EMT for Large Loads

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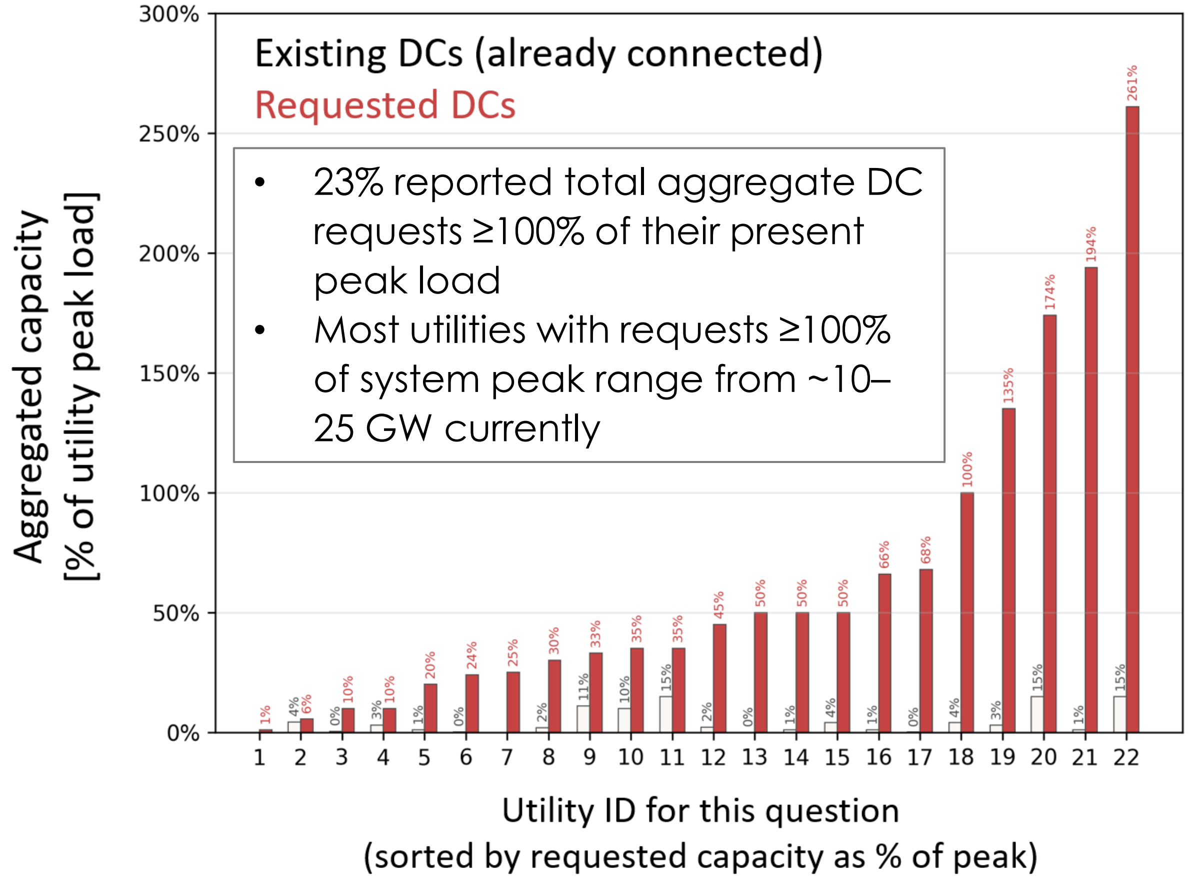
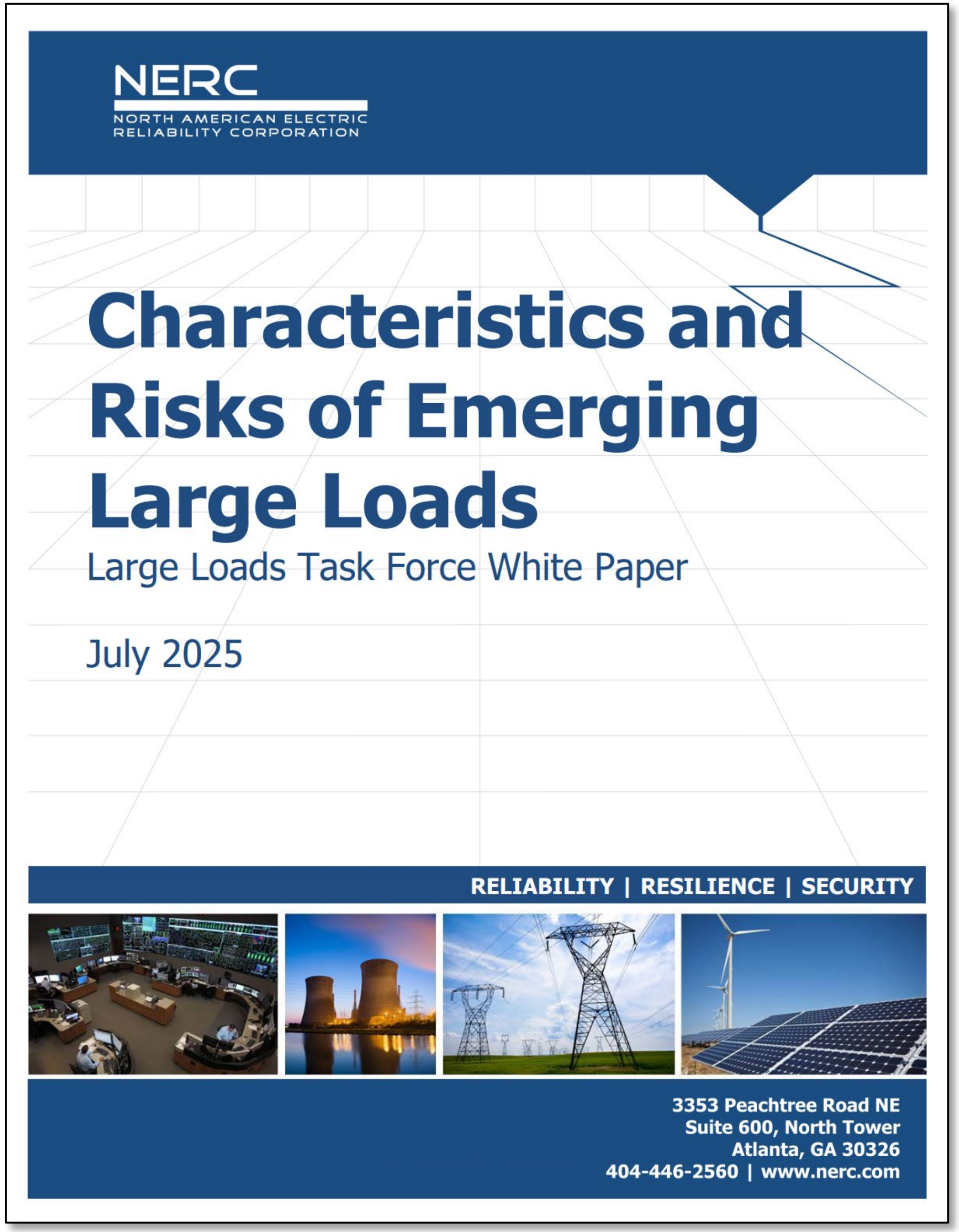
Introduction/Context

- NERC Large Load Whitepaper
  - [White Paper Characteristics and Risks of Emerging Large Loads]
- EPRI Industry Surveys:





Challenges with Large Loads

Fast and Uncertain Load Ramps

AI Training Fluctuations

Unanticipated Load Disconnection

Resource Adequacy

Modeling and Simulation

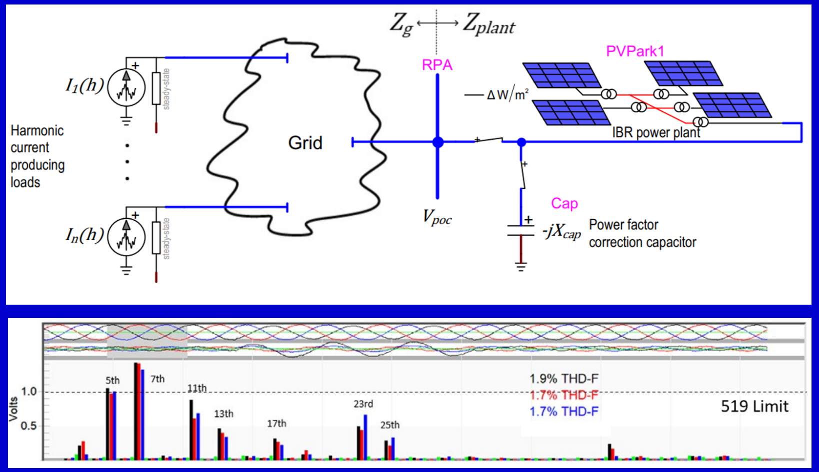
Forecasting

Infrastructure

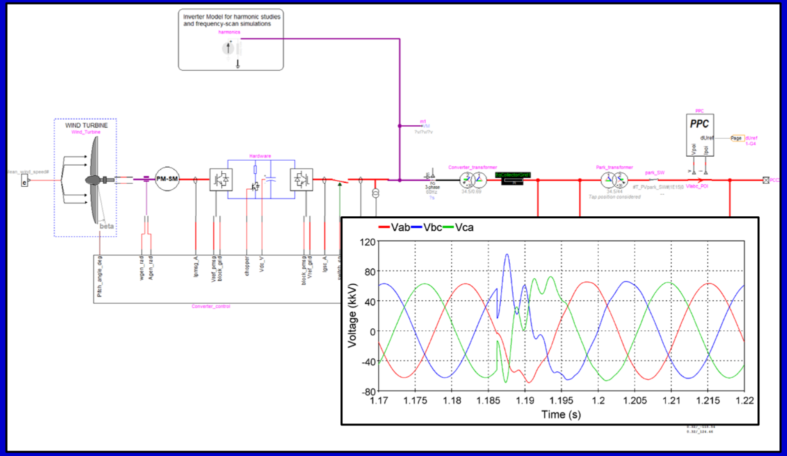
EMT Large Load Modeling Gaps

- Can the EMT assessment process be more streamlined?
- How to model power system components in EMT?
- What level of detail should they be modeled for a given study type?
- Where to source model parameter values?
- Why the study is being run and what results are critical?

B – Transmission Harmonics

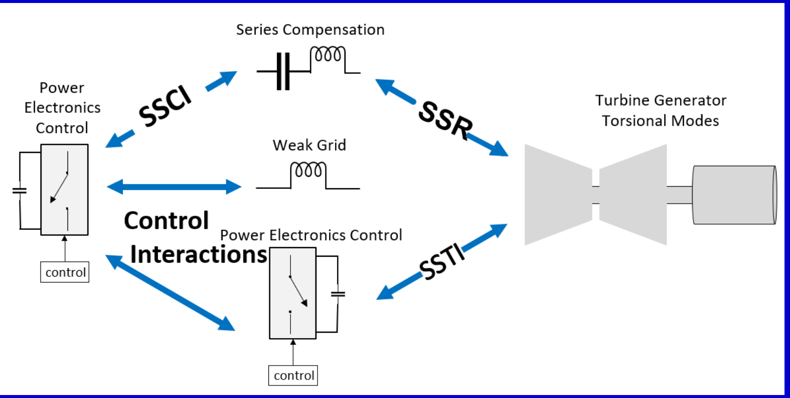


C – Transmission EMT



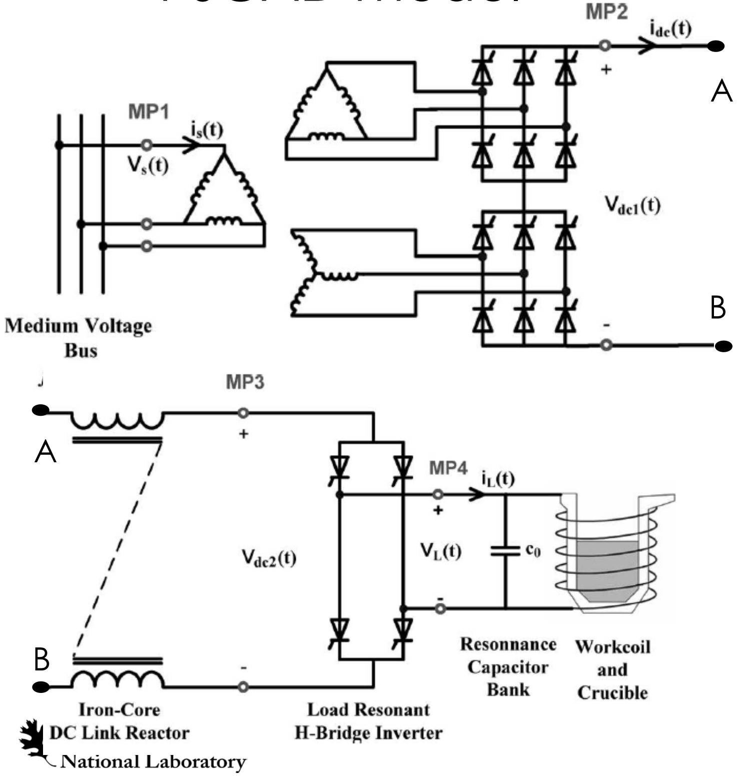
- **PS40D – Special Planning Studies, Methods, & Tools**
  - **PS40D.B:** Increase efficiency in transmission harmonic modeling and analysis.
  - **PS40D.C:** Develop methods/tools to improve EMT studies.
  - **PS40D.D:** SSO due to control interactions, torsional interactions especially in connection to Large Loads.

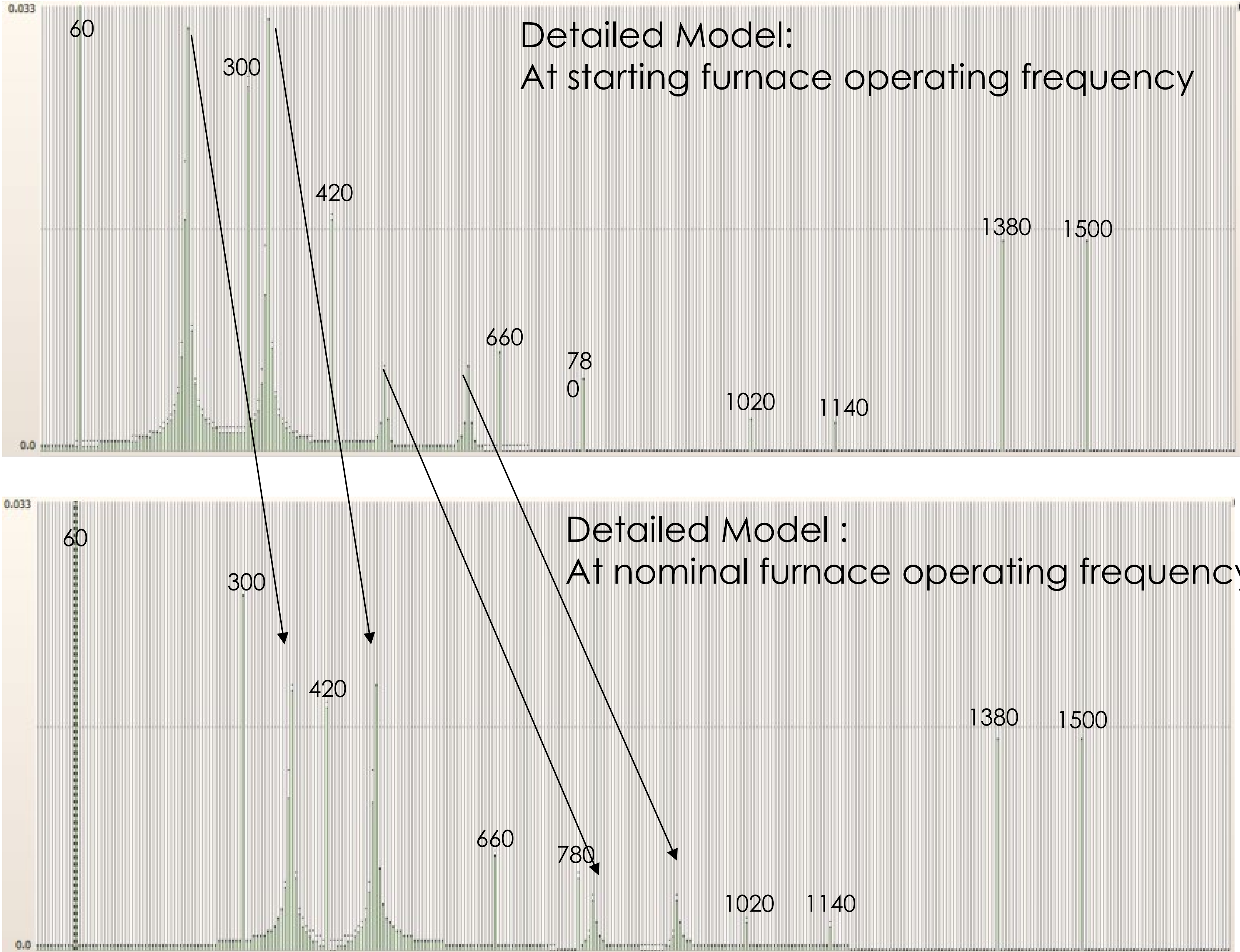
D – Sub-Sync. Interactions



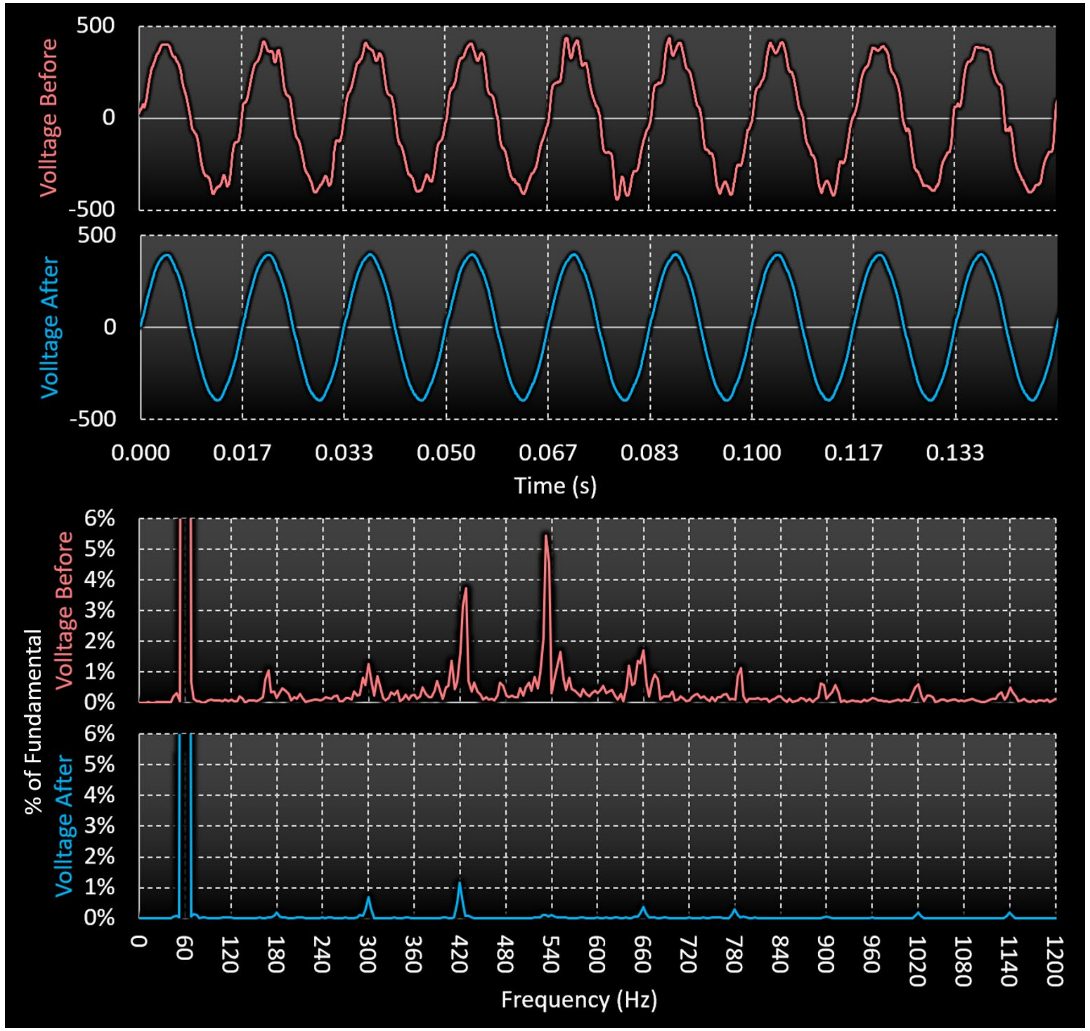
Library of Large Load EMT Models

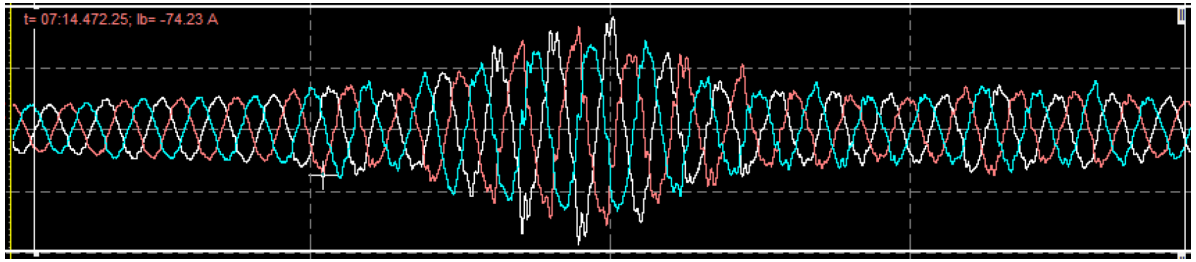
- EMT Model of a Medium Frequency Induction Furnace
- Developed both
  - EMTP model
  - PSCAD model

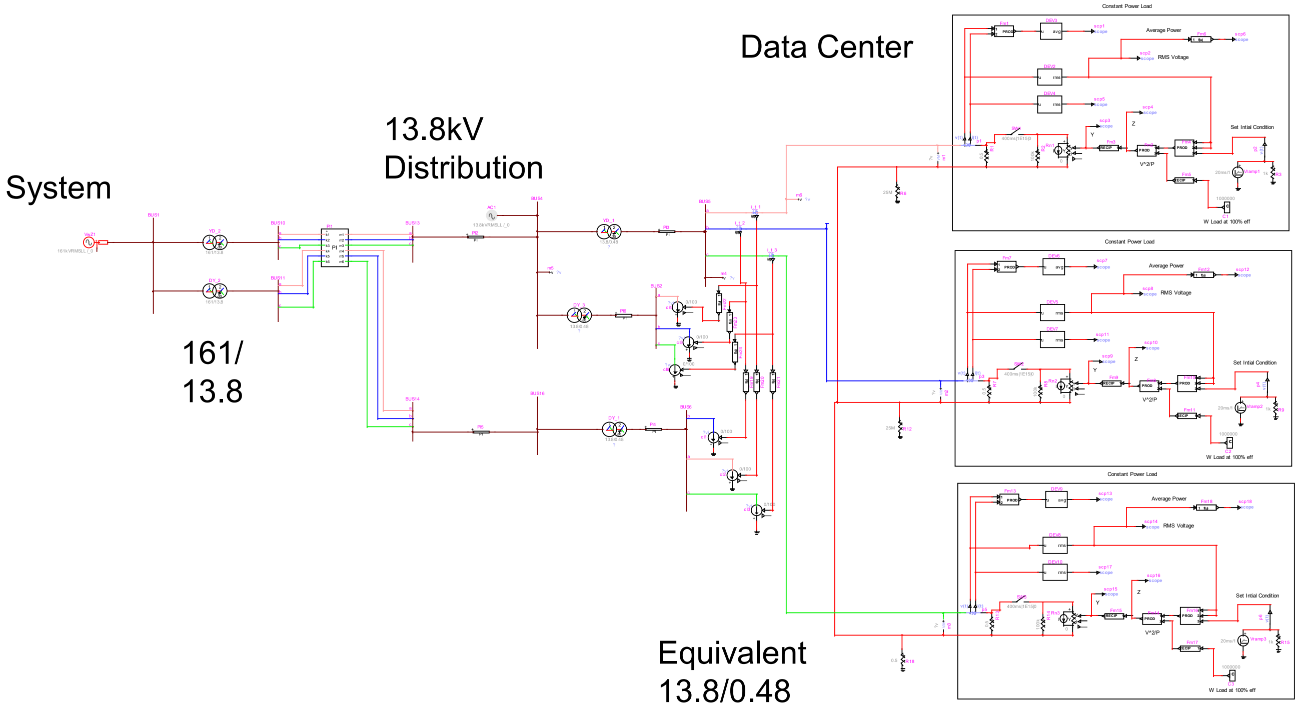




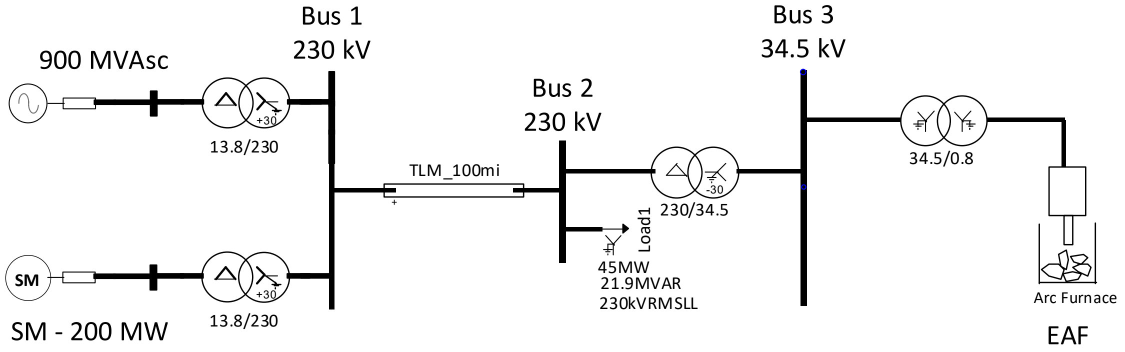
Large Load System Interactions

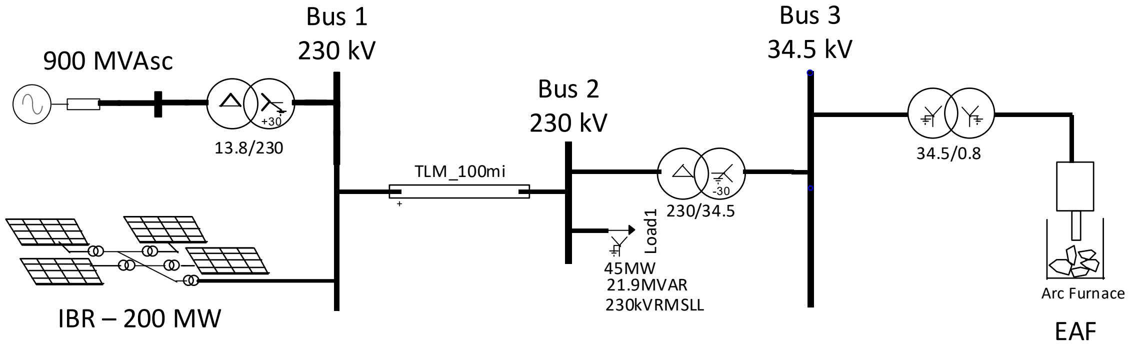


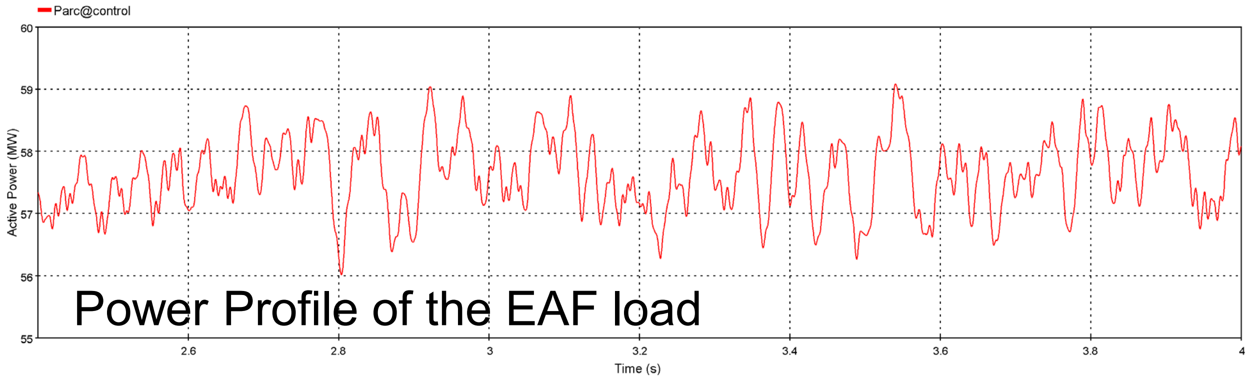




Electric Arc Furnace Flicker Example



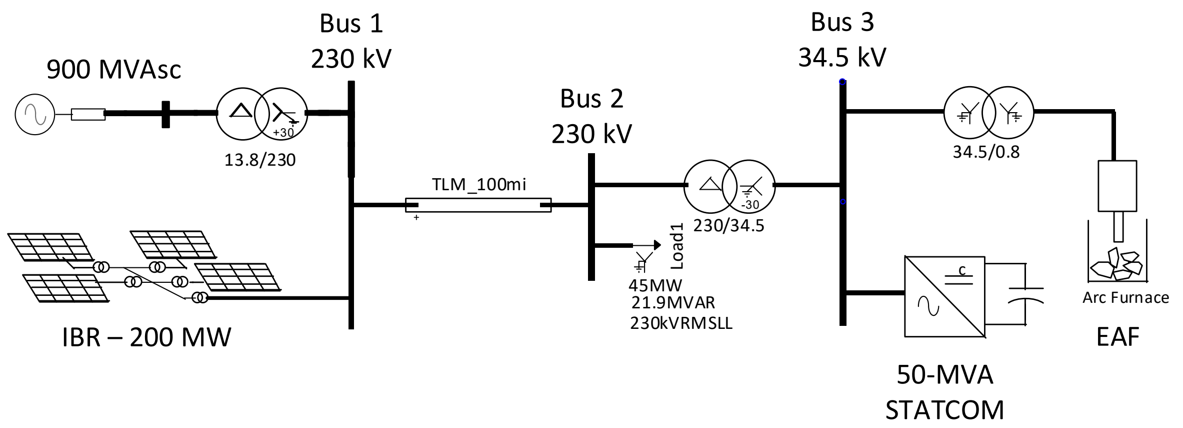


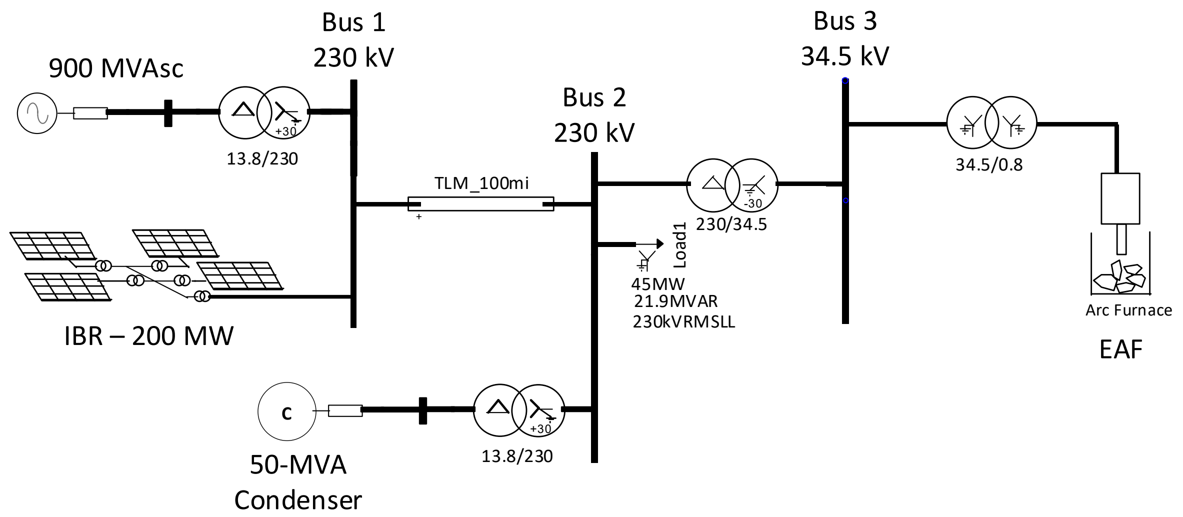


			SCC	PST	PST
Generation Type	Arc Furnace	Mitigation	MVA	230kV	34.5kV
System + 200MW Synchronous Gen	70MW	None	689	1.21	1.66
System + 200-MW PV (Replaced 200MW SM)	70MW	None	492	1.85	2.4

Replacing a 200-MW SM with a PV farm causes voltage fluctuation and flicker disturbances.

Grid Enhancement Technology Modeling

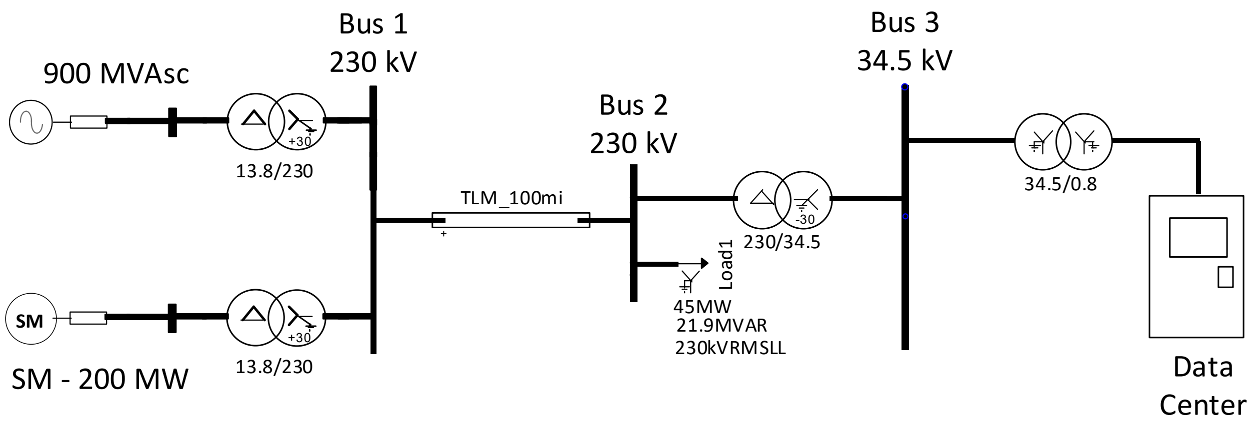


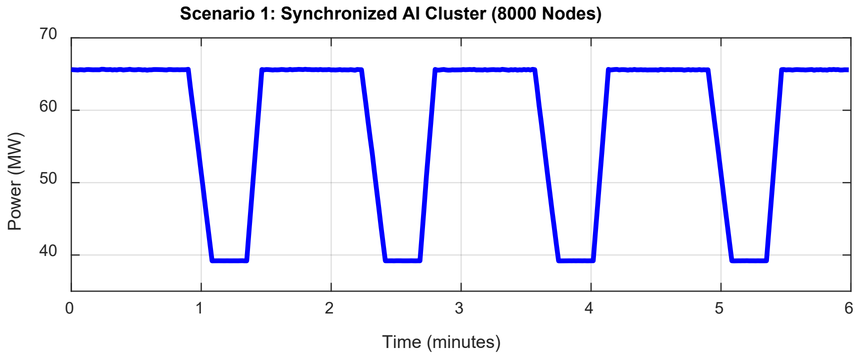


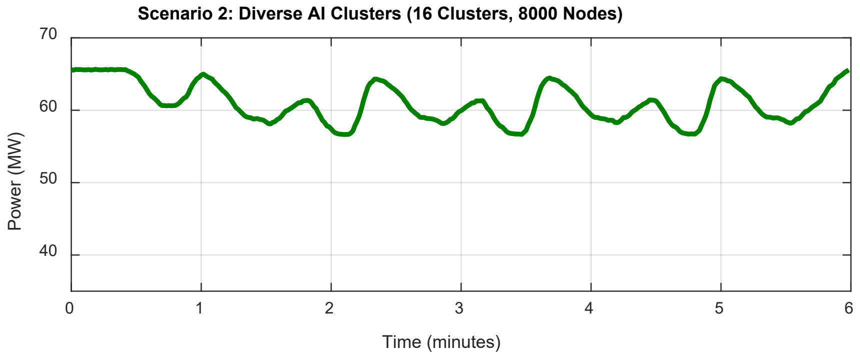
		SCC	PST	PST
Generation Type	Mitigation	MVA	230kV	34.5kV
System + 200MW Synchronous Gen	None	689	1.21	1.66
System + 200-MW PV (Replaced 200MW SM)	None	492	1.85	2.4
System + 200-MW PV (Replaced 200MW SM)	40MVA STATCOM (connected to 34.5kV bus)	492	1.25	2.07
System + 200-MW PV (Replaced 200MW SM)	50MVA Condenser (connected to 138kV bus)	858	0.92	1.27

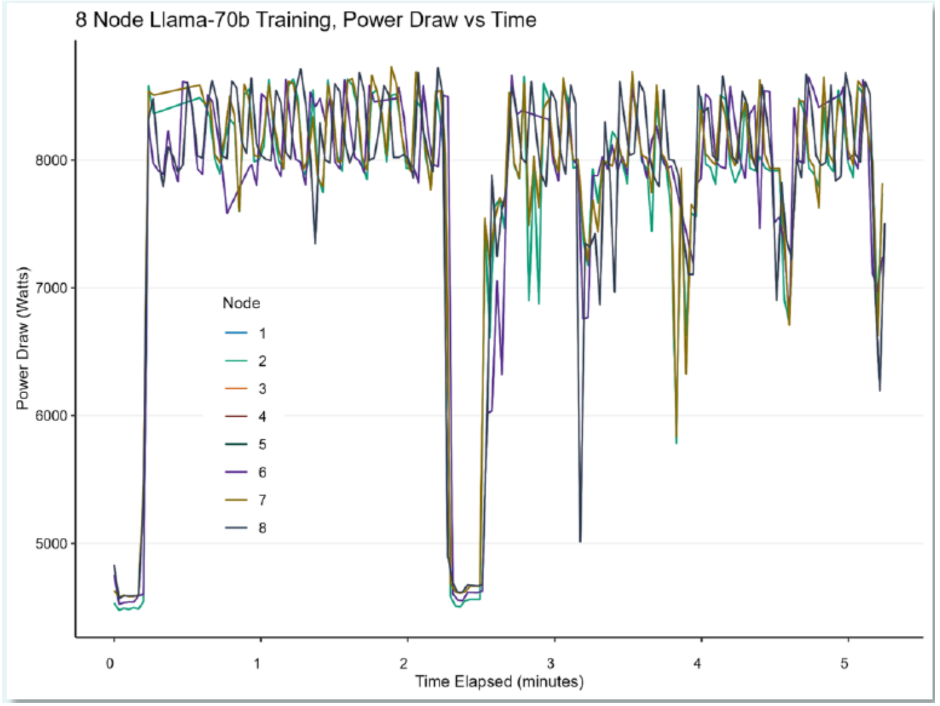
A synchronous condenser (50 MVA) is more effective than a STATCOM in mitigating voltage fluctuation and flicker disturbances. It brings PSTs to a lower level than when the 200-MW SM is present.

Data Center Flicker Example









[lbnl-2024-united-states-data-center-energy-usage-report_1.pdf]

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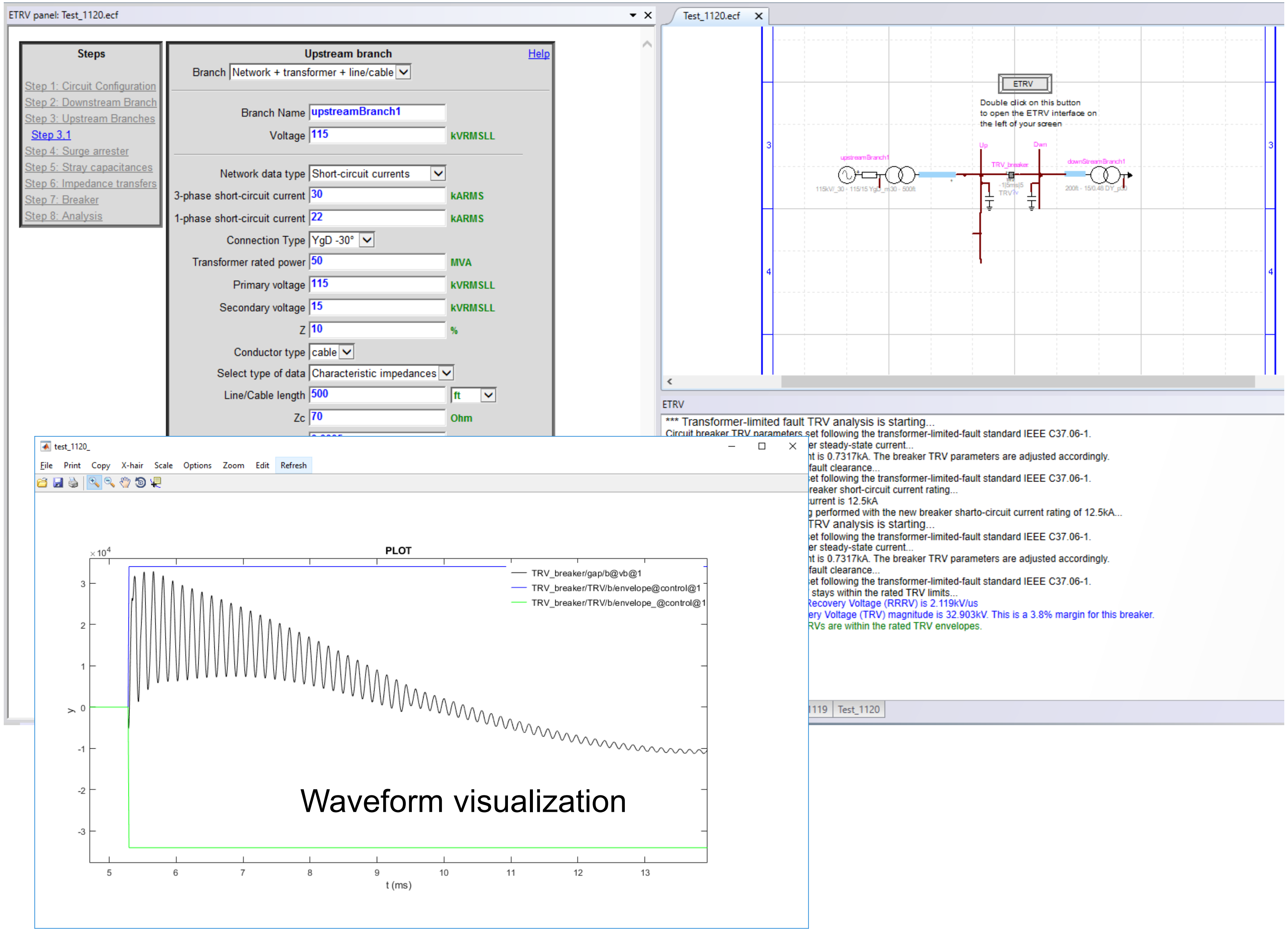
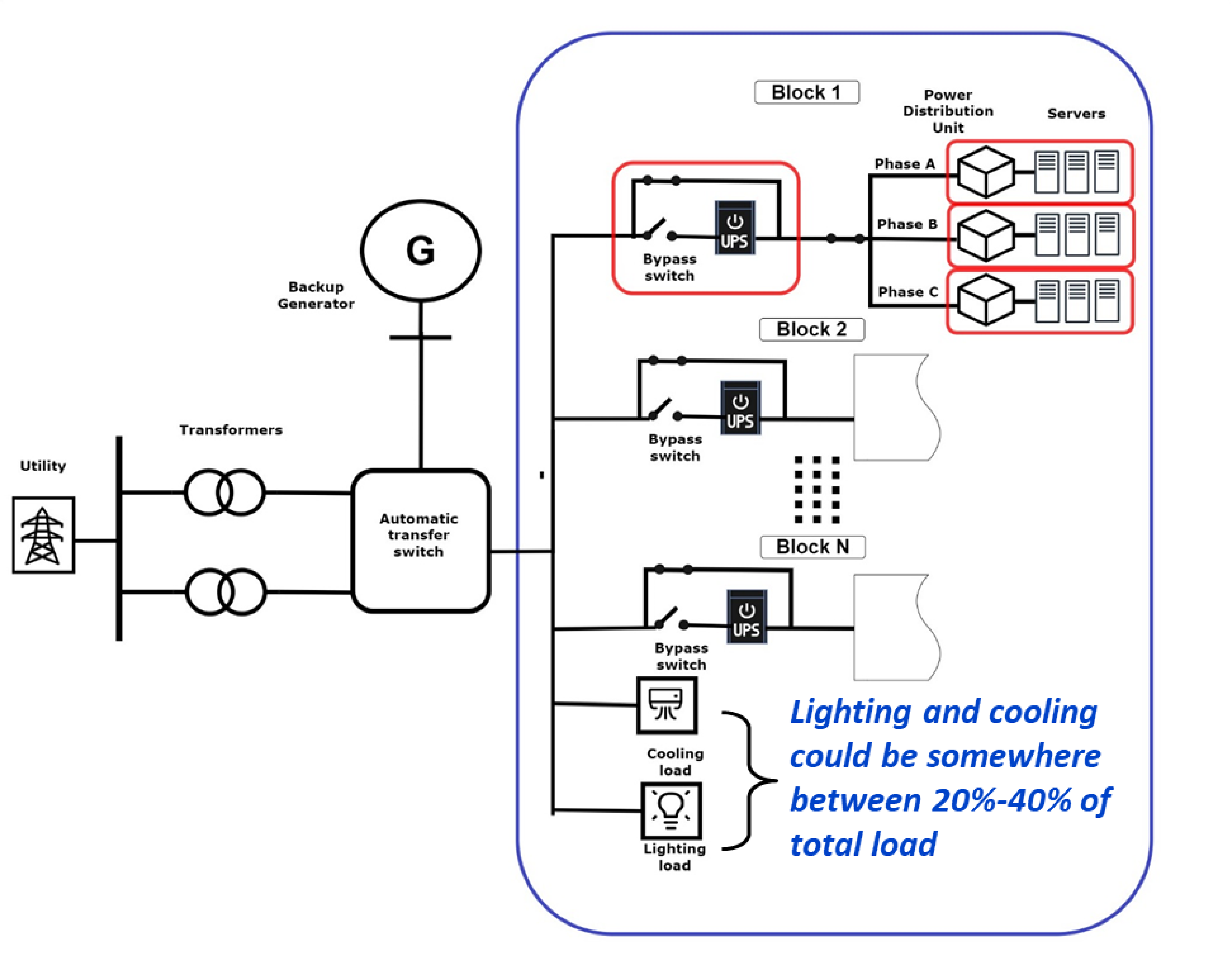
Streamlined EMT Assessment Process – GUI

- EMTP GUI has been modified to allow a more guided use of the software
- Circuits are automatically built with the minimum amount of data required for TRV studies
- The prospective TRVs obtained by simulation are automatically superimposed with standard breaker capability curves.
- Reports are automatically generated after the analysis is completed



Data Center Electrical Distribution



About 90% of the total load is electronically driven (Switched Mode Power Supplies and Electronic Drives)

The main electrical equipment that interfaces with the grid are:

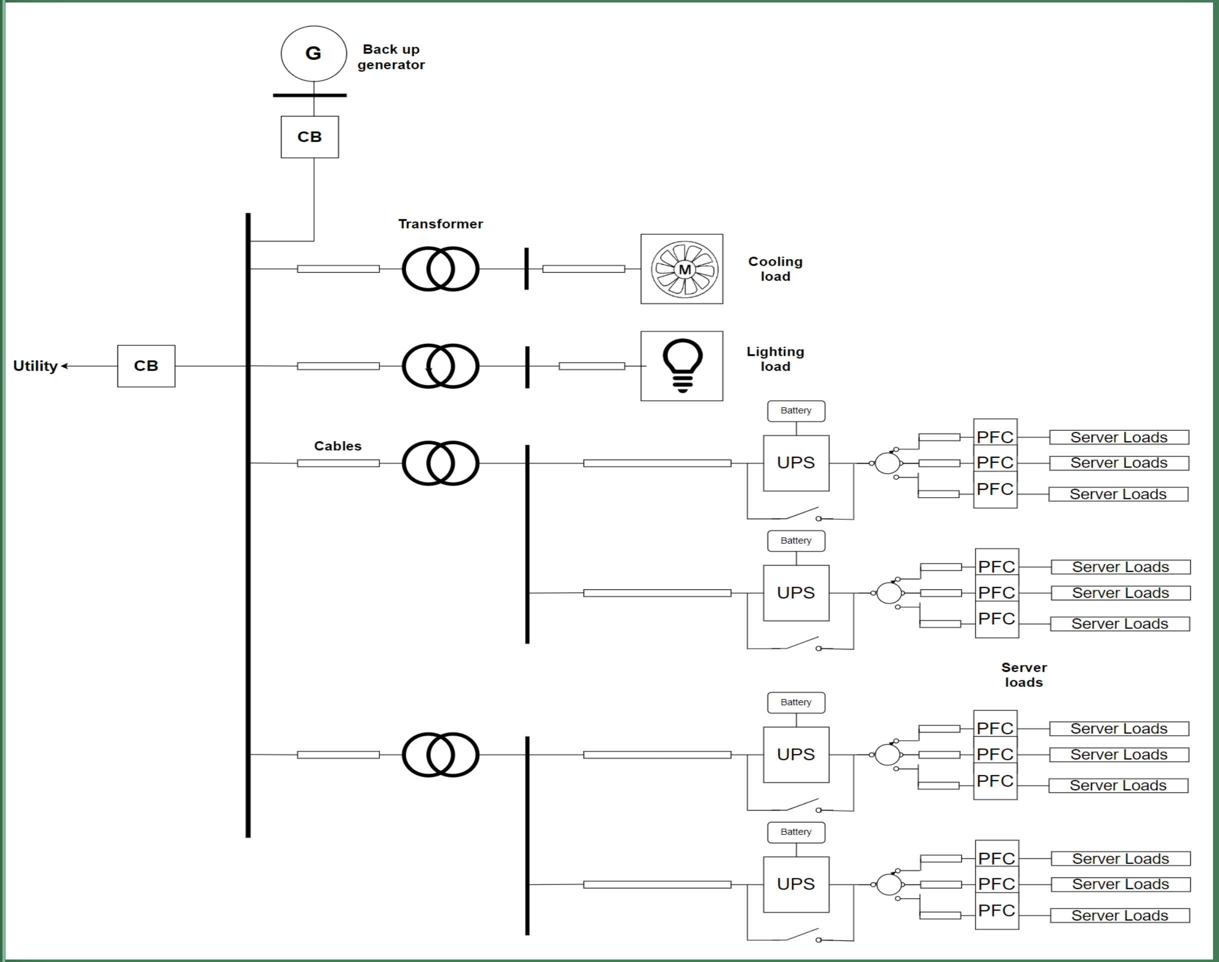
- ***Uninterruptible power supply***
- ***Single phase power supply units (*)***
- ***Variable speed drives/direct connected motors***
- ***Lighting (LED)***
- ***Battery Energy Storage/Power Conditioning Equipment (*)***

EMT Modeling of Data Centers

- ***Full facility model***. Details of cables and transformers taken from sample real data center layout

- Each equipment modeled to the switch level; model can be utilized for studying high frequency interactions

- Model includes transformers and cables, and all active and reactive power losses can be captured at site POI



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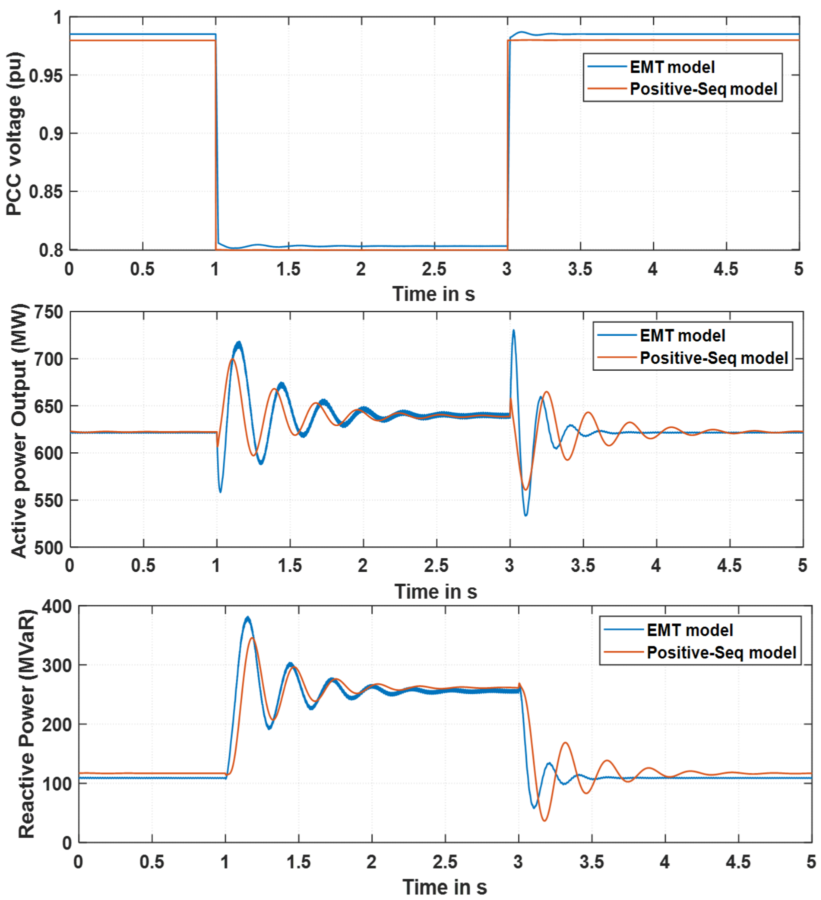
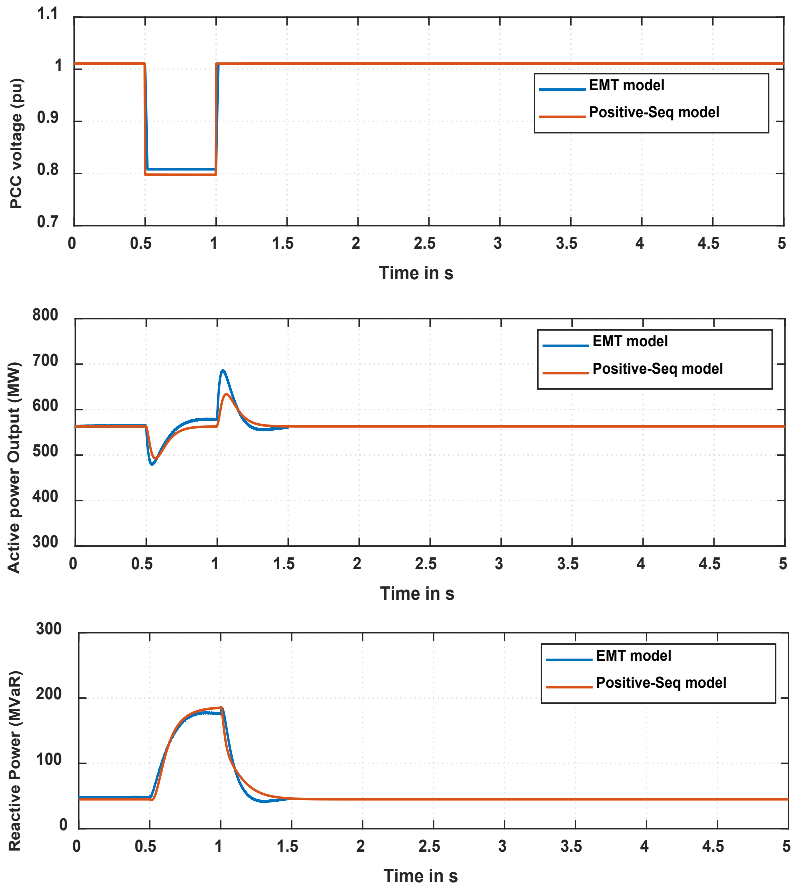
Simulation results (Data center)

The response of a detailed EMT model (switching) of a data center was tested with 80% reduced terminal voltage

UPS mode



Bypass mode



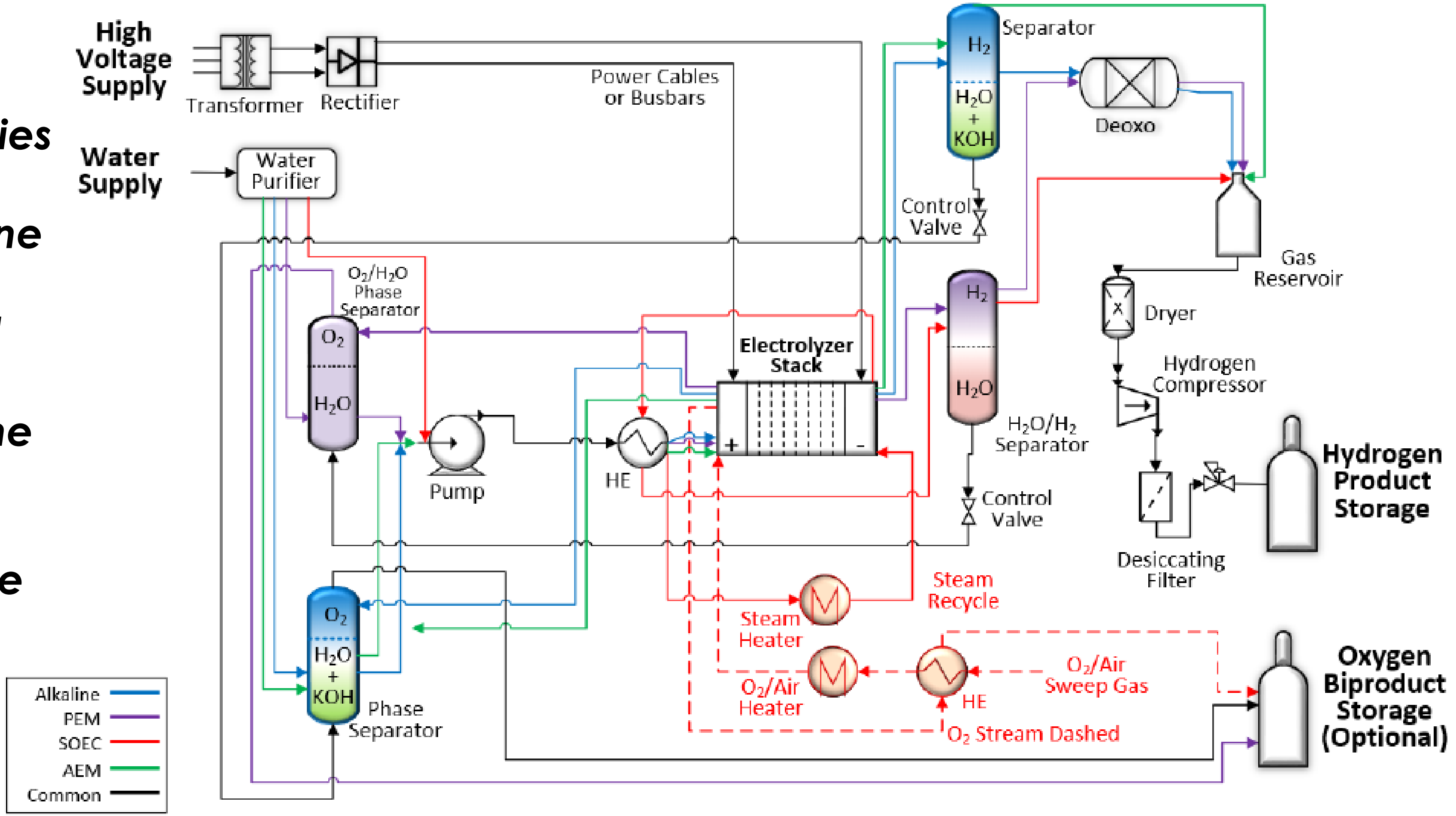
- **Active power response reached the pre-disturbance level after a time delay**
- **Reactive power consumption increased due to shunt capacitors in the facility**
- **Second order response in active/ reactive power was observed in the UPS mode**
- **First order response was observed in the bypass mode**

Electrolyzer technologies

4 Main Electrolyzer Technologies

1. ***Alkaline - Mature***
2. ***Proton exchange membrane (PEM) - Mature***
3. ***Solid oxide electrolysis cell (SOEC) – New***
4. ***Anion exchange membrane (AEM) – New***

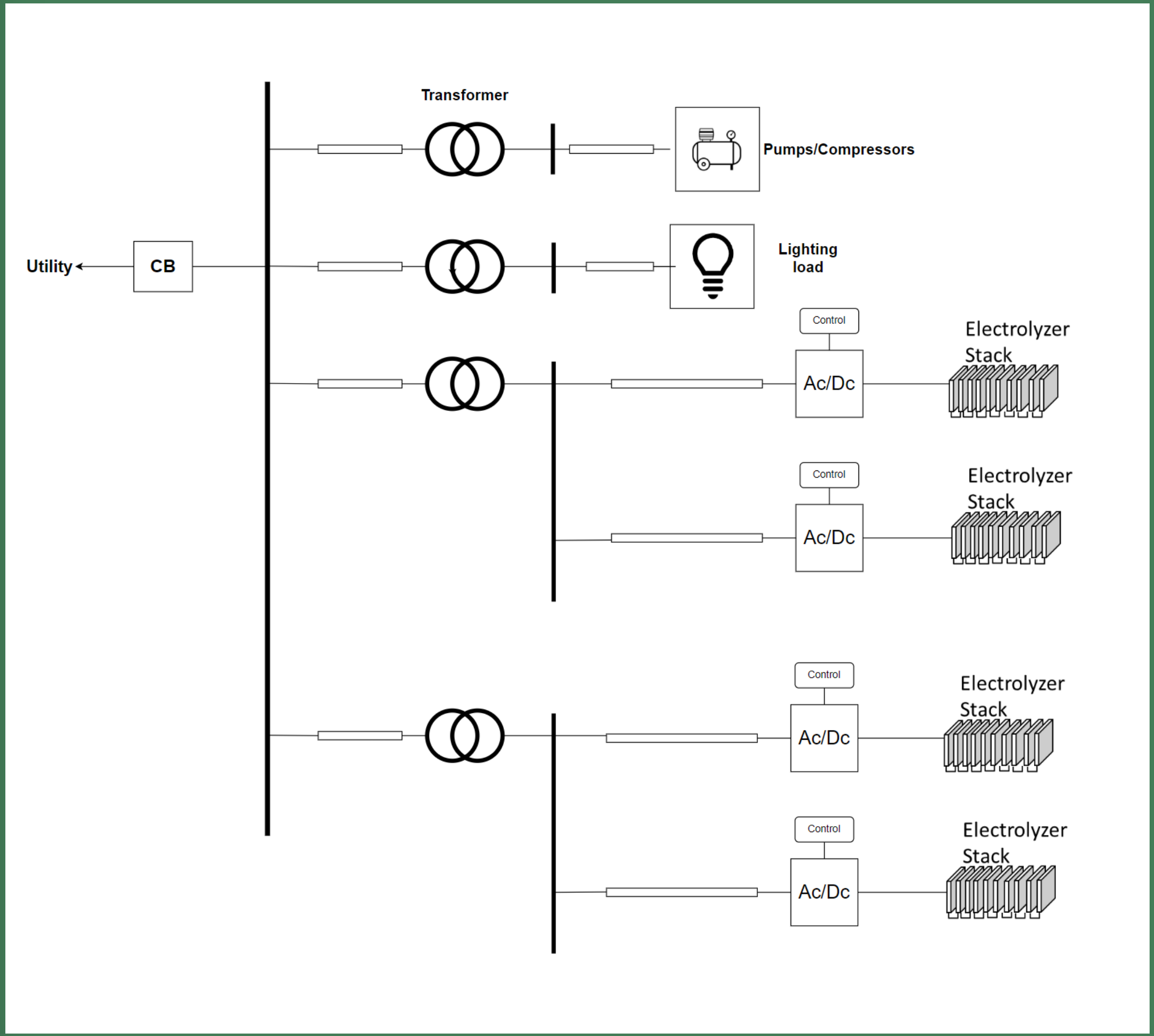
90% power is consumed by the electrolyzer stack common to all technologies



All electrolyzers technologies have similar electrical loads

EMT modeling of H_2 Electrolysis Facility

- Full facility models with an assumed layout of the facility
- Includes models of cables and transformers
- All observations to be compared made the POI of the facility



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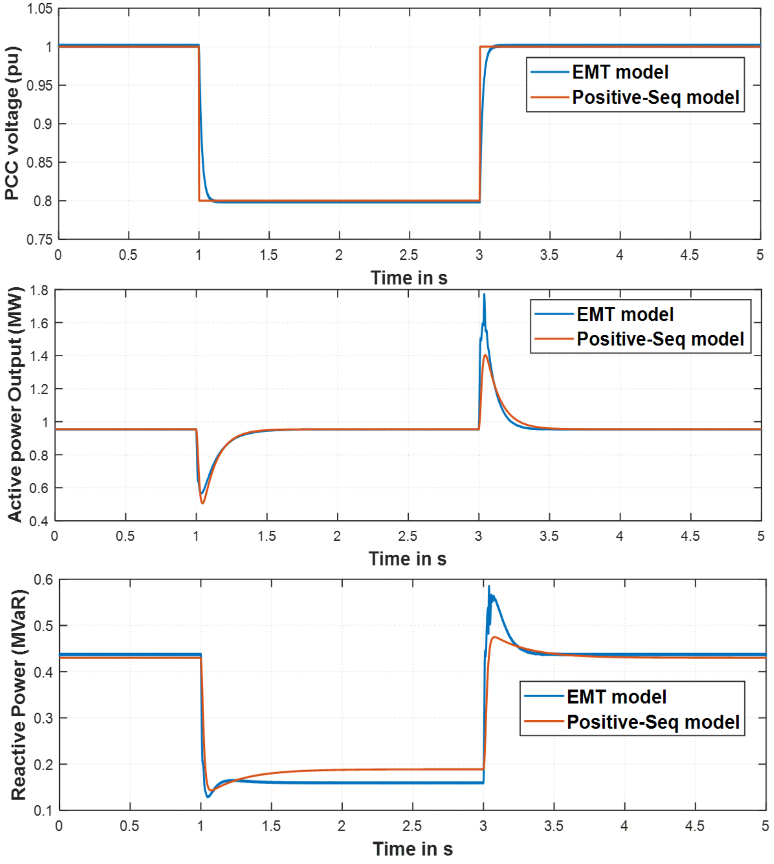
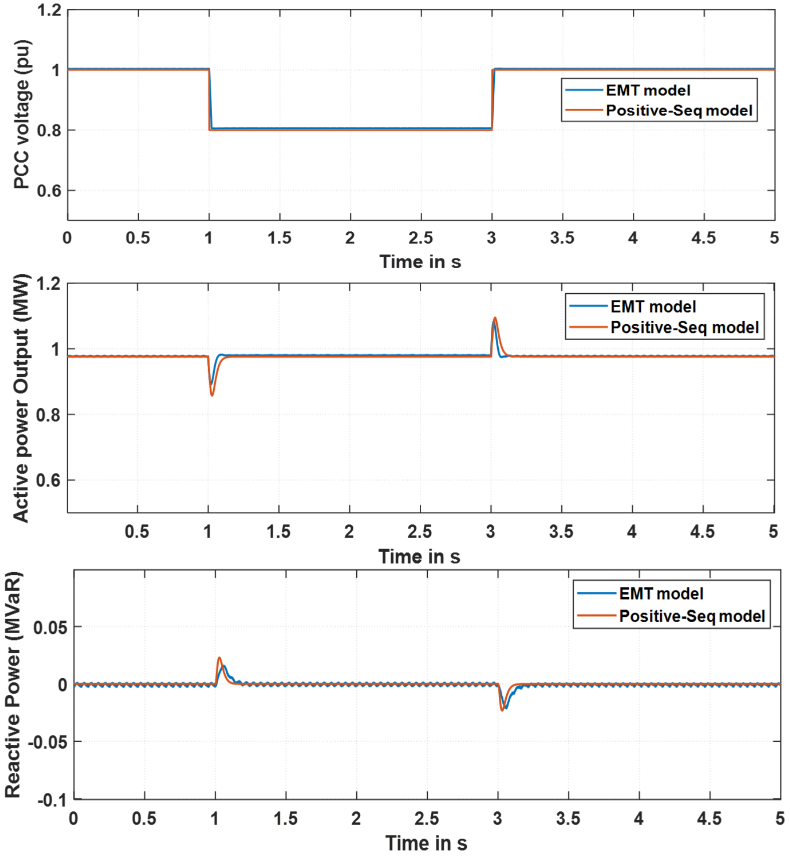
Simulation results (Hydrogen electrolyzer)

The response of a detailed EMT model (switching) of a hydrogen electrolyzer facility was tested with 80% reduced terminal voltage

Thyristor based rectifier



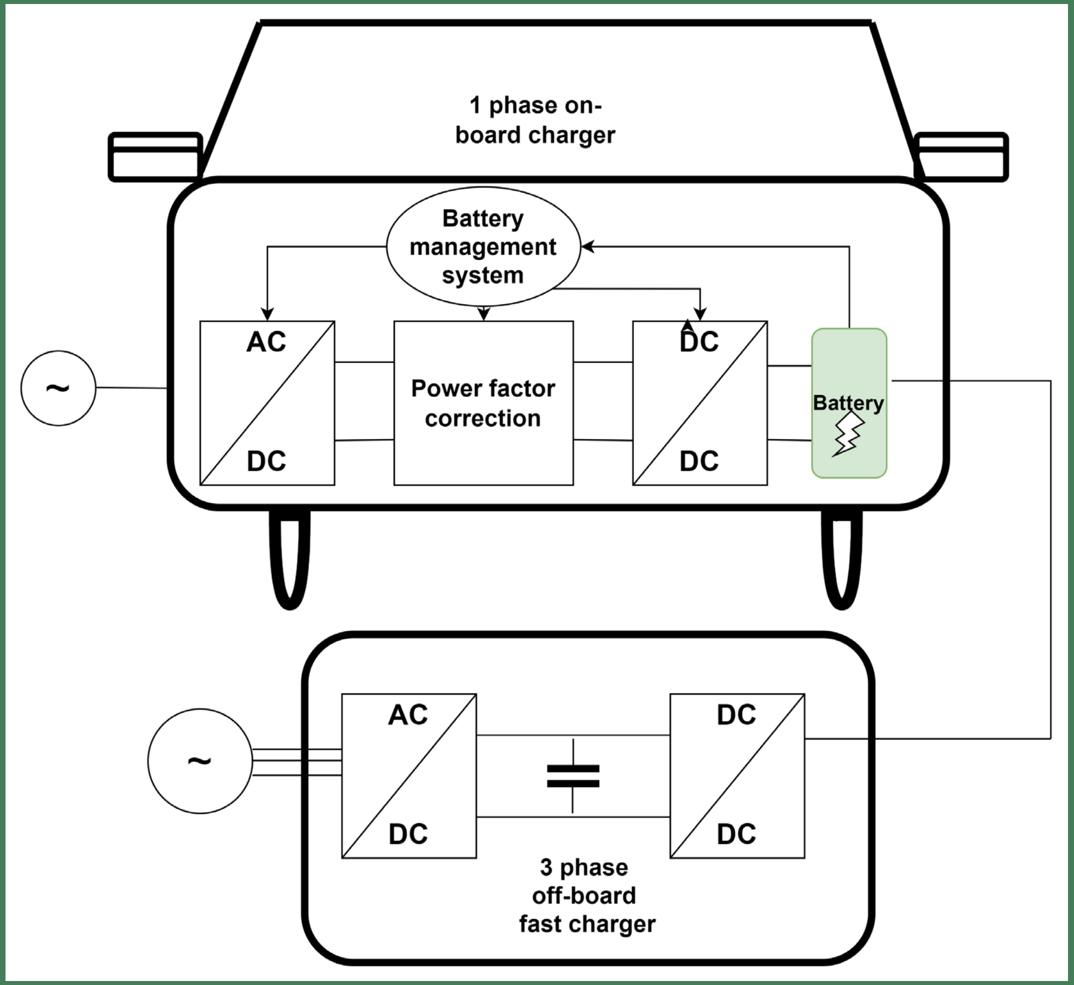
IGBT based rectifier



- **Active power response reached the pre-disturbance level after a time delay**
- **Reactive power could be maintained at the pre-fault levels in the IGBT rectifier case**
- **Reactive power consumption of the thyristor-based rectifier depends on the terminal voltage**
- **First order response in active/ reactive power was observed in both configurations**

EMT modeling of EV charger (aggregated)

- Average model
- Bidirectional power flow
- PLL model
- Dc voltage control loop
- Current control loops (Id, Iq=0)
- EV load disconnection modeling (Aggregated)
- 3 phase and 1 phase EV chargers



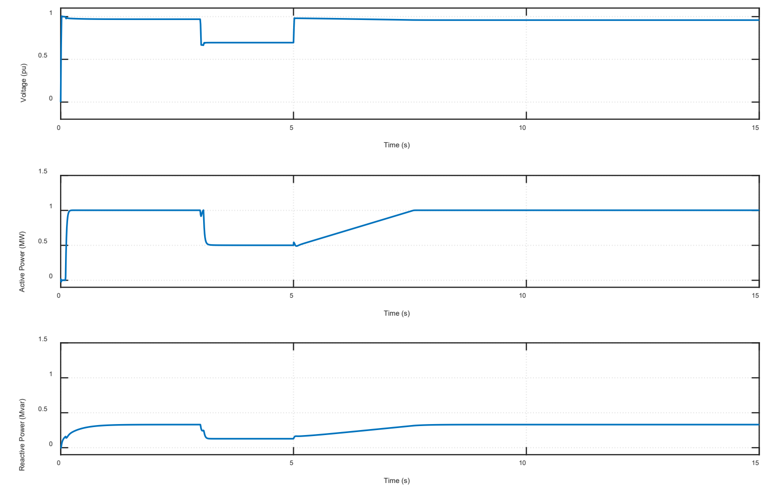
3 phase EV charger : Terminal Voltage reduced to 0.7 pu for 1s (Fraction cease =0.5)

Parameter	Value
Power Rating	1 MW
V cease	0.8 pu
T cease	0.01 s
T delay	0.01 s
V reconnect	0.9 pu
T reconnect	0.01 s
T ramp	5 s
Fraction to be ceased	0.5
Imax	1.2pu

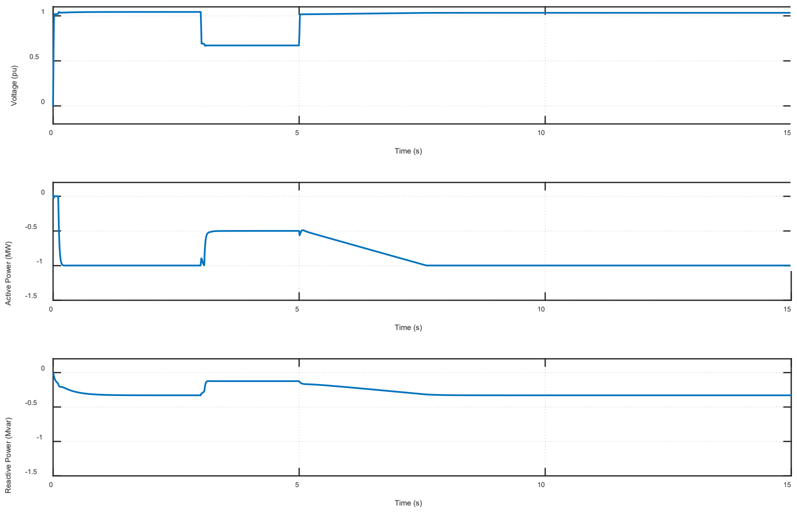
Key Takeaway

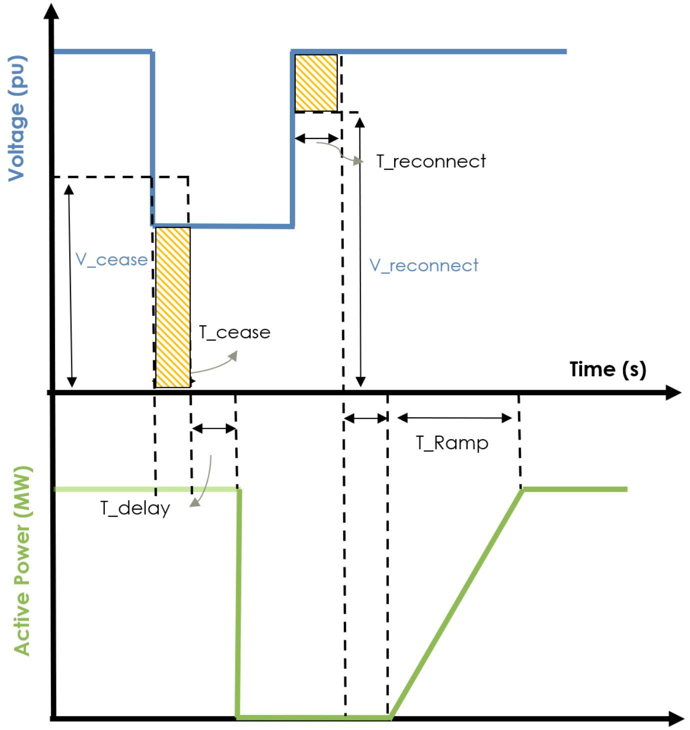
- For deeper voltage disturbances, mode can temporarily disconnect a fraction of the load and reconnect with a ramp after a delay (Fraction ceased =0.5)

Grid to Vehicle

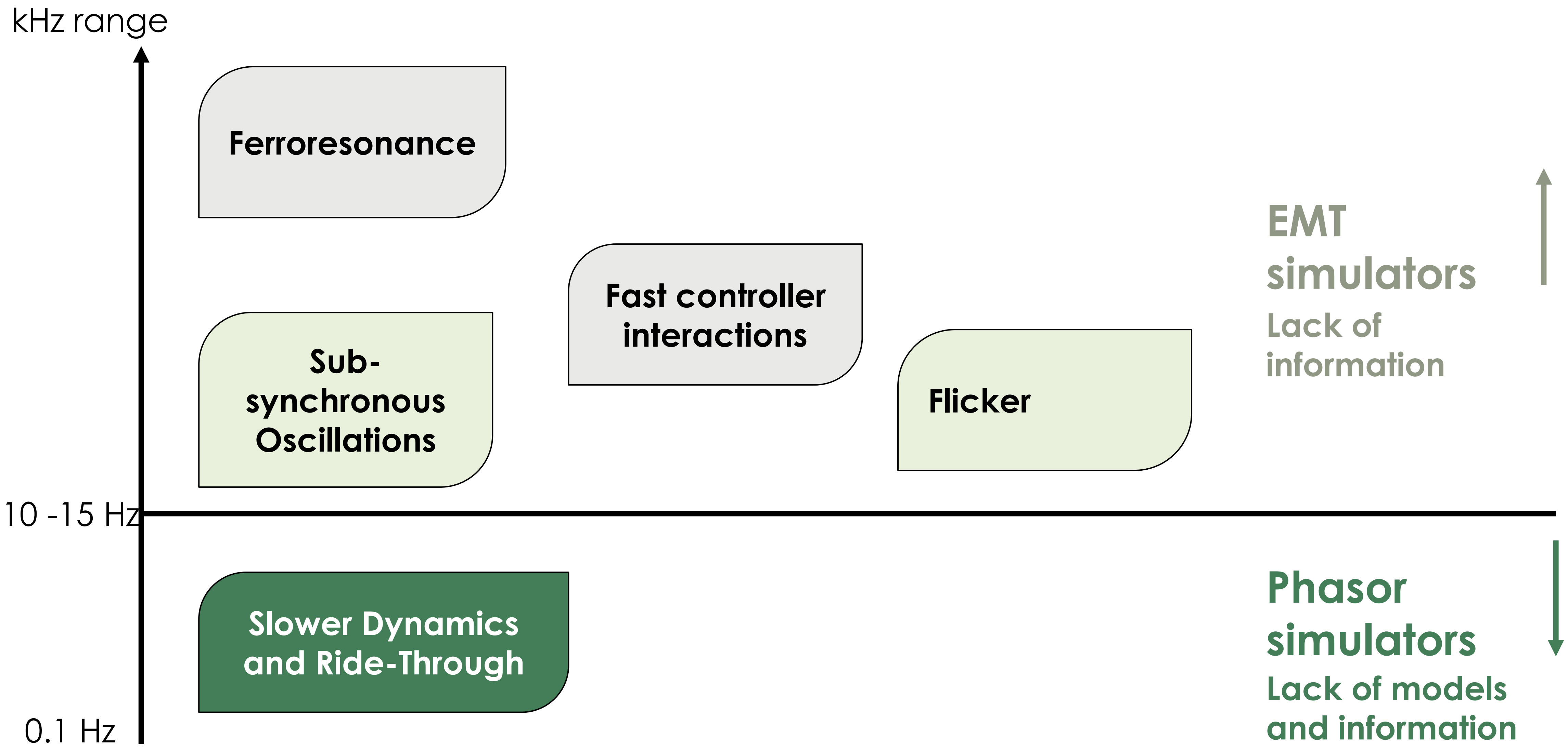


Vehicle to Grid





Modeling for Transmission Planning Studies



EMT vs Phasor Model – What are the needs?

	EMT	Phasor
Generic	Develop understanding of device at hand, Screen for possible risks, Possibly use as starting point of OEM models. **Not suitable for issue resolution.**	Long-term assessments, Bulk system reliability risks. **Not suitable for equipment specific dynamics that might be of interest.**
Vendor Specific	Actual risk screening, solution for issues arising at facilities. **Not suitable for developing understanding of device at hand (generally black-box models).**	Actual risk screening, solution for issues arising at facilities not represented by generic models. **Not very suitable for long-term assessments.**

EPRI Power Delivery Research

Planning (PS40A)	Planning (PS40D)	Operations (P39)
• Modeling of Large Loads. • Bulk system impacts of large loads – Stability, voltage and frequency response. • Ride-through capabilities and supporting industry on ride thru requirements • Local interactions with large loads.	• Transmission power quality impact assessment from large loads, e.g. voltage sags, voltage fluctuations, harmonics • EMT Modeling, e.g., transients, full-phase modeling, negative and zero sequence impedances • Fluctuations/ Sub-synchronous interactions	• Reactive Power Management considering Large Loads in operation and Planning. • Detection and source location of forced oscillations from large loads in real-time operations. • Operational solutions to deal with large load disconnection

Transmission Planning and Large Load Research