EMT Study Considerations for Integration and Operation of Large Loads in SPP

Mostafa Sedighizadeh

Lead Engineer, Planning Policy & Research
Southwest Power Pool (SPP)

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Introduction/Context

- large loads are important in SPP because the numbers clearly show a rapid growth trend that has real operational and planning impacts:

Significant Installed Base already (2021-2025)	• **16 large loads** are already in service or near commissioning (5.5 GW~10% of SPP summer peak)
Pipeline Still Growing (2025-2027)	• **5 large loads** are under active development (1.5 GW)
Large load matters because	• Planning & Reliability; Operational Flexibility; Market & Tariff Implications

How does SPP define a large load?

Definition

- A new commercial or industrial load, or increase in commercial or industrial load, at a single site connected through one or more shared Points of Interconnection (POIs) or delivery points

MW Threshold

- Less than or equal to 69 kV
  - Greater than or equal to 10 MW
- Greater than 69 kV
  - Greater than or equal to 50 MW

Challenges Observed

Step-Change Demand Growth

- Example: In 2024, a Pumping station (810 MW) came online in SPP's southwest region (equivalent to adding ~810,000 homes worth of demand overnight).

Unpredictable and Emerging Industries

- Example: In 2022, a 500 MW crypto load was added in SPP's southeast region. These loads often operate 24/7 but can curtail abruptly depending on power prices.

Grid Stability and Dynamic Performance

- Gas compressor stations (600 MW in 2022, SPP southwest region)can cause local voltage dips or reactive power swings—something RMS studies alone can't capture.

Challenges Observed (Cont.)

Transmission Constraints & Upgrade Needs

- Example: A 459 MW data center in Nebraska (2025) requires multi-million-dollar transmission reinforcements before it can interconnect.

Resource Adequacy & Market Impacts

- Example: A 350 MW load in the Southwest region (2025) may need to be studied both as firm and curtailable, affecting Planning Reserve Margin (PRM) and LOLE studies.

Community and Reliability Impacts

- A pumping station or industrial park tying into a weaker part of the grid can cause local instability, requiring synchronous condensers or special protection schemes.

why are phasor-domain tools insufficient?

Limited Ability to Capture Fast Dynamics

- Example: A 500 MW crypto mining load (2022) with high-frequency switching converters introduced harmonics and fast flicker effects.

Voltage Stability and Motor Starting

- Example: A 600 MW gas compressor load (2022) triggers local voltage depression at energization, risking equipment trips if not modeled at EMT level.

Inverter-Based Load Components

- A 200 MW data center (2021) may drop offline within milliseconds after a fault, something RMS cannot simulate but EMT can.

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why are phasor-domain tools insufficient? (Cont.)

Fault-Induced Delayed Voltage Recovery (FIDVR)

- Example: A pumping station load in SPP could worsen fault recovery locally, requiring EMT to validate voltage ride-through.

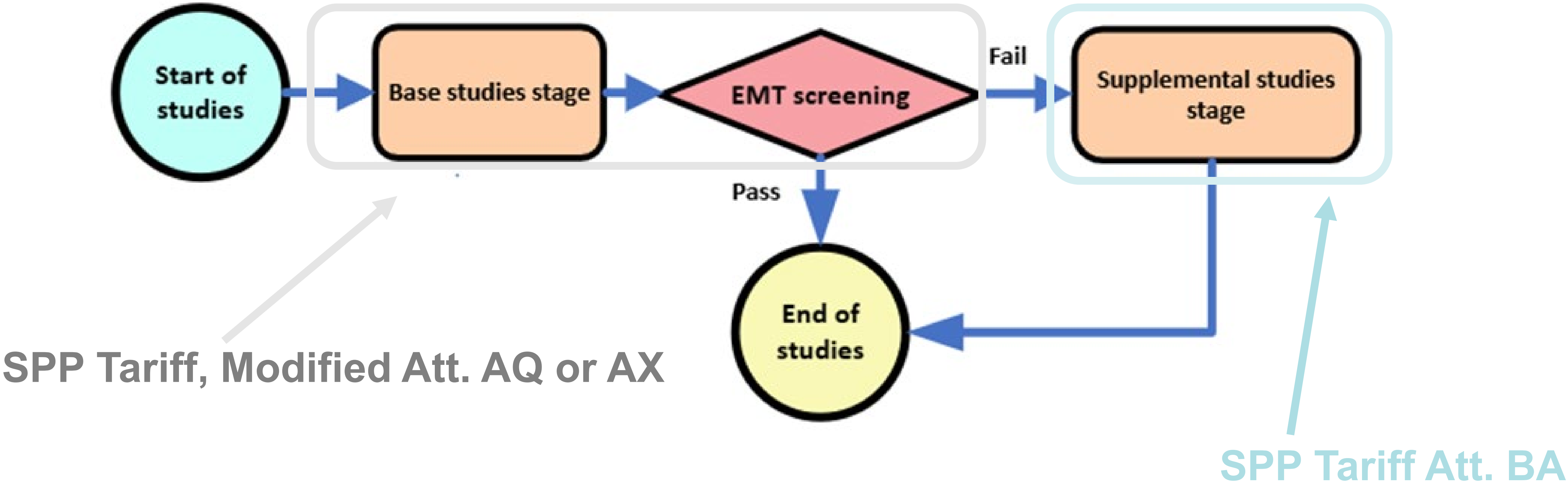
Local Weak Grid Impacts

- Example: The 459 MW data center in Nebraska (2025) is planned in a relatively weak transmission pocket; EMT studies are needed to check short-term stability.

Study Load–Renewable Interactions

- Many large loads co-locate with renewable generation, requiring EMT to study coupled behavior.

recommended large load interconnection studies



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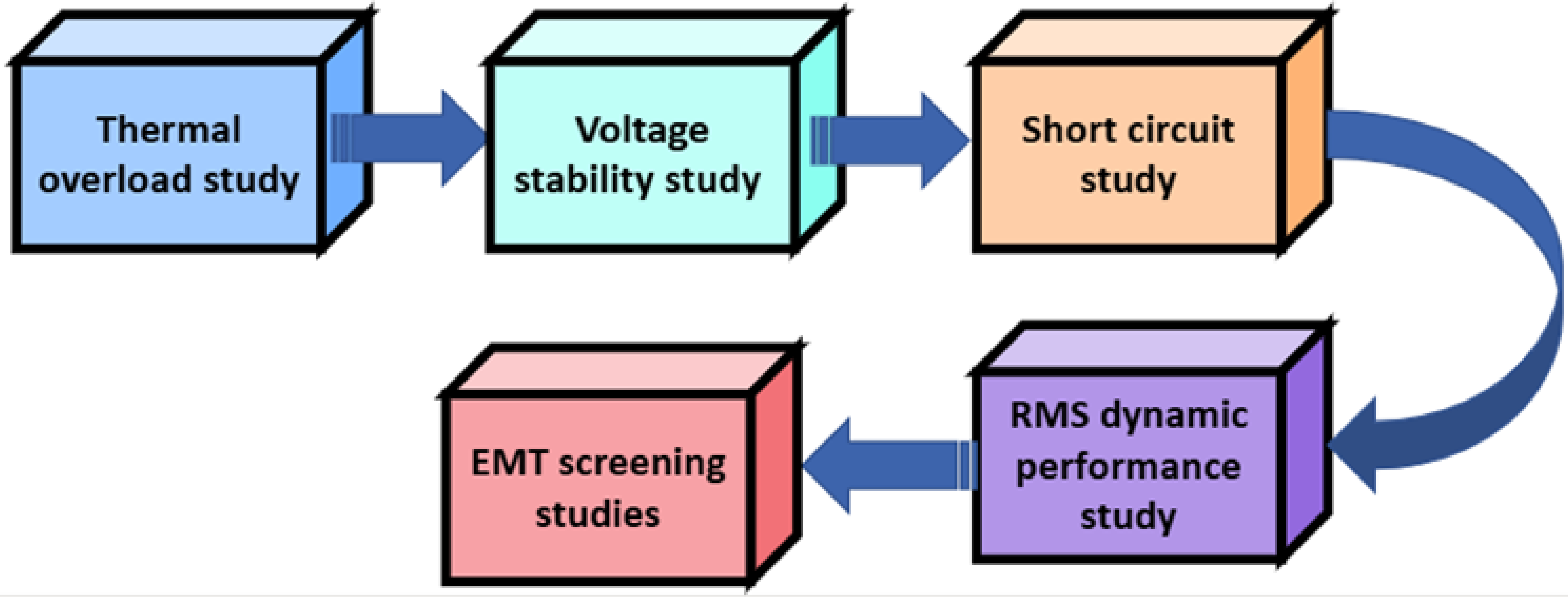
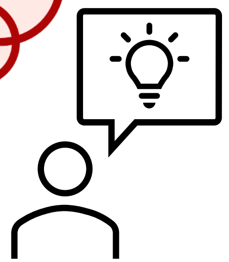
Base Studies Stage



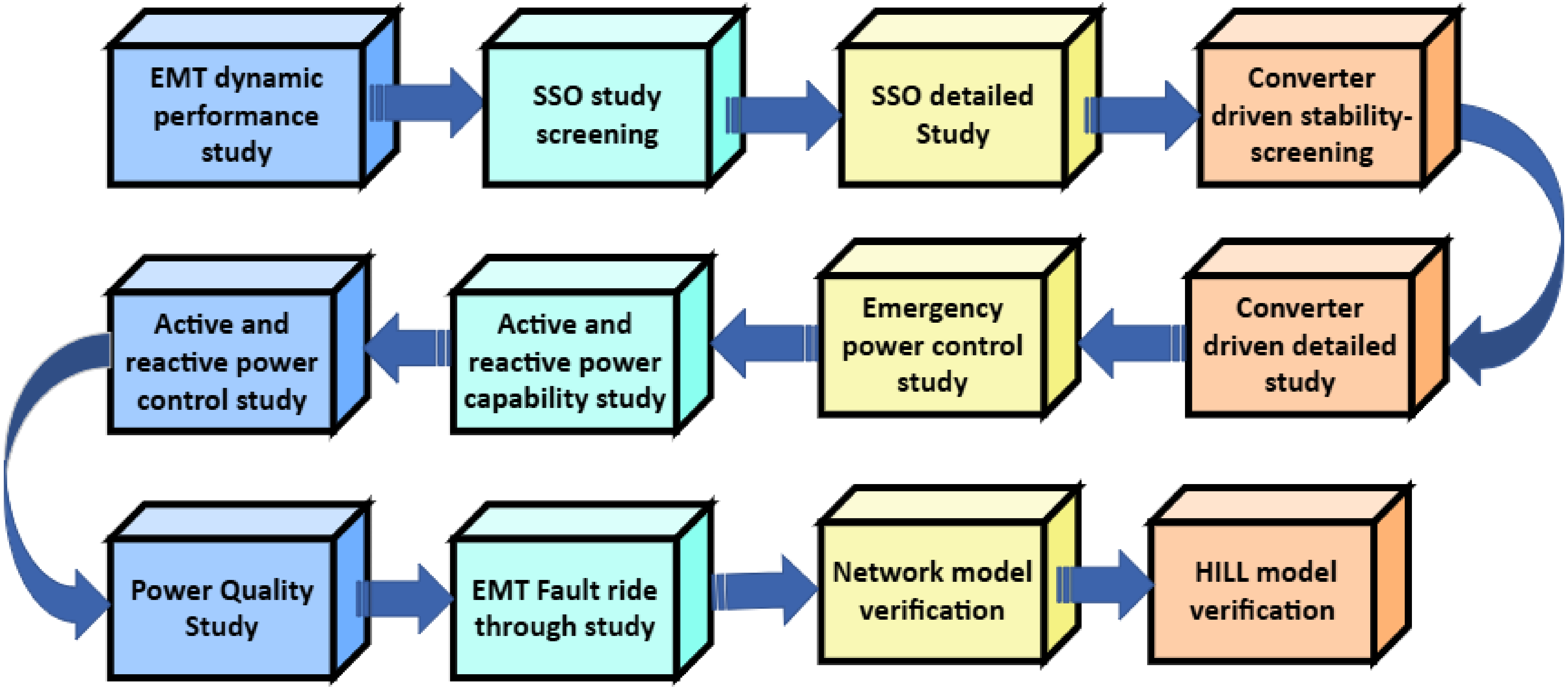
EMT screening

- **Screening thresholds:** identify weak/unstable interconnection points.
  - **SCR, WSCR, CSCR ≥ 6.0:** required; < 6.0 = electrically weak → higher risk of voltage/control instability.
  - **CCT ≥ 0.15 seconds:** required; < 0.15s = system may not withstand common fault durations → transient stability risk.
  - **If thresholds not met (SCR/WSCR/CSCR < 6.0 or CCT < 0.15s):** detailed studies (e.g., EMT simulations) are required.

Are these metrics and thresholds are applicable to large loads?



Supplemental Studies Stage



Approach: Modeling/Processes Needed

- **Challenges in EMT Network Modeling**
  - **Software Limitations :** Current EMT platforms are not fully scalable for system-wide or multi-thousand-bus simulations.
  - **Lack of Vendor / Third-Party Models:** for existing IBRs & large loads

STUDY TITLE	POWER SYSTEM MODEL	STAGE	
		MAIN	SUPPLEMENTAL
Thermal overload study: Power flow	DNM – RMS	✓	
Voltage stability study (Steady state): Power flow	DNM – RMS	✓	
Short circuit study	DNM – RMS	✓	
RMS Dynamic performance study	DNM – RMS	✓	
EMT studies Screening (SCRCCT)	DNM – RMS	✓	
EMT Detailed study	DNM- EMT/RMS/TM		✓
Sub-synchronous oscillation study - screening	DNM – RMS		✓
Sub-synchronous oscillation study - detailed	DNM – EMT		✓
Converter driven stability study - Screening	DNM – RMS		✓
Converter-driven stability study - detailed	DNM – EMT and TM – EMT		✓
Emergency power control	TM – EMT		✓
Active and reactive power capability study	N/A		✓
Active and reactive power controllers' study	TM – EMT/RMS		✓
Fault ride-through study	TM – EMT		✓
Power quality study	Impedance Model		✓
Network model verification study	EMT/RMS		✓
HILL model verification study	EMT/RMS		✓

Approach: Modeling/Processes Needed (Cont.)

- **Challenges in EMT large load Modeling**
  - **Are SPP EMT model requirements** (for IBRs) **applicable to large loads?**
  - **Can vendors and OEMs of large loads efficiently prepare EMT UDM models?**

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SPP ELECTROMAGNETIC TRANSIENT (EMT) MODEL REQUIREMENTS

Next Steps

- Develop Standardized EMT Modeling Requirements.
- Improve Large-Scale EMT Model Availability.
- Develop EMT study workflows that can handle multi-GW load clusters.
- Explore large-scale EMT simulation tools to handle detailed models efficiently.
- Stakeholder Guidance and Training