

GRID EMT

SIMULATION INITIATIVE

WG2 Activities Overview & Large Load Models/Benchmark Models

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Acronyms

EMT: Electromagnetic transient

LLTF: Large load task force

NERC: North American Electric Reliability Corporation

CIM: Common information model

DLL: Dynamic-link library

IBR: Inverter-based resource

DER: Distributed energy resource

SPP: Southwest Power Pool

ESIG: Energy Systems Integration Group



Scope of WG2

- (i) Develop standardized input data structure for EMT models
- (ii) Develop specifications for creating EMT benchmark models with primary focus on large load integration
- (iii) Develop specifications for large load models
- (iv) Identify current practices and gaps of large load ride through and model quality testing



Input Data Structures: Gaps and Challenges

- (i) Lack of Standardized Model Formats
- (ii) Vendor Black-Box Models (DLLs)
- (iii) Poor Interoperability
- (iv) Inconsistent Input Data Quality
- (v) Event/Scenario Management is Manual
- (vi) Limited Support for Large Systems
- (vii) Documentation & Metadata Deficiency
- (viii) Integration with real-world data is Manual
- (ix) Validation & verification
- (x) Workforce development

Standard data format will help with building, updating, validating, and simulating EMT models



Models: Gaps and Challenges

- (i) Complexity and Computational Cost
- (ii) Model Accuracy vs. Efficiency
- (iii) Model Integration
- (iv) Data Availability and Calibration
- (v) Benchmark models**
- (vi) IBR/DER-specific issues
- (vii) Large load-specific issues
- (viii) Misc. Generic Issues:** i. Compatibility across EMT platforms; ii. Compiler version compatibility of User Defined Models (UDMs); iii. Challenges with portability due to compiler dependence; iv. Legacy plant model compatibility; v. Different discretization time-steps



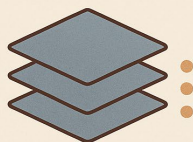
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High-Level Overview of Approaches in FY26

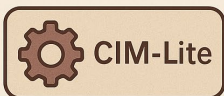
- Input data structure

CIM DESIGN



CIM can be used as a protocol to accommodate model evolution; interface grouping can help layering models while hiding metadata

PRELIMINARY CIM IMPLEMENTATION



This follows CIM-Lite which inherits well-established properties of CIM and is leveraged as a software development kit (SDK)

- Models

Models



Large Load
Component Models



Repository of
Data Center Models



Advanced Large Load
Component Models



Benchmark Models for
Large Load Integration

- Focus areas

Three Major Focus Areas

Develop standardized
input data structure
for EMT models



CIM and CIM-Lite

Develop specifications
for creating EMT
benchmark models with
primary focus on large load
integration



Specific requirements
identified

Develop
specifications for
large load models



AI and cryptocurrency
loads



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Input Data Structure

- Existing methods require customized, ad-hoc extensions for EMT modeling from base case power flow (e.g., .raw), dynamic (e.g., .dyr), and short circuit (e.g., .seq) analysis
- Common Grid Model Exchange Standard (CGMES) Library under Common Information Model (CIM)
- Extension from base case popular in North America: CGMES CIM is not popular
- Real-code EMT models by Joint Working Group of CIGRE B4.82 and IEEE: Dynamic Linked Libraries (DLL) are associated with Windows
- Glen K. Halley (City Utilities of Springfield) gave a presentation in the WG titled “Input Data Structures (IDSs) EMT Model Metadata.”
- Thomas McDermott (Chair, IEEE P3743 Working Group) gave an EMT Webinar presentation titled “Electromagnetic Transient Model Interoperability” on April 21, 2026. (The recording and presentation are available at: <https://events.ornl.gov/emt-simulations/emt-webinar-input-data-structures-models-emt-interoperability/>)



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EMT benchmark models

- **Small:** IEEE 4-machine (Kundur), IEEE 9-bus (WECC), IEEE 39-bus (New England), IEEE 118-bus;
Medium: 240-bus reduced WECC, Texas 2000-bus synthetic, **Large:** 70k-bus EI synthetic
- Models to be augmented with 125 inverter generic Inverter-based load (IBL) model

Key Attributes for testing solvers

Attribute	Typical values
Network Type	Transmission, distribution
Network size	1000's – 100000's
Enables cross-tool import	Solver agnostic sparse systems
Existence of IBL types	IBL: data center, crypto-mining loads;
Parallel/HIL ready	CPU-GPU architecture systems, mixed precision.
Initialization of states	e.g., snapshot file, power flow solution file

Key Attributes for testing features

Attributes	Typical formats/values
Data processing and generation	.csv, .txt
Ride-through capabilities and requirements	FRT, HVRT, LVRT; PRC-029-02
Variable inertia and SCR	Inertia:0-11s ; SCR: 0.5-20
P0-P7 tests capability	Loss of line, loss of generator, loss of load, faults: SLG, L-L, 3-phase,
Compatible input and output data structures	.xml, .dss, .dyr, and .raw
Network type	Transmission, distribution
Network size	100s' – 100000s'
IBL	Data center loads, crypto-mining loads

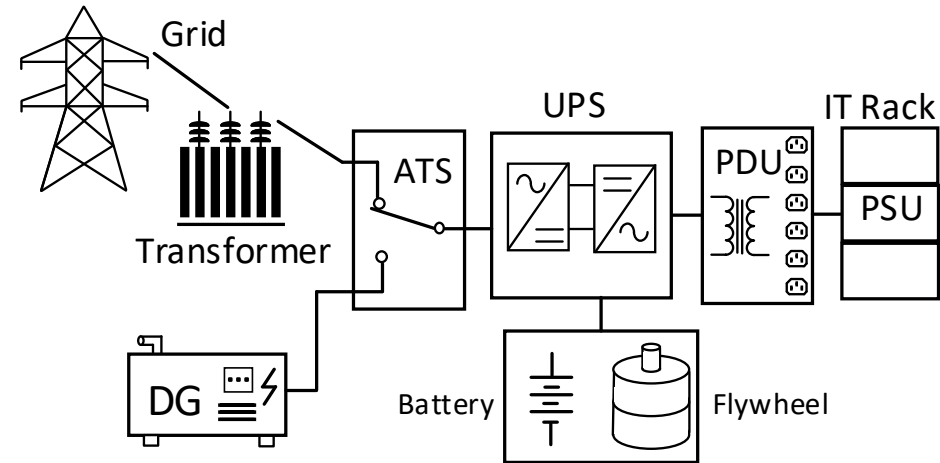


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Specifications for Large Load Models

- The specification document summarized the component models needed to build large-load models, such as data centers and crypto-miner load.
- The components of a typical data center model include:
 - Uninterruptible Power Supply (UPS)
 - Floor-mounted Power Distribution Units (PDUs): transformer, circuit breaker, and monitoring hardware
 - Power Supply Unit (PSU) for supplying IT loads: boost Power Factor Correction (PFC) converter and DC/DC converter
 - Backup generator
- A crypto-miner load may not have a UPS or a backup generator.
- Aggregated and disaggregated large load models



Ongoing WG Activities: Large Load Model Specifications

- Two major focus areas:
 - Large load ride-through requirements
 - Large load model validation/quality testing
- SPP presented large load ride through requirements in their footprint
 - Categorization of large loads
 - Large loads with co-located generation
 - Ride through requirements for power electronic loads
 - Similarity and difference with ERCOT's requirements
- ESIG document on the summary of ride through requirements
- NERC LLTF's efforts discussed
- Brainstorming on model validation/quality testing
 - Component-level model validation at the vendor's end
 - System level aggregation by developers, utilities, ISOs
 - Sampling rate decided by utilities, ISOs



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Some takeaways from brainstorming sessions

- Requirement on model quality testing will be crucial
- Requirements on ride-through behavior and the reclosing sequence of large loads are evolving and region specific
- Point of interconnection (POI) requirement of large loads during disturbances are specified: how does that get translated into individual component behavior is less understood
- RAS might be required for meeting ride-through requirement with co-located generation
- What if co-located generations are only few buses away from the large load? What's ride through at that point? Combined (Large load or generation) or separate?
- Different interpretation by plant owners regarding “may trip/may ride through region” in the ride-through curves may lead to tripping of some load/generation while others ride through. Could this lack of coordination pose stability challenges?
- Interaction among large load clusters need to be better understood
- Lack of field data on customer-initiated large load tripping (except Dominion)



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Future WG Activities

- Bi-weekly meetings will continue throughout FY '26
- Two key issues for discussion: model quality/testing and large load ride-through requirements
- WG members and external speakers will continue delivering talks
- White paper on these topics
- Coordination with NERC efforts through participation in LLTF activities
- Benchmark model development will continue and speakers will present
- Large load model development will continue and speakers will present
- Webinar in September planned and speaker confirmed



Next up

Technical session 2

- Study-driven CIM Architecture
- Benchmark Models
- HVdc Studies in EMT
- Large Load Models & Disturbance Challenges Observed

Technical session 3 (tomorrow starting 9:30)

- Model Requirements & Needs
- Large loads/BESS and E-STACOM integration
- Data Center Models in PSCAD: Studies with Co-located Generation
- Advanced Data Center Model
- RE-INTEGRATE: Large Load Models



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