ESIG Large Load Task Force
WS3 – Modeling

Parag Mitra PhD.

Principal Technical Leader

Electric Power Research Institute

ESIG

ENERGY SYSTEMS
INTEGRATION GROUP

Scope of the Modeling Guidelines

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1. Provide clear guidance on how to accurately model large load facilities
2. Define what modeling components and behaviors must be represented
3. Clarify when and how to use different simulation frameworks.
4. Establish expectations for verification, validation, and quality testing of large load models.
5. Identify current modeling gaps and outline recommendations for improving industry practices.

Our Contributors

Anuoluwapo Aluko, RMS Energy
Poria Astero, EPE Consulting
Debargha Brahma, Imperial College London
Amalie Jenna Bullen, Monash University
Youhong Chen, Imperial College
Amin Dadashzade, Zero-Emission Grid (ZEG)
Sreetama Das, Hitachi Energy
Mehdi Ghazavi Dozein, Monash University
Bikiran Guha, Hitachi Energy
Nick Hatton, Western Electricity Coordinating Council
Taulant Kërçi, EirGrid
Mohammad Reza Khalghani, Electric Reliability Council of Texas
Babis Marmaras, PIQ Energy
Supun Meetiyagoda, Monash University
Eric Meier, Electric Reliability Council of Texas
Tayeb Meridji, Orsted
Mohammad Mohammadi, Australian Energy Market Operator
Nihal Mohan, NextEra Energy Transmission
Nima Omran, Independent Electricity System Operator (Ontario)
Matin Rahmatian, EPE Consulting
Ronak Rathore, Amazon Data Services
Farshid Salehi, CogniSim Power Inc
Parth Shailesh Shah, Hitachi Energy
Thair Shaker Mahmoud, Electric Reliability Council of Texas
Amritpal Singh Koushal, Enerzinx, LLC
Sebastian Sørensen, Energinet
Kannan Sreenivasachar, Independent System Operator New England
Dionysios Stamatiadis, Piq Energy Corp
Alexander Stewart, Bonneville Power Administration
Douglas Tucker, Western Electricity Coordinating Council
Ridma Wijethunga, Monash University
Ali Yazdanpanah, Electric Reliability Council of Texas
Novan Zakkia, Hitachi Energy

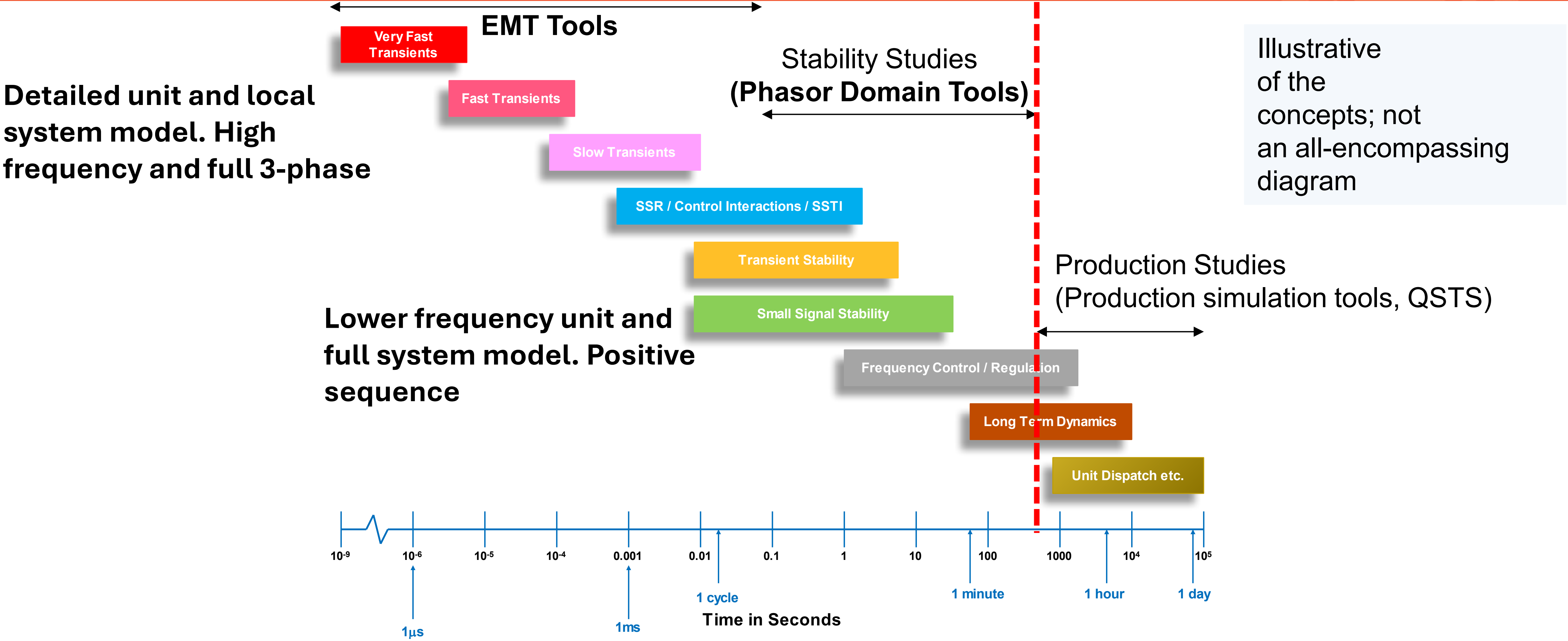
Chapter Breakdown

- **Introduction**
- **Dynamic Models for New Large Loads**
- **Essential Components of Large Load Models**
- **Key Modeling Requirements for Power System Dynamic Assessments**
- **Dynamic Model Development Guidelines and Requirements**
- **Model Parameter Verification Validation and Quality Testing Guidelines**
- **Reliability Impacts of Inadequate or Improper Modeling**
- **Recommendations for Accurate Large Load Model Development**

Modeling for What?

- **Challenges to be addressed by this modeling guidance**
  - Model development for phasor domain +ve seq and electromagnetic transient simulators (PDPS and EMT simulators)
- **What types of phenomenon are addressed using these simulators (and these models)?**
  - Rotor angle stability
  - Voltage stability
  - Frequency stability
  - Resonance stability
  - Converter driven stability
- **Brief summary of the load modeling practices in the US and Europe**
- **Brief summary of the WECC composite load model**

Phasor Doman and EMT Modeling



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More Modeling Lingo

Dynamic Modeling

Higher Frequency Dynamics (EMTP, PSCAD)

Model creation is less challenging

EMT
- **Generic**: White boxed, good for research, exploratory, or initial risk screening studies
- **OEM**

Lower Frequency Dynamics (PSS®E, PSLF)

Model creation could be slightly tricky

Phasor Domain
- **OEM**
- **Generic**: White boxed, good for planning studies when actual equipment is undefined, risk screening, many OEMs also parameterize these models

OEM (EMT and Phasor Domain): Black box models, considered true representation of the equipment, available only after equipment is finalized, suitable for resolving site-specific issues

Key Characteristics that Models should Reflect

Active Power and Frequency Control	Reactive Power and Voltage Control	Load Profiles
Ride-Through Behavior	Ramp Rate Limits	Mechanical Load Behavior
Blackstart Consideration	Onsite Generation Behavior	Unbalanced Voltage Operation

Model Development Principles

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Fidelity to Actual Response

- ✓ Models should accurately represent real plant responses, particularly during disturbances.
- ✓ If a model allows for assessing reliability risks, it is adequate for use even if the response isn't perfectly matched.

Modeling Details

- ✓ A single large load facility can have 100s of motors or power electronic devices. Meaningful aggregation is key
- ✓ Prime example is wind and PV plant modeling
- ✓ What we model also depends on the analyses at hand

Numerical Stability

- ✓ Models must be stable when used with solver supported by the respective simulation
- ✓ Time step for simulation should be chosen based on model time constants
- ✓ Models representing very high frequency dynamics require smaller time-step and higher simulation times

Dynamic Model Development Guidelines

PSPD Modeling

- Capture low-frequency dynamics (<10 Hz) essential for bulk-system stability assessments.
- ***Include outer-loop controls (P–f, Q–V), ride-through logic,***
- ***Ensure proper power-flow initialization***.
- Ensure aggregation is done such that model can be parameterized properly
- Add time constants where needed to ensure numerical stability

EMT Modeling

- ***Include models of all important components within the load facility including of protection and control as needed***
- Detail of modeling to depend on the type of assessments at hand
- Model must reliably self-initialize, support flexible time steps and multiple instances
- Include appropriate compiled binaries with timed-snapshot capability.

Documentation

- ***Supply a complete Releasable User Guide (RUG) with parameter definitions, allowed ranges, control descriptions, and operating assumptions.***
- Include a model-development and validation report detailing assumptions, benchmarks, and limitations
- Document all required inputs and provide guidance for correct setup in simulation tools.

Model Parameter Verification and Validation

- **Model parameter verification** - Ensure all model parameters (controls, protection settings, equipment values) accurately match real facility settings, using OEM data, documentation checking as appropriate
- **Model validation** – Confirm the model behaves like the actual facility by comparing simulations against field measurements, staged tests, and disturbance recordings; apply deviation thresholds and update models as facility behavior
  - **Electrical system data**: Collect detailed information on cables, overhead lines, impedances, transformers, reactive devices, filters, and any dynamic var support.
  - **Component data and MVA ratings**: Quantities of different load components within the facilities and their respective ratings
  - **Control and protection settings**: Supply voltage/frequency ride-through thresholds, protection schemes (over-voltage, over-current, DC-link protection), and any control logic influencing disturbance response.
- **Event and Continuous Measurement –** Install appropriate measurement devices to capture facility operation during events as well as during continuous operating conditions for model validation exercise

Model Quality Tests

- **Model Quality Testing**- Ensures that models submitted during the interconnection process are of acceptable standards such that they can be included in any interconnection study case files.
  - Flat-run stability test - Verify the model can initialize correctly and remain numerically stable with no disturbances for ~20 seconds, with real/reactive power and frequency staying steady.
  - Voltage & frequency ride-through test - Test model response to voltage dips/swells and frequency excursions, ensuring behavior matches expected ride-through or trip logic for the facility
  - Phase angle jump test - Apply sudden voltage phase shifts to confirm the model's ability to stay connected and maintain proper synchronization/control behavior under abrupt angle changes.
  - Controlled load change test - Introduce rapid increases/decreases in active power to observe model response, checking for correct P/Q behavior, oscillation characteristics, and stability.

Recommendations

- ❑ **Standardized Modeling Requirements** Establish clear guidelines and minimum data needs for both PSPD and EMT large load models.
- ❑ **Generic Library Model Development** Create generic models to support bulk-system studies and assess impacts of emerging large loads.
- ❑ **Model Quality Testing and Validation** Implement structured testing, verification, and validation to ensure trustworthy model behavior.
- ❑ **Industry Collaboration and Integration** Enhance collaboration among manufacturers, owners, and providers; integrate modeling into interconnection processes.