

GRID EMT

SIMULATION INITIATIVE

EMT-Based Short Term Voltage Performance (STVPI) and Stability (STVSI) Assessment.

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The authors thank U.S. Department of Energy (DOE) Office of Electricity (OE) Advanced Grid Modeling (AGM) and the EMT initiative for their invaluable guidance and kind support in this work!



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Approach

Two complementary indices turn EMT voltage waveforms into faster simulations, fewer scenarios, clearer weak-area identification, and stability quantification.

P

STVPI — Dynamic Performance Index

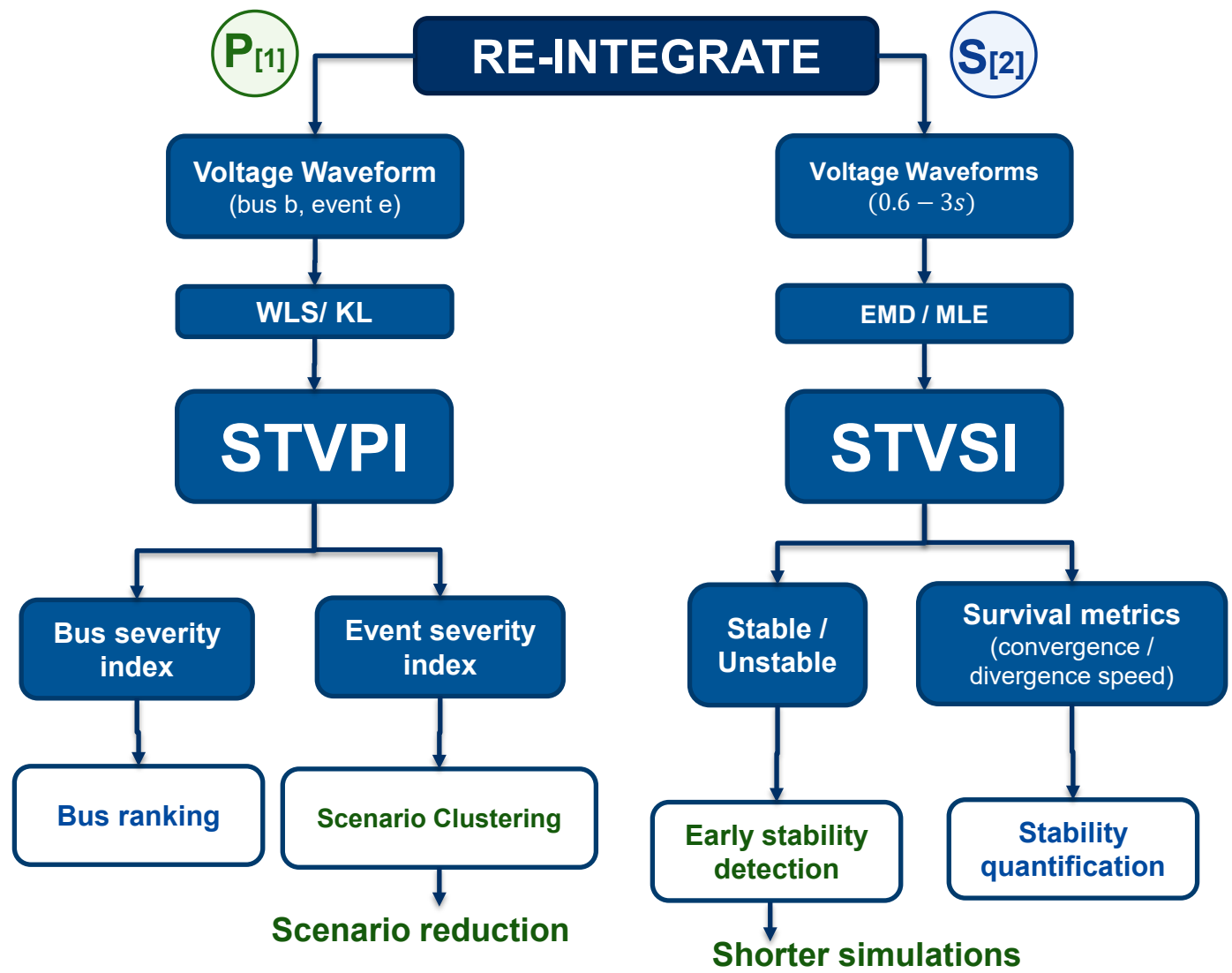
✓ Supports: Scenario reduction + Bus ranking

S

STVSI — Stability Detection & Quantification

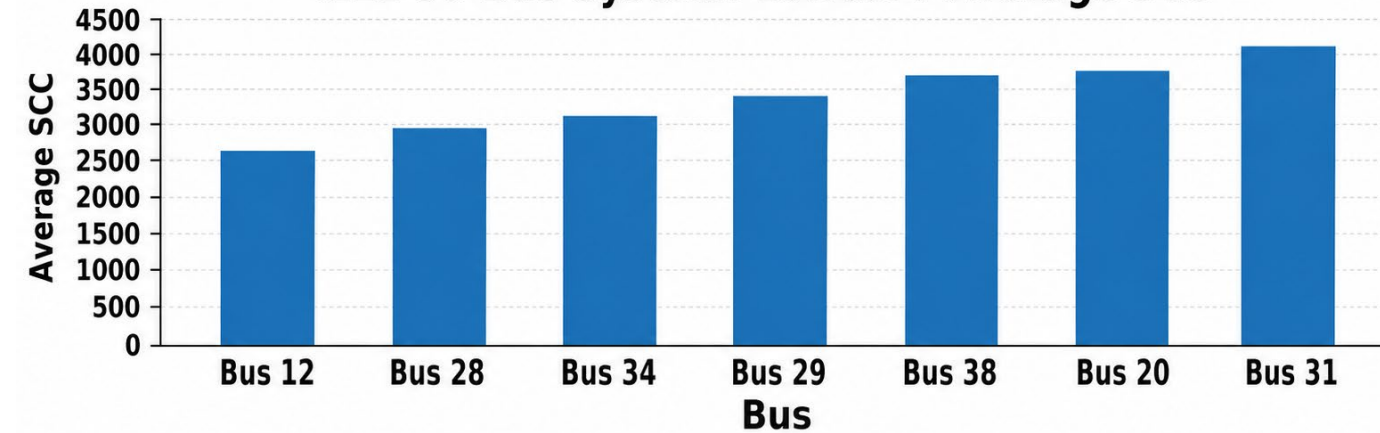
✓ Supports: Shorter simulations + Stability quantification

STVPI: Short-Time Voltage Stability Index.
STVSI: Short-Time Voltage Stability Index
WLS: Weighted Log Similarity.
KL: Kullback–Leibler divergence
EMD: Empirical Mode Decomposition
MLE: Maximum Lyapunov Exponents

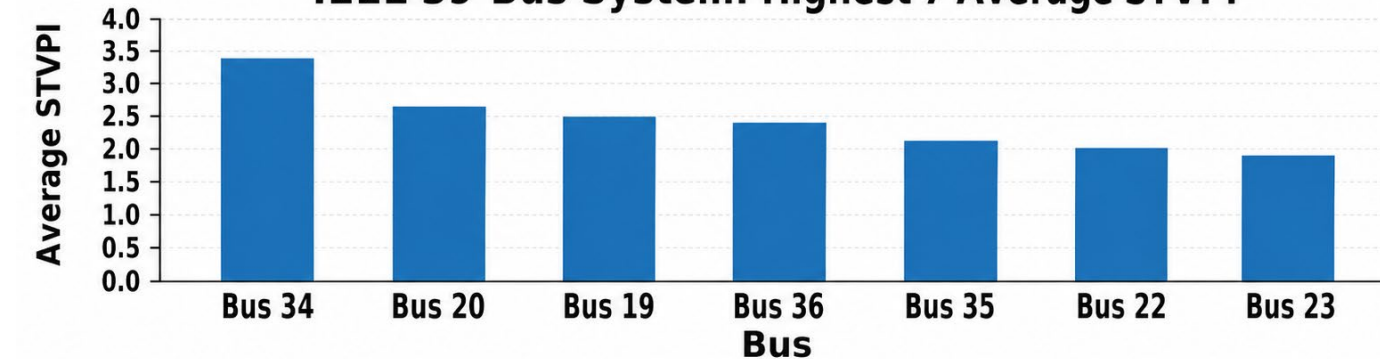


Application 1: Bus ranking (SCC Vs STVPI)

IEEE 39-Bus System: Lowest 7 Average SCC



IEEE 39-Bus System: Highest 7 Average STVPI



Comparison with Short-Circuit Capacity (SCC)

Low SCC does not necessarily translate into poor dynamic voltage performance. STVPI identifies event-dependent weak areas that static SCC screening may overlook.

Comparison with Dynamic Indices in the Literature

The existing literature primarily focuses on voltage performance, whereas our proposed index assesses both voltage stability and criteria-based voltage performance. It is also applicable to both RMS and EMT simulations.

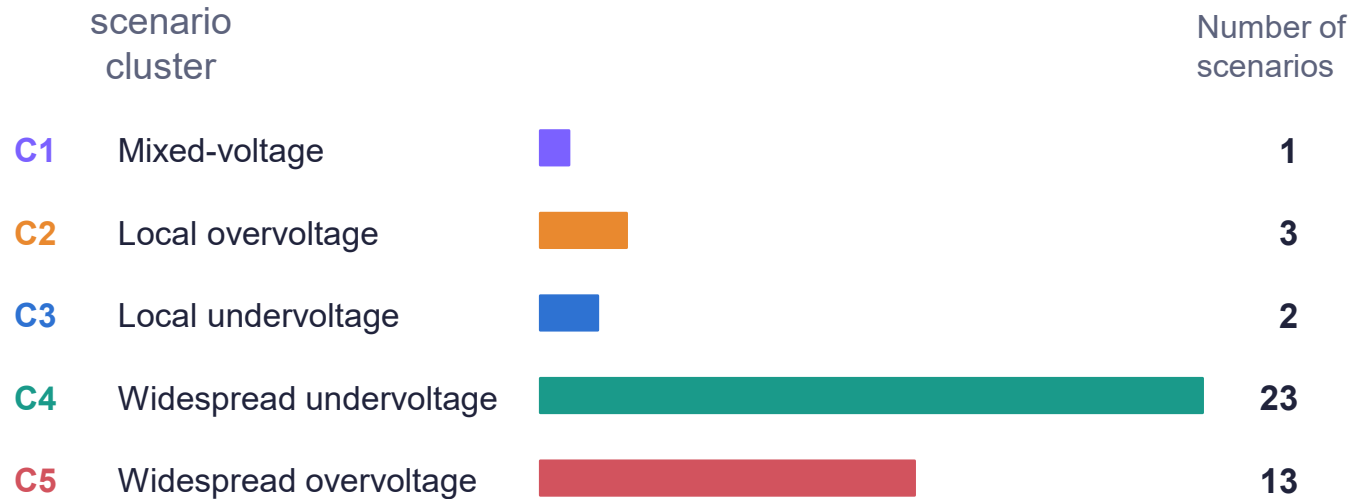


Application 2: Scenario Clustering & Reduction

Index-based clustering compresses the scenario study while preserving representative behavior.

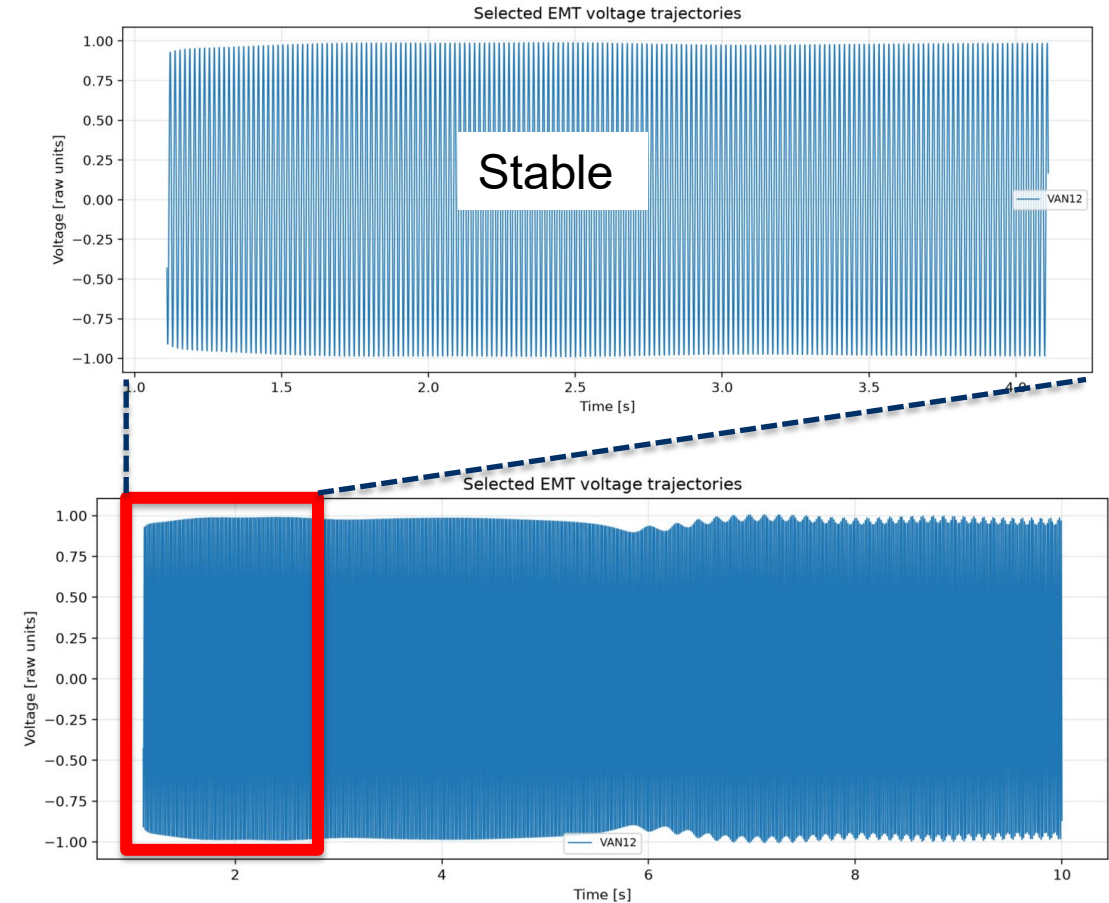
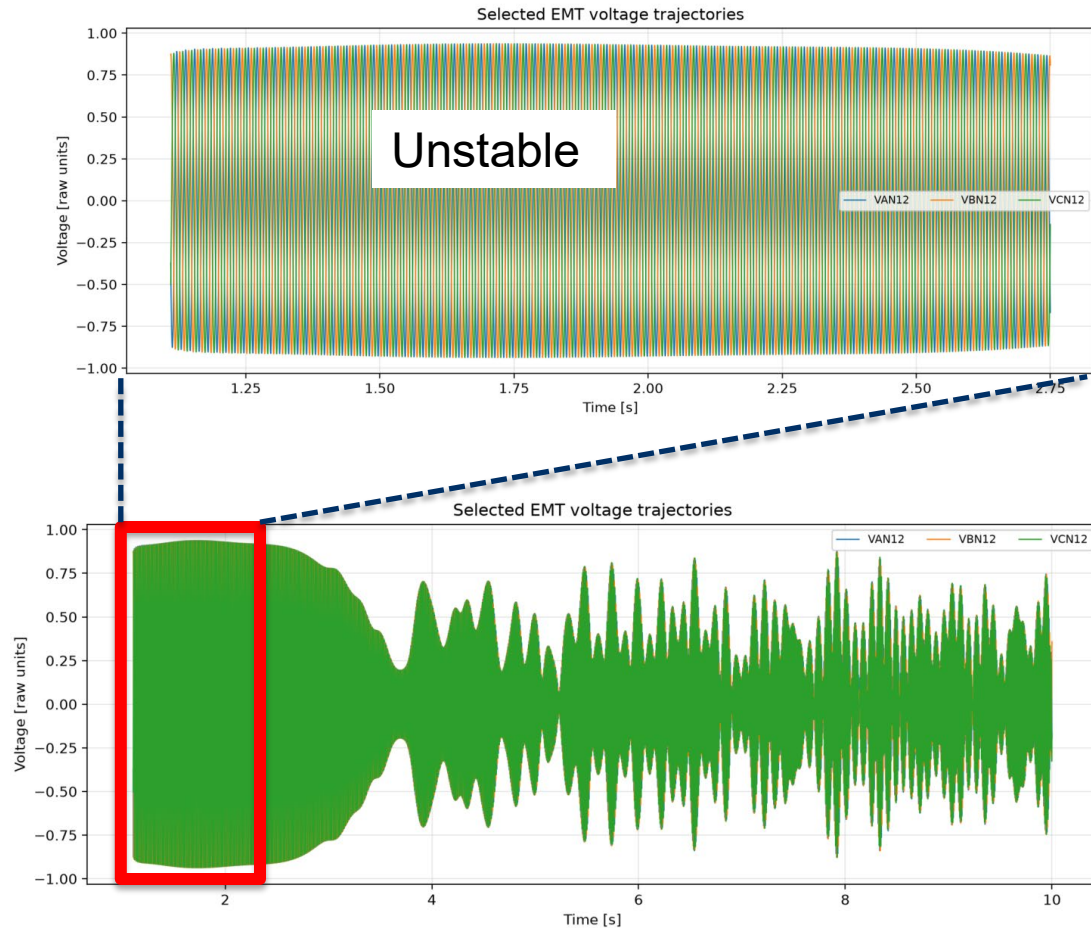


Cluster distribution



Application 3: Fast Stability Detection

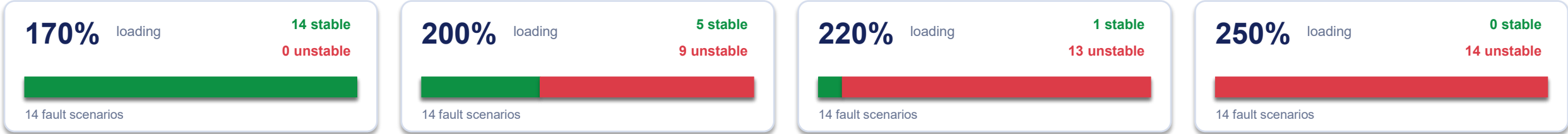
STVSI provides an early warning of short-term voltage instability before instability is clearly visible in the raw waveform.



Application 4: Stability Quantification

STVSI quantifies distance to the critical boundary for both stable and unstable operating points.

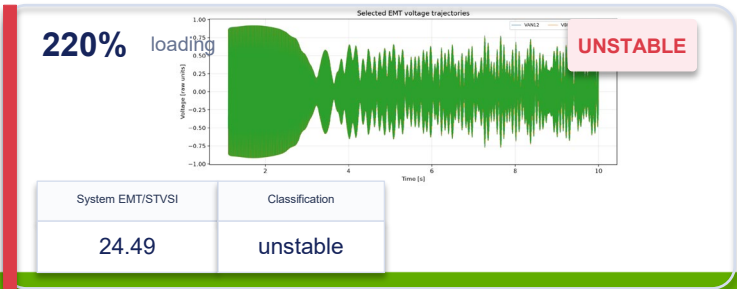
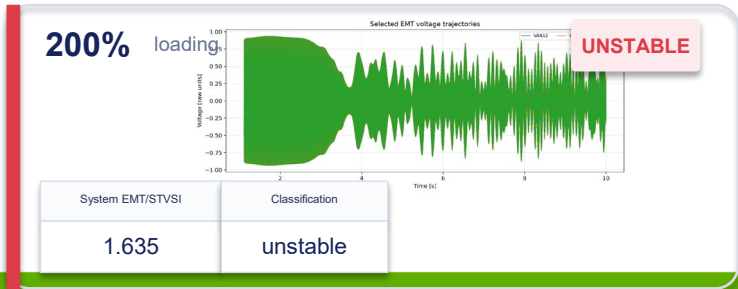
LOADING SWEEP · 14 FAULT SCENARIOS



Representative quantified cases

Examples showing how the metric changes with system loading

Example shown: 3Ph fault at Bus 12



KEY QUANTIFICATION INSIGHT

STVSI measures severity — not just status



As loading rises, the metric moves from safely stable to near-critical, then escalates sharply in unstable conditions.



Conclusions / Next Steps

- **Develop the STVTI:** Finalize the tripping-risk prediction logic, cascading-event update mechanism, and device-level risk assessment.
- **Develop sliding-window indices for online monitoring:** Extend the proposed indices for continuous real-time assessment using simulator outputs or field measurements.
- **Extend the framework to localization and source identification:** Apply information-theoretic methods to identify the source and location of performance degradation or stability weakness.



Thank you

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