Unified Tensor Systems

Analytic Stability Acceleration for Nonlinear Dynamical Networks

Patent Pending — yoonikolas@gmail.com

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 $13 \times 3{,}000 \times 4 = 156{,}000$ 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 the geometry of the stability manifold.

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

The approach is validated on the IEEE 39-bus standard benchmark, 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	$\zeta = 0.00$–0.20 (full realistic range)
Cross-val	$\binom{10}{2} = 45$ generator subsets
Stability	Universal parameter, 2.3% range across all splits
Test suite	2,239 automated tests passing

The key parameter is universal across all generator subsets — a **structural property** of the system, not a curve-fitting artifact. A network with 1,000 generators uses the same value, pre-computed once.

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
- No ODE solver required at inference time

A multi-objective interface enables simultaneous targeting of stability margins, component 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
- Online stability monitoring for grid operators
- Inverter and grid-forming control validation

Power Electronics

- Converter stability margins
- Switching transient analysis

Multiphysics Simulation

- Accelerated PDE stability screening
- Structural and thermal transition analysis

Market Opportunity

N-1 contingency screening is a mandatory regulatory requirement for transmission operators in all major electricity markets. The power systems simulation software market serves thousands of utilities, grid operators, independent system operators, and engineering consultancies globally.

Accelerating stability computation by orders of magnitude opens use cases previously out of reach: real-time operation, tighter renewable integration margins, and automated remedial action schemes — all requiring sub-second stability decisions.

Commercial Model

The acceleration engine is offered as a licensed module for integration into existing simulation platforms, or as a standalone API for direct deployment by grid operators and engineering firms.

- **Platform licensing** — embedded in PSS/E, PowerFactory, PSCAD, or equivalent workflows
- **API licensing** — direct access for ISO/RTO and utility operations teams
- **Pilot deployment** — scoped N-1 screening integration with measurable throughput improvement

Competitive Advantage

	Approach
Traditional	Time-domain integration, brute-force iteration
Ours	Proprietary analytic method, stability manifold geometry
	Advantage
Speed	Orders-of-magnitude acceleration
Accuracy	Bounded error, validated under realistic damping
Scale	Linear scaling, real-time capable
IP	Provisional USPTO patent filed

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 nonlinear dynamical infrastructure — enabling real-time contingency analysis at scales previously impossible.

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