



New Metrics and Tools to Evaluate Need for EMT Study

Rachel Bernhardt

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ELECTRANIX

SPECIALISTS IN POWER SYSTEM STUDIES

Acknowledgements

- This work was done in collaboration with individuals at MISO and Electranix

MISO

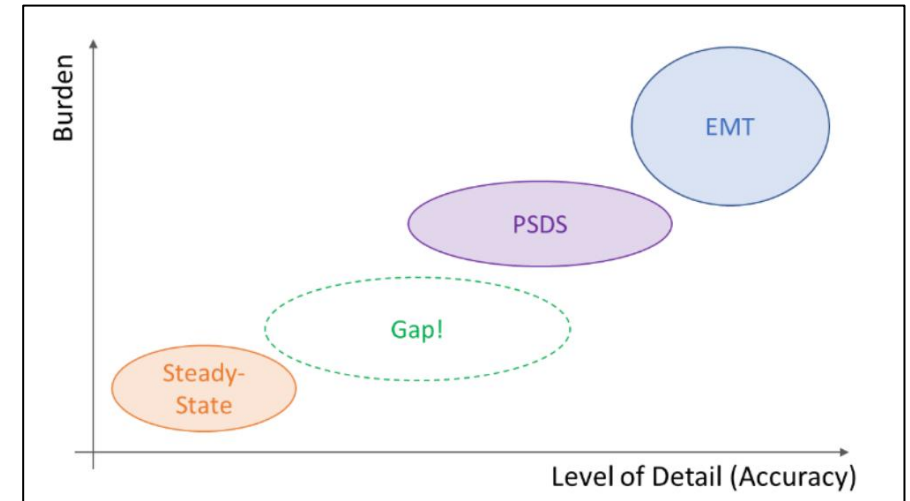
Weiqing Jiang
Tari Jung
Patrick Dalton

Electranix

Andrew Isaacs
Lukas Unruh
Kasun Samarawickrama
Noah Wu
Rachel Bernhardt

Background – Use of EMT

- Why are we doing EMT studies?
 - NERC recommends... and soon requires
 - IEEE recommends
 - Other people are doing it
 - It isn't going away!
- Most important:
 - EMT fills in gaps missed by other tools
 - It answers questions that other tools cannot answer
 - This is becoming incredibly important as our grids become more complex
- When using EMT we need to consider:
 - Necessary people power
 - Computational power
 - Time to set-up, run and analyze



Source: M. Richwine et al., Power System Stability Analysis & Planning Using Impedance-Based Methods, 2023

We should utilize screening metrics to help us determine whether an EMT study is necessary

Screening Metrics

- Short Circuit Ratio (SCR) and simple derivatives have historically been and continue to be used

$$\text{Short Circuit Ratio (SCR)} = \frac{\text{Short Circuit MVA (SCMVA)}}{\text{Rated Power (Prated)}}$$

- Most effective when considering a single IBR connecting to the grid
 - Does not take into account nearby IBRs
 - Simple derivative metrics like CSCR and WSCR have analogous limitations
- This metric starts to break down as our grids become more complex and GFL resources displace synchronous machines
 - Our hand wavy metric becomes even more hand wavy
- How can we build a more robust metric that accounts for system complexity?

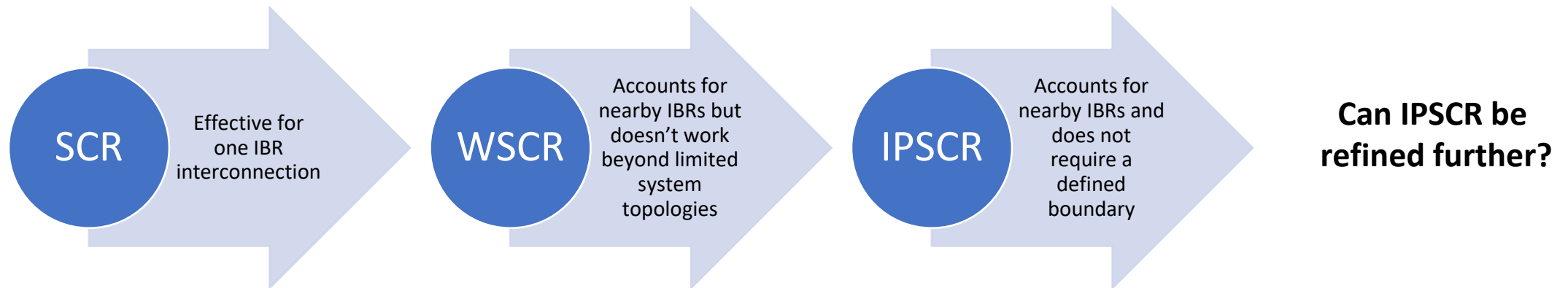
IPSCR & Metric Evolution

- Inverter Penetration SCR (IPSCR) [1]

$$IPSCR = \frac{SCMVA_{Case\ B}}{SCMVA_{Case\ C}}$$

IBR penetration ↑
IPSCR ↓

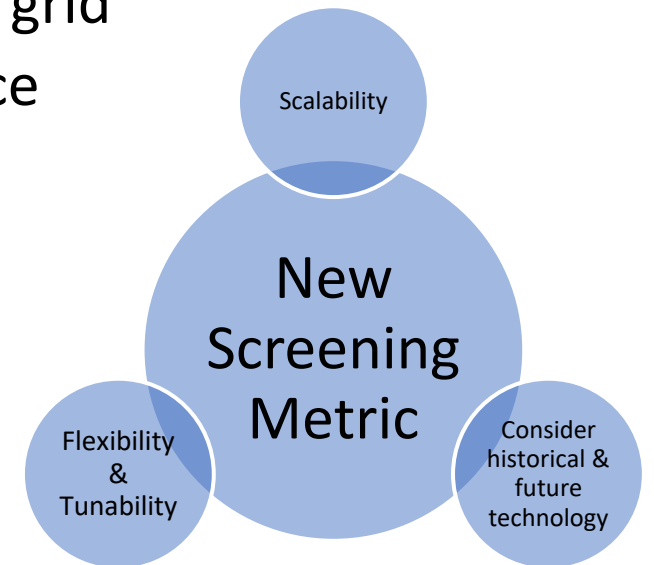
- Evaluates how much system strength comes from IBRs
 - Case B = with all IBRs turned off
 - Case C = with all conventional generation turned off and IBR Xsource tuned until it contributes 1 p.u. SCMVA



[1] L. Unruh and A. Isaacs (2021), 'Description of Inverter Penetration (IPSCR) Metric for Quantifying System Strength in Large Networks'

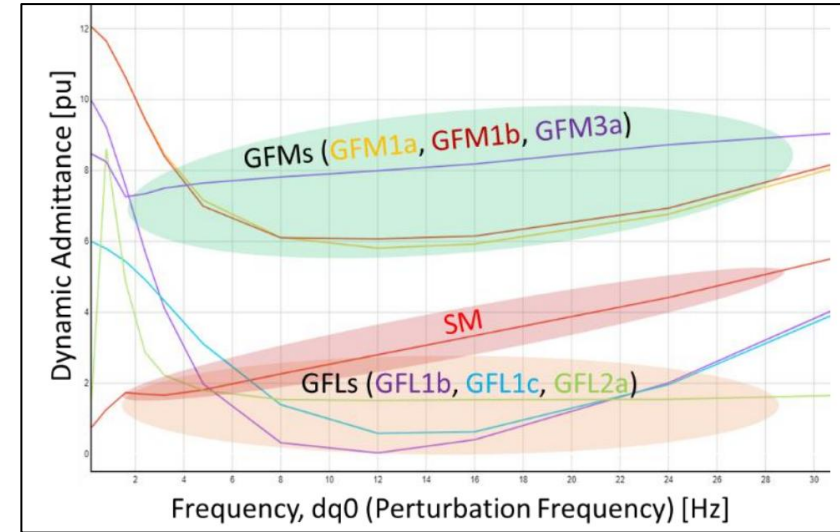
Combining Trends

- We know that:
 - SCR metrics are easy to use and scalable
 - IPSCR accounts for the presence of nearby IBRs throughout a grid
 - GFM provides benefits and can be quantified using impedance
 - Commonly used metrics lack the ability to differentiate between technologies
- **Development of a new screening metric was done collaboratively between Electranix and MISO, building on existing work**



Generation Resource Characterization

- Industry has been exploring how to characterize GFM technology using impedance scans
- Entities are suggesting or requiring impedance scans for GFM technology
- Provides insight on how technology will behave
- GFM technology routinely shows very good stability enhancing behaviour when compared to GFL
- How do we tie resource characterization into our metric? We make it impedance based...



Source: M. Richwine et al., Power System Stability Analysis & Planning Using Impedance-Based Methods, 2023

A Reminder: SCRIF

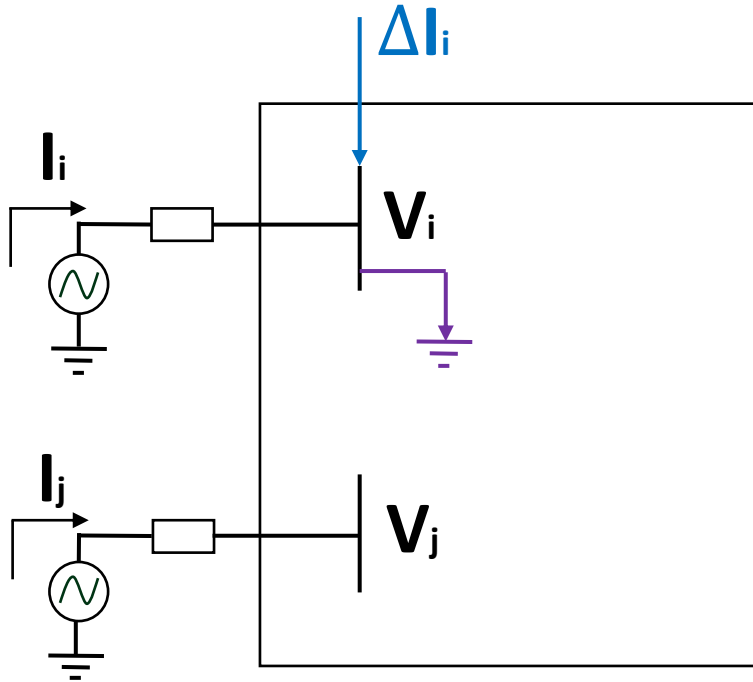
- SCR with Interaction Factors (SCRIF), or Equivalent SCR (ESCR) [1]

$$SCRIF_i = \frac{S_i}{P_{WFi} + \sum_j (WPIF_{ji} * P_j)} \quad WPIF_{ji} = \frac{\Delta V_j}{\Delta V_i}$$

- Inject a reactive current at the project POI bus and obtain the resultant voltage change in all POI buses considered (including project POI bus), then calculate $WPIF_{ji}$
- Benefits:
 - Allows for consideration of other plants for evaluation of system strength for a single interconnection
- Drawbacks:
 - Does not provide a common metric for a group of resources
 - Requires more substantial calculation
 - Does not distinguish between resource types

[1] Cigre WG B4.62 (2016), 'Connection of wind farms to weak AC networks'

Modifying SCRIF



$$\begin{bmatrix} \Delta V_i \\ \Delta V_j \end{bmatrix} = \begin{bmatrix} Z_{ii} & Z_{ij} \\ Z_{ji} & Z_{jj} \end{bmatrix} \begin{bmatrix} \Delta I_i \\ \Delta I_j \end{bmatrix}$$

Calculate interaction factor:

$$\begin{bmatrix} \Delta V_i \\ \Delta V_j \end{bmatrix} = \begin{bmatrix} Z_{ii} & Z_{ij} \\ Z_{ji} & Z_{jj} \end{bmatrix} \begin{bmatrix} \Delta I_i \\ 0 \end{bmatrix}$$

$$\Delta V_i = Z_{ii} \Delta I_i$$

$$\Delta V_j = Z_{ji} \Delta I_i$$

$$\frac{\Delta V_j}{\Delta V_i} = \frac{Z_{ji}}{Z_{ii}}$$

Calculate SCMVA:

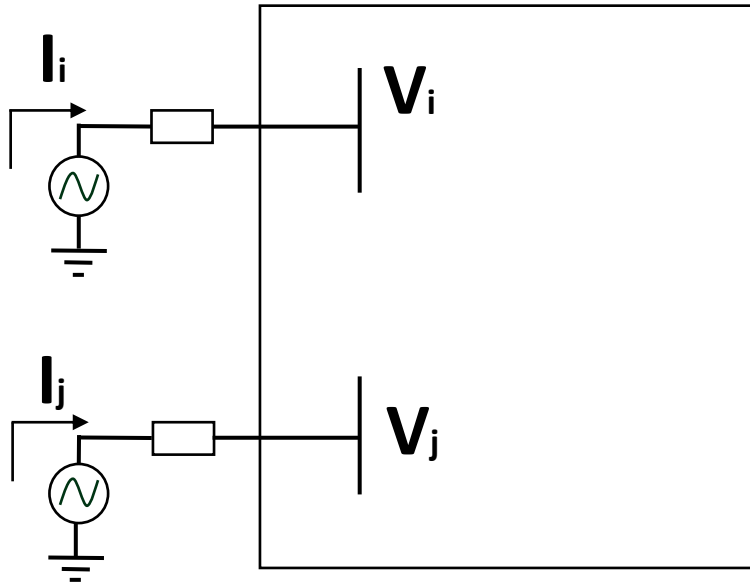
$$\begin{bmatrix} \Delta V_i \\ \Delta V_j \end{bmatrix} = \begin{bmatrix} Z_{ii} & Z_{ij} \\ Z_{ji} & Z_{jj} \end{bmatrix} \begin{bmatrix} I_{sc i} \\ 0 \end{bmatrix}$$

$$\Delta V_i = Z_{ii} I_{sc i} \longrightarrow I_{sc i} = \frac{\Delta V_i}{Z_{ii}} \longrightarrow$$

$$SCMVA_i = \frac{\Delta V_i^2}{Z_{ii}}$$

Modifying SCRIF

Developing Impedance-Based SCR Metric:



$$SCRIF = \frac{SCMVA_i}{P_i + \sum_{j=1, j \neq i}^n (P_j * IF_{ji})}$$

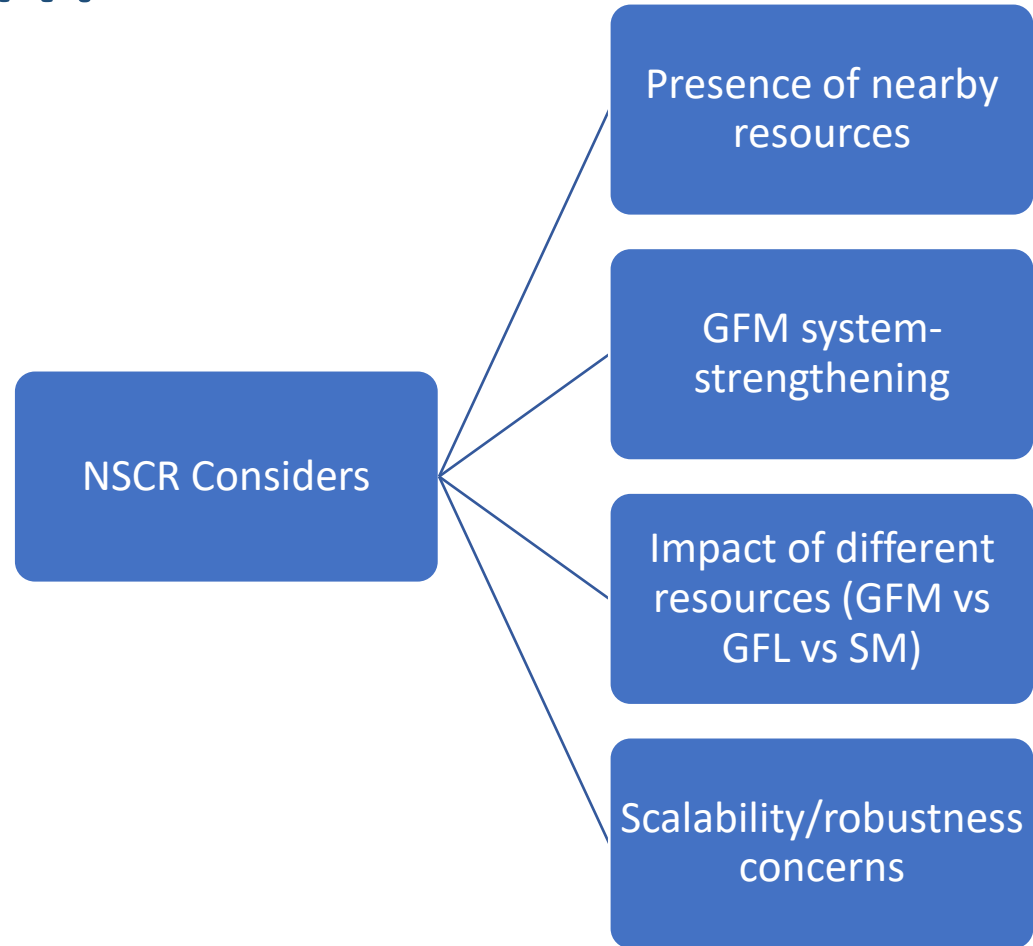
$$IF_{ji} = \frac{\Delta V_j}{\Delta V_i} = \frac{Z_{ji}}{Z_{ii}}$$

$$SCMVA_i = \frac{\Delta V_i^2}{Z_{ii}}$$

$$SCRIF = \frac{\frac{\Delta V_i^2}{Z_{ii}}}{\sum_{j=1}^n \left(P_j * \frac{Z_{ji}}{Z_{ii}} \right)}$$

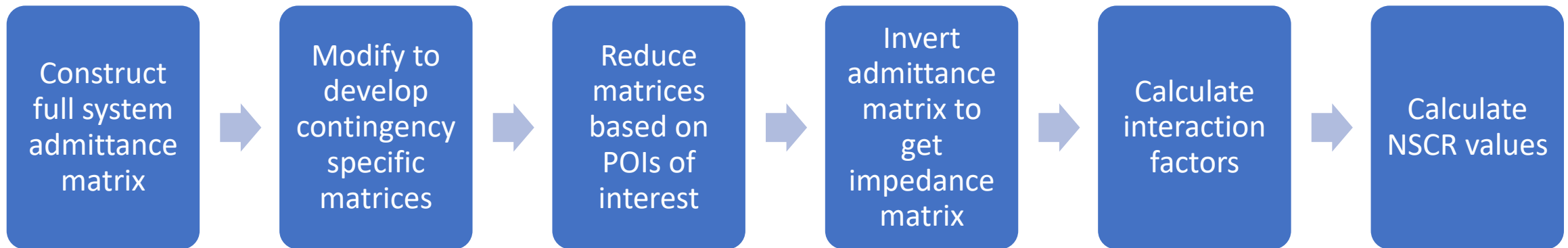
$$NSCR = \frac{\Delta V_i^2}{\sum_{j=1}^n (P_j * Z_{ji})}$$

Why NSCR?

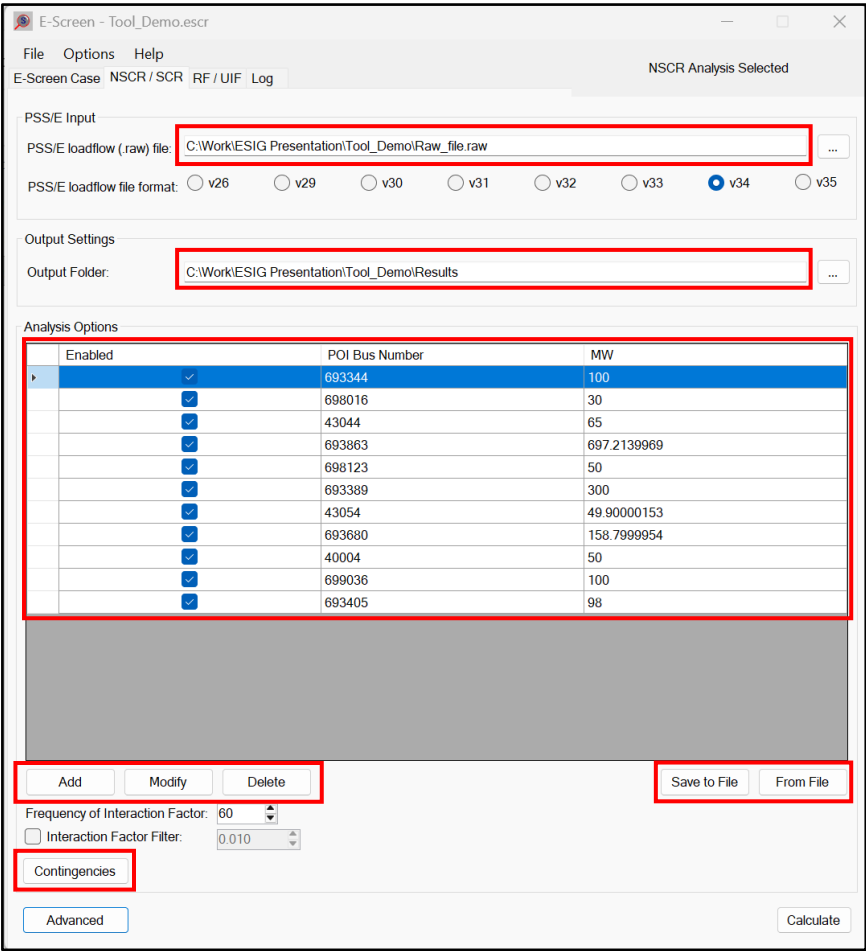


Expanding to entire system

- The NSCR calculation can readily be expanded to large systems



Building a Tool: E-Screen



Raw file with correct Zsource

Folder to output results to

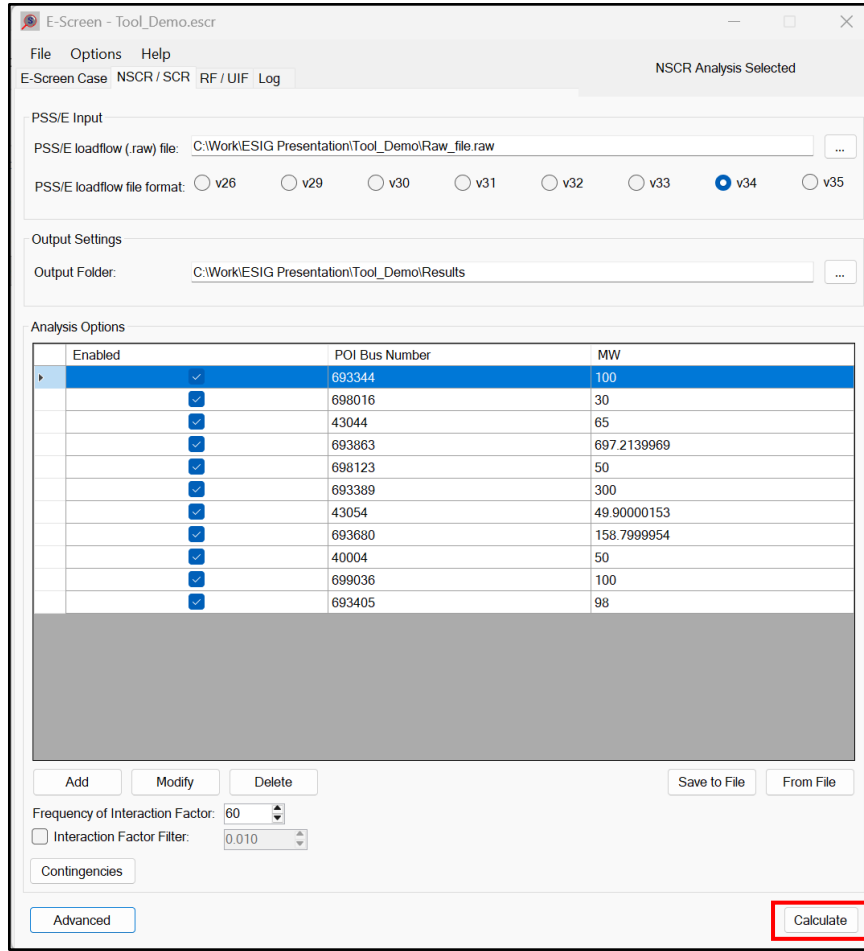
POI buses of interest and corresponding MW injections

Easily load in buses from file

Manual option to change buses

Add contingencies for which NSCR values are calculated

Building a Tool: E-Screen



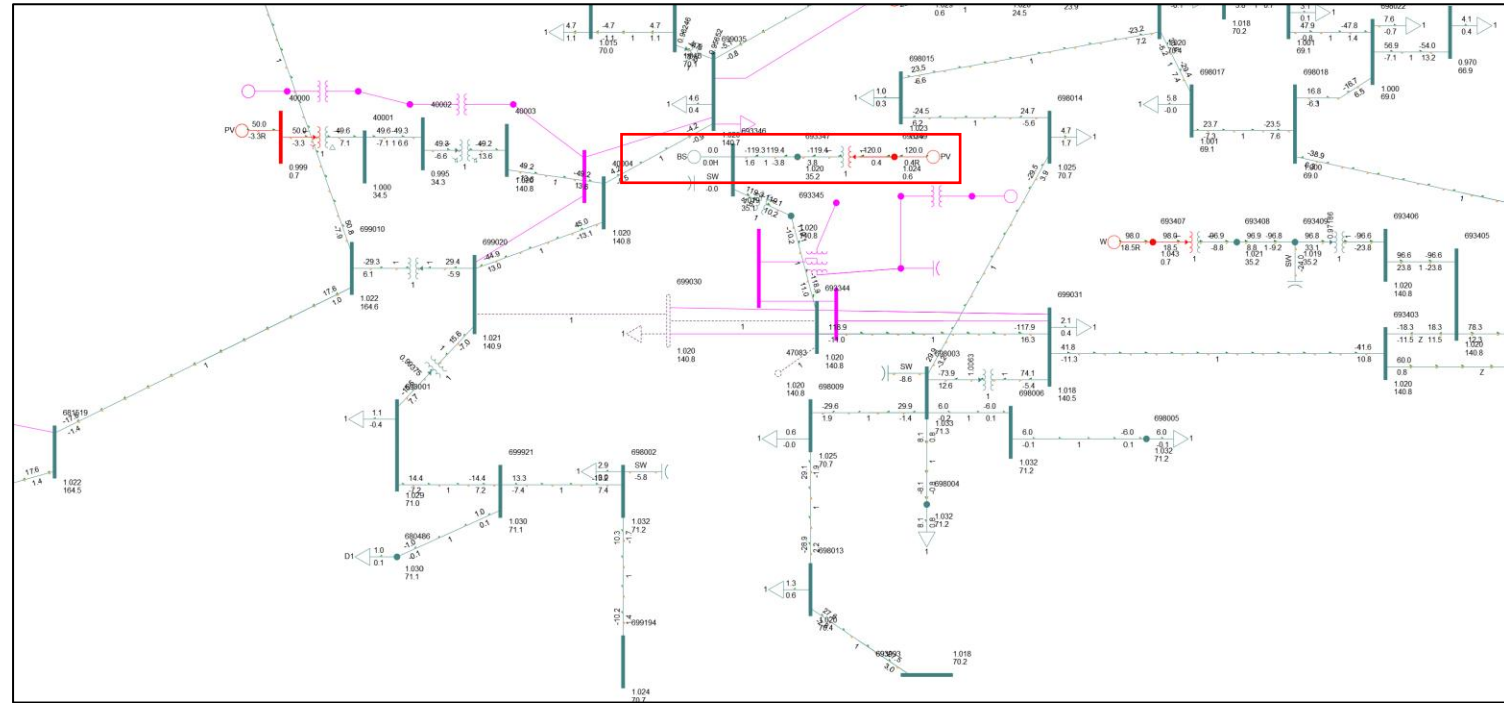
Within the 'Results' folder:

CONT_MAP.out	2026-03-03 9:16 AM	OUT File	1 KB
ESCREEN_LOG.html	2026-03-03 9:16 AM	HTML File	98 KB
ESCREEN_LOG.txt	2026-03-03 9:16 AM	TXT File	91 KB
NSCR.out	2026-03-03 9:16 AM	OUT File	1 KB
SCR.out	2026-03-03 9:16 AM	OUT File	1 KB

Both NSCR and SCR values are computed for every bus listed

Calibrating the Tool

- We can use known system instabilities to set “bad” NSCR numbers
- PV plant was found to have:
 - Stability @ 100 MW
 - Marginal stability @ 120 MW
 - Instability @ 140 MW



Setting Unstable NSCR Values

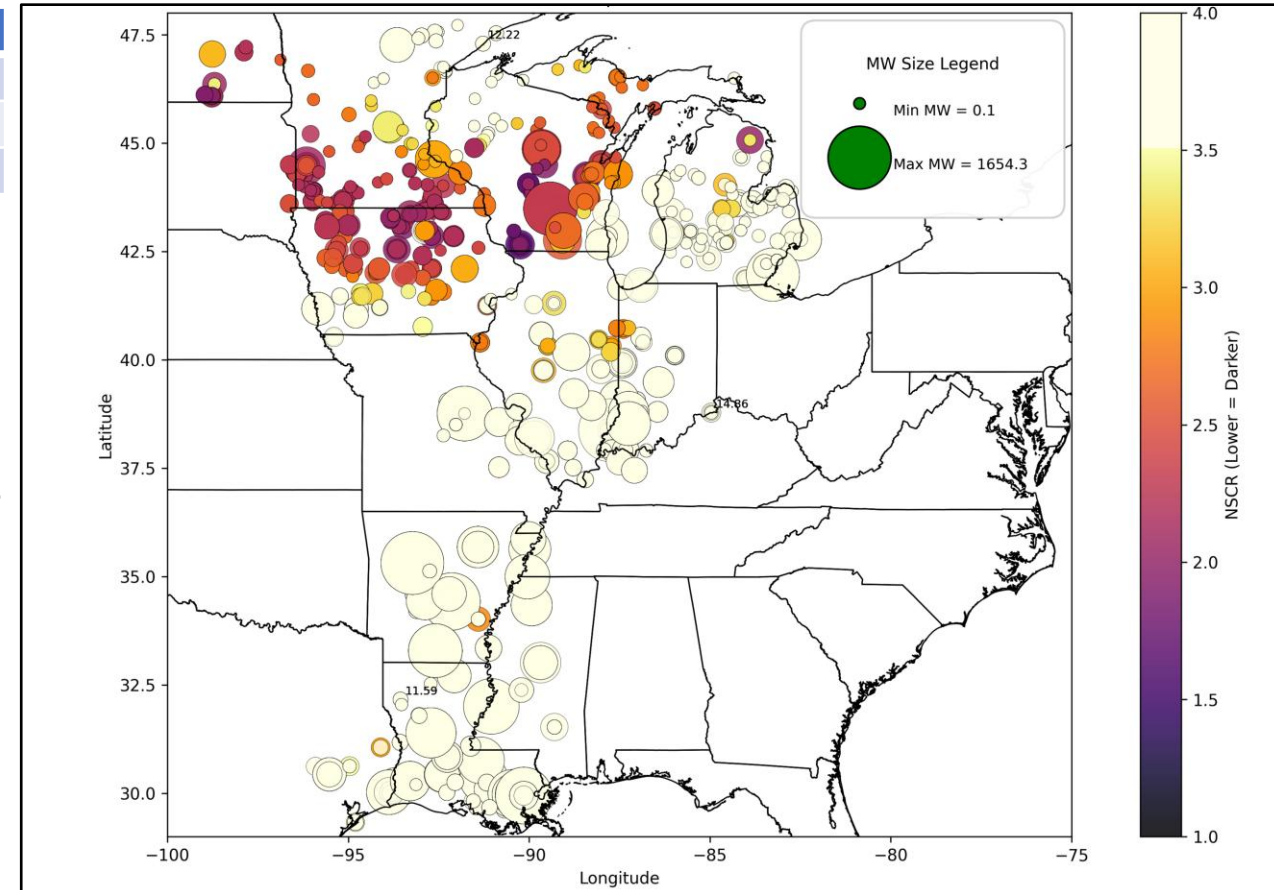
Contingency, NSCR693344, NSCR698016, NSCR43044, NSCR693863, NSCR698123, NSCR693389, NSCR43054, NSCR693680, NSCR40004, NSCR699036, NSCR693405, 2.19896, 3.24457, 13.6542, 4.63208, 4.93447, 3.25918, 5.76742, 3.69095, 5.76815, 4.48435, 2.24

100 MW

Plant Dispatch	PSCAD Result	NSCR
100 MW	stable	2.1989
120 MW	marginally stable	2.0250
140 MW	unstable	1.8767

Calibrating the tool is a time-intensive process, **but it enables the development of heat maps.** These heat maps are valuable for identifying problematic areas that require more detailed EMT analysis.

Heat map developed by Weiqing Jiang, MISO



To Conclude

- Our NSCR calculation:
 - Provides a sensible evolution to SCR
 - Accounts for the stabilizing impacts of GFM resources
 - E-Screen allows for NSCR to be applied across a wide area to screen for EMT studies

Thank you!

Rachel Bernhardt

Power Systems Studies Specialist

Electranix Corporation

rb@electranix.com

1-204-560-4298

Winnipeg, MB, Canada