

GRID EMT

SIMULATION INITIATIVE

WG1 Applications and Pilots Overview and White Paper on EMT Modeling for Large Load Integration Studies

Marcelo Elizondo (PNNL)
and Mostafa Sedighizadeh (SPP)

EMT Simulation Workshop
August 18-21, 2026



U.S. DEPARTMENT
of **ENERGY**

Office of
Electricity

EMT Initiative: Working Group 1 – Applications & Pilots

- **Scope:** This Working Group collects information on current, emerging, and future applications and pilots for Electromagnetic Transient (EMT) modeling in power systems.
- **Co-Leads:** Marcelo Elizondo (PNNL) and Mostafa Sedighizadeh (SPP)
- **WG Members:** Henry Hadjor (Radian Generation), Glen Halley (City Utilities), Kevin Dowling (Silicon Ranch), Abhijith Ravi (Dominion), Nicole Rexwinkel (SCE), Amir Mohammednur (SCE), Ransome Equnjobi (ENEL), Joshua Park (SCE), Xavier Sosa (SCE), Phani Marthi (ORNL), Zhong (Kyle) Zheng (NYPA), Huzaifa Karmjee (Southern Co), Korede Ibukunoluwa (Dominion), Gad Ilunga (Dominion), Juan Castaneda (MKI), Roberto Favela (EPE), Prashant Kansal (ERCOT), David Deloach (TVA), Thomas Anderson (TVA), Spencer Coffman (SPP), Wei Du (PNNL), Quan Nguyen (PNNL), Fahmid Sadeque (PNNL), Qianxue Xia (ORNL), Suman Debnath (ORNL), Md Shamim Hassan (ORNL), Dulip Madurasinghe (ORNL), Harvey Scribner (former SPP), Peter Hoang (Danovo)



U.S. DEPARTMENT
of **ENERGY**

Office of
Electricity

Evolving use of EMT models

- Expanded scope of EMT models
 - New technologies quickly integrated into the grid (e.g.; large load data centers)
 - Power electronics components in load, generation, transmission, and distribution
 - Larger footprint of study system – need to model components and grid interactions



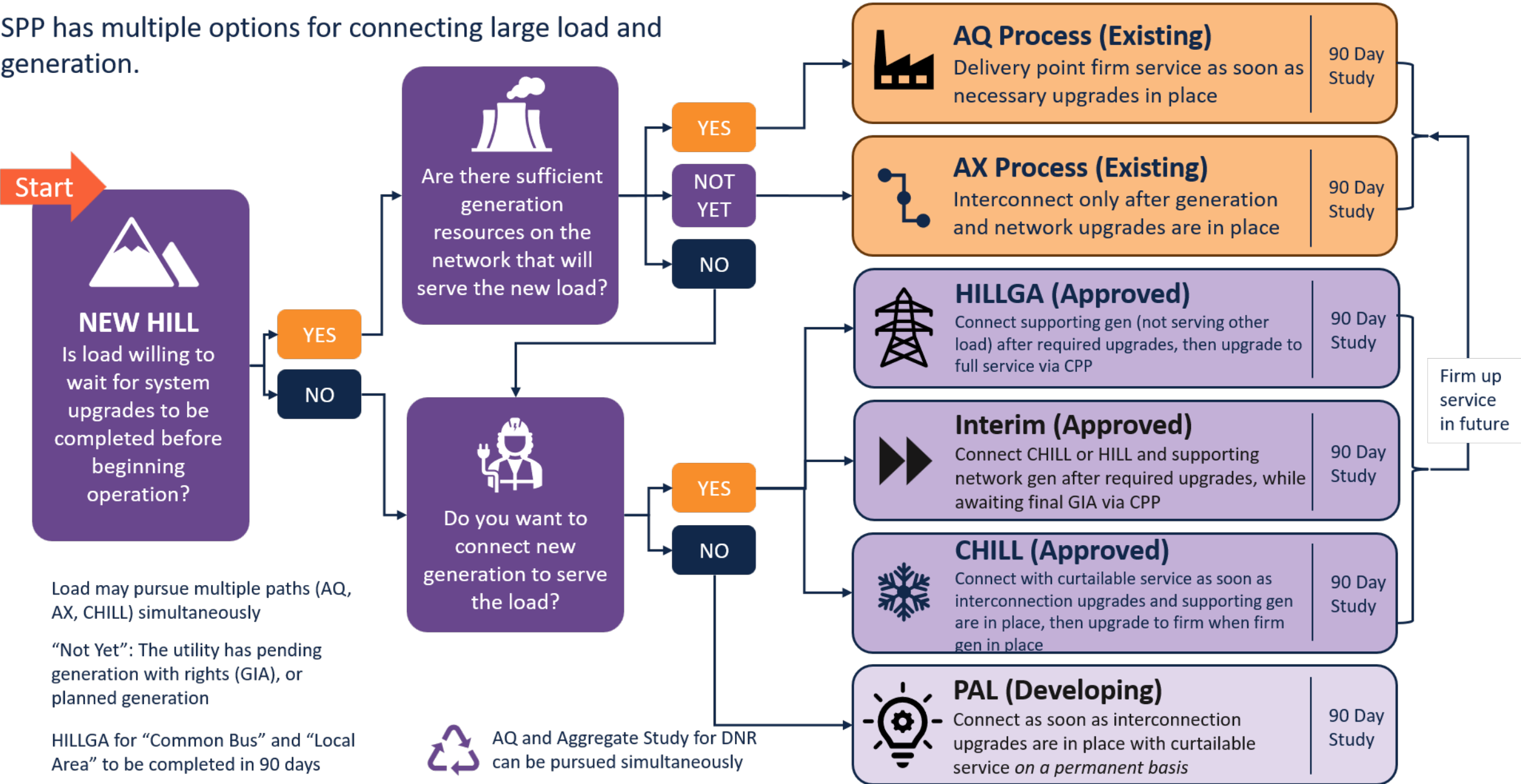
Current Activities WG 1

- Contributed to initiative road map report
- 2 webinars in March and September 2026
- Working on a white paper on EMT modeling for large load integration
 - Current practice and gaps
 - Evolution of stability studies
 - Recommended updates
 - Possible use cases and pilots



Connecting through Optionality in SPP

SPP has multiple options for connecting large load and generation.



SPP Large Load Reliability Policies

- **Ramp Limit**
 - 20MW per minute for large load.
- **Oscillation Limit**
 - Still being defined; studies ensure loads don't create harmful oscillations during disturbances.
- **Basic Facility Information and Modeling**
 - Required to provide enhanced upfront data to improve representation in studies, particularly for stability analysis.
- **Telemetry**
 - Required to install and provide phasor measurement unit (PMU) data and appropriate metering.



U.S. DEPARTMENT
of **ENERGY**

Office of
Electricity

ERCOT Large Load Interconnection Process: Modeling Aspects

- ERCOT large load interconnection process in coordination with Transmission Service Provider (TSP)
 - Phase 1: interconnection request and planning studies
 - ERCOT and TSP agree on study scope and assumptions
 - TSP reliability study, identification of needed upgrades
 - ERCOT establishes load amount that can be served, may depend on upgrades
 - Phase 2: Agreements and modeling
 - Load added to ERCOT's planning and operations models
 - ERCOT interim ride-through evaluation – Load may be curtailed under some conditions; large load may update settings/equipment to be reevaluated
 - Phase 3: Approval to Energize:
 - ERCOT evaluates load model quality

ERCOT Modeling Quality Test:

Necessary parameters, and accurate representation of the equipment.

- Site-specific
 - ✓ Flat start (no-disturbance test)
 - ✓ Large voltage disturbance test
 - ✓ Model performance requirements
 - ✓ PSS/E, PSCAD, TSAT
- Converter model validation
 - ✓ Hardware-type validation
 - ✓ Accuracy of PSCAD model
 - ✓ Voltage ride through
 - ✓ Subsynchronous test

References:

- ERCOT 1234NPRR-01 Interconnection Requirements for Large Loads and Modeling Standards for Loads 25 MW or Greater
- ERCOT 115PGRR-01 Related to NPRR1234, Interconnection Requirements for Large Loads and Modeling Standards for Loads 25 MW or Greater
- Sun Wook Kang, "ERCOT Large Load Modeling Requirements and Model Quality Test," ESIG Summer Workshop, June 2026



ERCOT Large Load Interconnection Challenges. Modeling Aspects

- Study scenario uncertainties
 - Assumptions may become outdated as more customers request connection to specific area
 - Other future large loads not fully confirmed could be in model
 - Mismatches with other ERCOT planning studies
 - TSPs can sign agreements with large loads before studies are completed
- Requirements are evolving as risks are better understood
 - Requirements could be identified after construction has started
 - Studies may need updating as more risks are identified

Reference: ERCOT's Large Load Interconnection Process Overview



Modeling Process for Large Load Integration

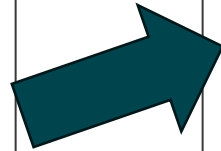
- Common modeling steps
 - Study scope
 - Data inputs
 - Build grid side model and base case
 - Modeling components of large loads EMT
 - Model testing
 - Perform studies
 - Acceptance criteria
- EMT Initiative team taking steps towards automation of modeling processes in RE-INTEGRATE



Evolution of stability analysis and emerging EMT modeling application for large load studies

Current attention by industry

- Load profile fluctuation / ramp rate limitations (e.g.; ERCOT 20 MW/min)
- Ride-through behavior
- EMT model development – but no standard requirements yet
- Cooling loads and power electronics portions modeled in separate aggregations for phasor-domain models



Possible evolution:

- Control interactions – including those caused by low short-circuit strength
- Protection mis-operation / undesired protection action
- DC system/bus dynamics
- Detailed models needed within study area
 - OEM-validated EMT models for rectifiers/UPS/dc systems?
- EMT study footprint sizing
 - Multi-infeed interaction
 - Short-circuit-strength criteria
 - Fault sensitivity
 - Nearby potentially dynamic sensitive equipment
 - E.g.; large generation, large arc furnaces, HVDC lines
 - Collective behavior of similar LLs



Recommended Updates

Develop standard EMT models and modeling practices

Develop methodologies for EMT models

- Large load under study
- Size of study area to be modeled in EMT
- Criteria to include important nearby equipment in EMT study area
 - Generators
 - Other large loads
 - Series capacitors
 - HVdc converters
- EMT parallelization methodologies for when EMT study area needs to be large
- Methods for SO/RTO-level EMT database management for extraction of EMT study areas



Possible Use Cases for EMT Initiative to Focus On

- Detailed fault ride-through behavior validation
 - Ride through evaluation with EMT models
 - Model quality test as part of network, in addition to in single machine equivalent
 - How do right through criteria at POC translate to individual inverters?
 - Criteria from different system operators (e.g.; ERCOT, SPP, ATC) could be applied
- Subsynchronous torsional interaction studies
 - Cyclic intra-second variability can introduce forced oscillations; 5-35 Hz forced oscillations exciting subsynchronous torsional modes in nearby generators
 - For high-frequency cycling use-case, EMT models of all components in the vicinity of the load center needs to be modeled. Components include: power electronics generation, synchronous generators, series capacitors, voltage control devices, and other large loads.



Possible Use Cases for EMT Initiative to Focus On (...continued)

- Controller instability and subsynchronous oscillation root cause analysis
- Event replication and oscillation detection
 - Forced Oscillations; Example: ERCOT oscillation events reported
- Interaction with other nearby large loads, large generator, power electronics generation, and/or HVdc
 - Definition of footprint of area of study
 - Level of detail of models withing area of study



Next Steps

- Final white paper draft to the EMT initiative November 2026
- Develop technical requirements for use cases and pilot project for advanced EMT modeling



Thank You

Acknowledgement: 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!

Legal Disclaimer: This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.



U.S. DEPARTMENT
of **ENERGY**

Office of
Electricity



U.S. DEPARTMENT *of* ENERGY

Office of Electricity