Generic Models v. EMT



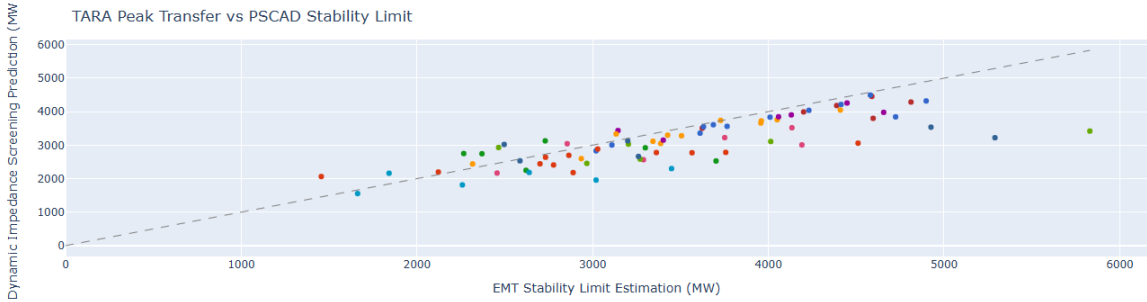
Oscillatory behavior of GFL IBR (mix 5)

GFL UDM Models v. EMT



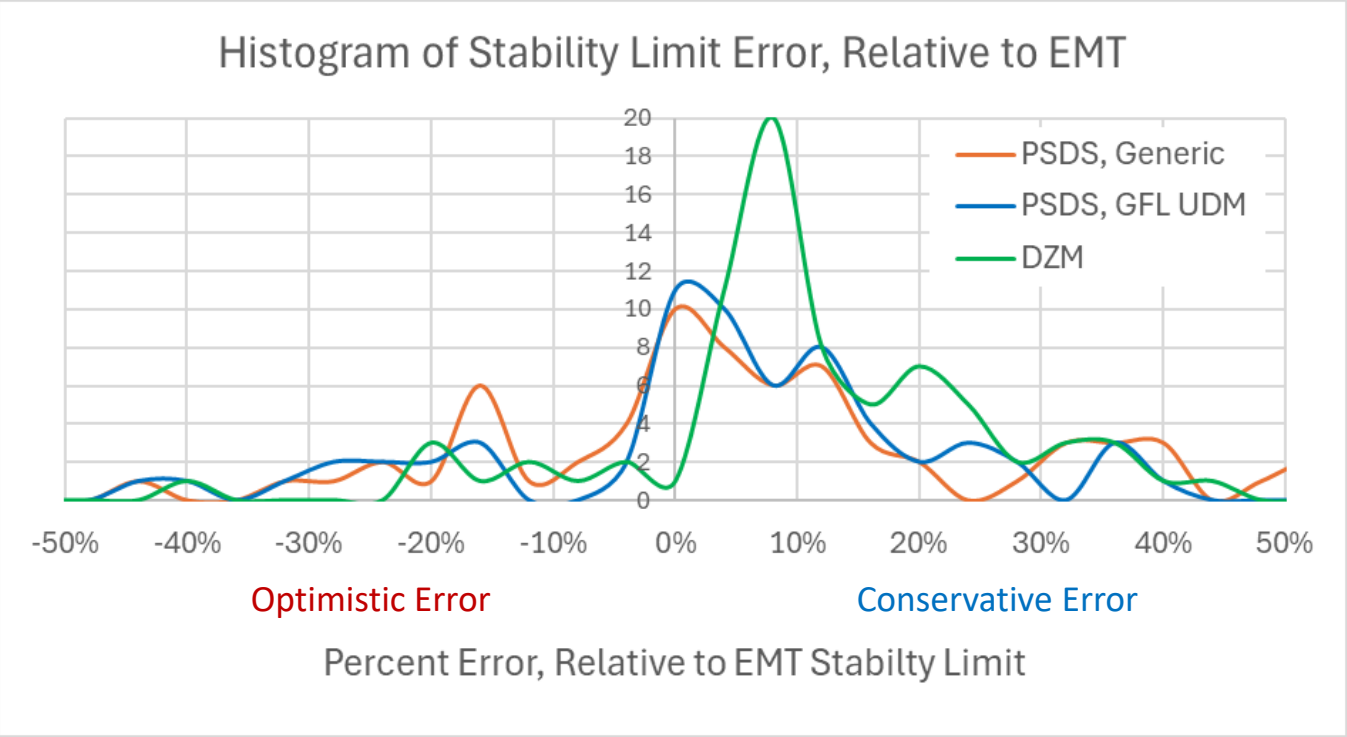
Different oscillatory behavior of GFL IBR (mix 13,14)

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

Why simulate?
Make better decisions!

THIS:

NOT:

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

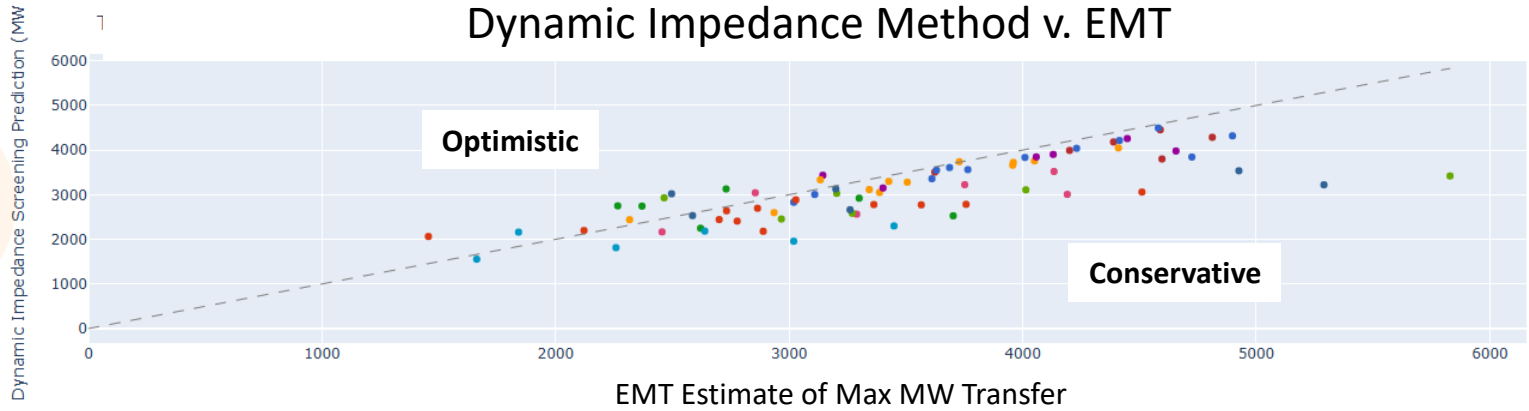
What's it worth? Limits provide boundary conditions for 8760 cost tools

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

DZM Analytical Methodology

TELOS ENERGY
HickoryLedge

Dynamic Impedance Method v. EMT



Fast method that will include representation of IBR Types → Enables evaluation of a **large set of scenarios with varied resource technologies**

Thank You! Questions?

More Details Planned at the ESIG/G-PST Webinar May 22, 2025!

Special thanks to the support provided by GridLAB!

GridLAB

Matt Richwine

Matthew.Richwine@telos.energy

TELOS ENERGY

Nick Miller

Nicholas.Miller@hickoryledge.com

HickoryLedge