

GRID EMT

SIMULATION INITIATIVE

WG3 Activities Overview & Solvers/Integrators Way Forward

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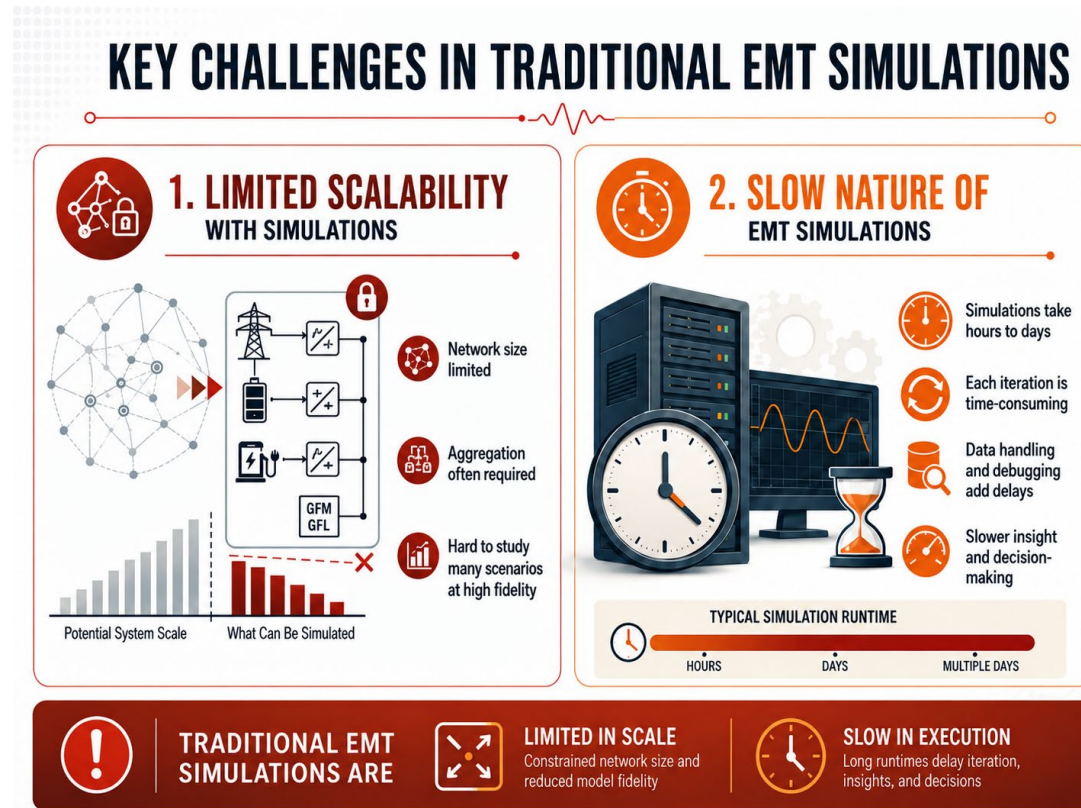


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Challenges

- Limited scalability feasible with simulations
- Slow nature of the EMT simulations



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Scope, Research Focus, and Impact

Scope & Objectives

Advance solver technologies and architectures for electromagnetic transient (EMT) simulation to address slowness of simulations and limited scalability of such simulations, with emphasis on near real-time studies of large-scale power grids comprising tens of millions of nodes and millions of inverters.

Research Focus

1. Structure-aware solvers to optimize solve
2. DAE properties-based optimization of integration
3. CPU, GPU, and multi-node parallelism
4. Approximate solves
5. Multi-timestep solves
6. AI-based methods

Impact

Speedup; Automation; Parallelism; Extensibility; Scalability; Intelligence



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Relevant Ongoing WG Activities

S. No	Task	Solvers/Methods	Leading Organization	Use-cases/Scenarios	Status
1	Approximate Solvers	single/multi-step methods, GMRES	Arizona State University	IEEE 39-bus system and its scaled versions	Performance of the Sparse Inverse Factor methods evaluated/benchmarked for large-scale EMT matrices
2	GPU-based Sparse Solvers; Mixed precision sparse direct solvers on GPUs	Variable-size batched sparse direct solvers on GPUs;	Lawrence Berkeley National Laboratory	IEEE 39-bus system + IBL	Performance of the SuperLU on AMD GPUs, Nvidia GPUs using mixed precision solvers on EMT matrices evaluated
3	Stiffness Identification	Dominant eigenvalue estimation; secondary embedded error estimates	Lawrence Livermore National Laboratory	Power system components and circuits	Eigenvalue based stiffness detection algorithm performance benchmark completed for power system components and circuits
4	Pattern Recognition and Re-ordering	Intelligence (re-ordering and multi-layer detection methods) (TD, BTD, BBTD, NBBDD)	Oak Ridge National Laboratory Florida International University	IEEE 3900-bus system IEEE 118-bus system + IBR I2-Feeder IBL	Successful GNN-based reordering methods benchmarked for BD and BBD matrices. BTD solver code-base development for standalone matrices; re-ordering detection algorithms for BTD and BBD matrices
5	Solver performance	Wide-variety of solvers; pre-conditioning methods	Purdue University	IEEE 39-bus system Decoupled IEEE 39-bus + IEEE 118-bus system	Performance analysis and structural analysis of EMT matrices studied
6	DAE Custom Integrators	Custom numerical integrators	Oak Ridge National Laboratory	Power system components and circuits	Option-2 code-base for various power system components and circuits created. Testing of Power electronics components is ongoing



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Relevant Past and Future WG Activities

- **Minisymposia at the Society for Industrial and Applied Mathematics (SIAM) Annual Meeting in July 2026. 4 presentations with successful math community engagement**
 - Fundamentals of EMT
 - Mathematics for EMT
 - Ongoing Research in EMT
 - Advanced Solutions for EMT
- **Webinars**
 - May 2026: “Introduction to WG3”; “RE-INTEGRATE Fast Simulations”; “GPU-Based Power System Simulations”
 - Oct. 2026 – “Stiffness Detection Algorithms”, “Automated Integrators”
- **EMT Workshop Session**
 - Several topics related to integration, algebraic solvers, automated methods
- Initiated a WG webpage design - intended to support both technical dissemination and public-facing outreach for the Solvers WG.



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Impact Expected from WG

Technical:

- ImEx methods ~ 1,000x faster (best case, limited cases)
 - Stiff detection
- Load balancing (MPI, OpenMP, GPU) ~ 100x faster (best case, large cases)
- Mixed precision ~ 2-3x faster (best case, most cases)
- Approximate solvers ~ 2-3x faster (best case, most cases)
- Structure-aware solvers ~ 10x faster (best case, structure specific)

Non-technical:

- Webinars: 2+
- Minisymposia talks: 1+
- Peer-reviewed articles: 2+



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Brainstorming Session: EMT Matrix Generation

- EMT Matrix and b vector generation in RE-INTEGRATE for $Ax = b$ system of linear equations
- Components and systems considered
 - Power electronics components
 - UPS; 2LC converter
 - Power systems
 - IEEE 39-bus system
 - IEEE 118-bus system
 - IEEE 39-bus system + IBL
- ***Key take-away: Users and attendees will get familiarized with EMT matrices and b vectors generated from RE-INTEGRATE software***

Brainstorming Session: GPU Solver Runs

- Solution of large-scale EMT matrices on different GPU compute nodes (NVIDIA, AMD)
- Systems considered
 - IEEE 39-bus system + IBL
 - IEEE 39-bus system + IEEE 118-bus system (not connected; but together)
- 3 tests are performed for each system:
 - Double precision solve
 - Single precision solve
 - Single precision solve with double precision iterative refinement
- ***Key take-away: Users and attendees will get familiarized with solver setup, and runs on various GPU compute nodes***

Future WG Research Tasks Beyond FY26

- Multi-step block preconditioned Newton–Krylov linear solver
- GPU-accelerated linear solvers
- Design of multi-rate and multi-order detection methods
- GPU-resident solvers
- Parallelism in linear solvers: preconditioned iterative methods and reuse of factorizations
- Use of tensor cores for mixed-precision acceleration, particularly in linear solves, with iterative refinement to recover full accuracy