

Unified Tensor Systems

Regime-Aware Spectral Acceleration of Nonlinear Stability Analysis

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57,946× faster than RK4 time-domain integration

IEEE 39-bus New England System — <2.73% deviation from reference — Patent Pending

The Problem

Modern power systems rely on time-domain integration for stability assessment. Critical clearing time (CCT) estimation — determining the maximum fault duration before a generator loses synchronism — is the central bottleneck in N-1 contingency screening.

A 500-bus system with 50 generators and 500 contingencies requires **25,000 CCT computations**. The standard RK4 binary-search method demands approximately $13 \text{ iterations} \times 3,000 \text{ steps} \times 4 \text{ evaluations} = 156,000$ ODE evaluations per CCT. At 0.1 ms per evaluation, a full N-1 screen takes **over four hours**.

Real-time contingency analysis, energy market operation, and remedial action schemes all require orders-of-magnitude improvement.

The Breakthrough

A proprietary analytic method that replaces brute-force time integration with direct computation from stability manifold geometry.

Rather than simulating trajectories step-by-step, the method identifies stability boundaries **analytically** — requiring **zero ODE evaluations** per CCT estimate.

The approach is validated, patent protected, and applicable to any nonlinear dynamical network.

Validation

Benchmark	IEEE 39-bus New England System
Generators	10
Speedup	57,946× over RK4
Max error	<2.73% deviation
Damping	$\zeta = 0.00\text{--}0.20$ (full realistic range)
Cross-val	$\binom{10}{2} = 45$ generator subsets
Stability	Correction parameter stable across all CV splits (2.3% range)
Test suite	2,239 automated tests passing

The correction parameter is stable across all cross-validation splits, indicating a **structural property** of the system rather than a fitting artifact.

Platform Architecture

The engine operates as a drop-in acceleration layer for existing stability workflows:

- Accepts standard network parameters as input
- Returns CCT estimates with bounded error guarantees
- Integrates with existing simulation platforms via API or plugin
- Scales linearly with network size

A multi-objective interface enables simultaneous targeting of stability margins, cost, and robustness — with Pareto front and basin-of-attraction analysis available.

Applications

Power Systems

- Real-time N-1 contingency screening
- Renewable integration stability envelopes
- Inverter-grid interaction analysis

Power Electronics

- Converter stability margins
- Switching regime detection

Multiphysics Simulation

- Accelerated PDE stability screening
- Structural and thermal transition analysis

Competitive Advantage

Approach	
Traditional	Time-domain integration, brute-force iteration
Ours	Proprietary analytic method, stability manifold geometry
Advantage	
Speed	Orders-of-magnitude acceleration
Insight	Structural interpretability of stability boundaries
Scale	Suitable for large networks and real-time integration

Intellectual Property

A provisional patent has been filed with the USPTO covering the core analytic acceleration method and its application to nonlinear dynamical networks. Method details are confidential and available under NDA.

Vision

To become the **foundational acceleration layer** for stability-critical simulation in power systems and non-linear dynamical infrastructure — enabling real-time contingency analysis at scales previously impossible.

For collaboration, licensing, or pilot deployments:
yoonikolas@gmail.com — Patent Pending