

GRID EMT

SIMULATION INITIATIVE

LLM in EMT for Visualization Demonstration

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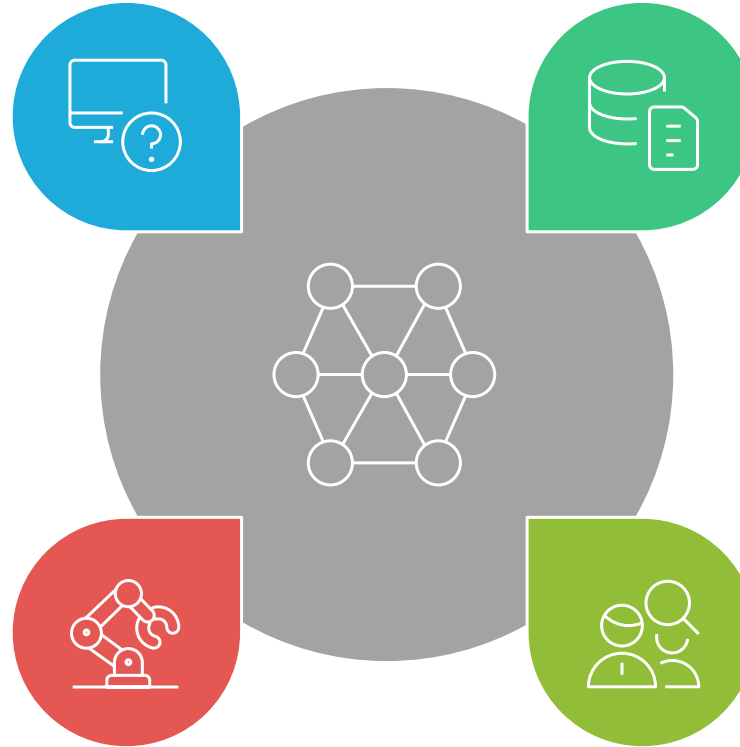
Motivation

Unmet Needs

Specific requirements like natural language interface are missing

Lack of Automation

No automated tools exist for data navigation and extraction



Massive Data Output

EMT simulations generate large multi-channel time-series data

Manual Processing

Engineers manually analyze and interpret simulation data



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Approach

- ❖ ChatGrid+: Ask your EMT Results in Plain English
- ❖ LLM-driven post-processing of EMT simulation data – query, visualize and analyze grid data without scripting
- Visualization & Query
 - ✓ Power grid visualization and data query
 - ✓ EMT output data query and plotting
- EMT Analytics (initial)
 - ✓ Sustained bus overvoltage detection
 - ✓ Sustained branch overcurrent detection
 - ✓ Bus voltage/branch current summaries
 - ✓ Full scan of overcurrent branches & overvoltage buses

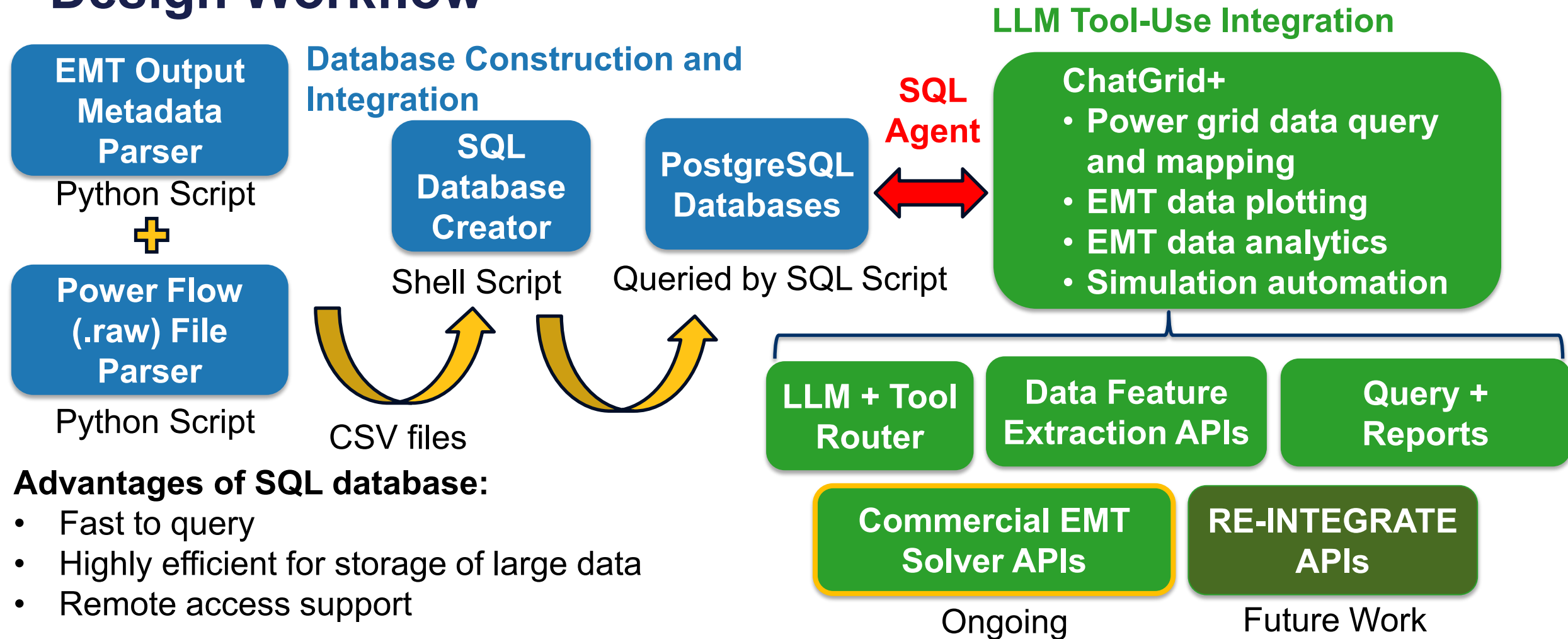
Built on power grid data and EMT simulation output → SQL database → integrated into PNNL's ChatGrid+



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Design Workflow



Advantages of SQL database:

- Fast to query
- Highly efficient for storage of large data
- Remote access support



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Updates after June Workshop

- ❖ Received a RE-INTEGRATE dataset with below event details:
 - Time step: 1 us,
 - Simulation window: 0 - 5.32s,
 - Fault (ABC) was applied at 5.1s on LOAD18 bus,
 - Fault was cleared at 5.2s,
 - Data collected window: 5.07s - 5.32s,
 - Only IEEE39 Network Bus Voltages are recorded.
- ❖ Integrated the dataset into PostgreSQL database.
- ❖ Modified the ChatGrid+ scripts to incorporate the dataset and tested it over various functions.
- ❖ Improved the ChatGrid+ graphic user interface (GUI) by making several panels foldable and adjustable.
- ❖ Implemented initial functions to interface ChatGrid+ with a commercial EMT solver.



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Demo 1 — Explore: what is in the EMT dataset

ChatGrid+

Grid map · EMT plots & analytics (RMS, overvoltage, overcurrent)

You:

In the selected EMT table, list all the columns for me.

ChatGrid:

Columns in the selected EMT table

"Output_507_532_ABC_network_vol_var_with_time":

- "iStepNo"
- "Time"
- "Bus_LOAD15_va"
- "Bus_LOAD15_vb"
- "Bus_LOAD15_vc"
- "Bus_BUS14_va"
- "Bus_BUS14_vb"
- "Bus_BUS14_vc"
- "Bus_LOAD16_va"
- "Bus_LOAD16_vb"
- "Bus_LOAD16_vc"
- "Bus_LOAD26_va"

Sample questions

EMT: Plot GEN30_VA · agent: RMS summary for BUS19 · Grid: highlight line 15-16

Send

Clear chat

Clear Map Highlights

Power Grid Statistics

Select Grid:

IEEE 39-bus v2

Generation Units: 10

Buses: 39

Transmission Lines: 34

Transformers: 12

Loads: 18

Switched Shunts: 2

Map Legend

Buses:

- Bus
- Load bus
- Generator bus
- Switched shunt bus
- Load + shunt bus

Branches:

- Transformer (dashed)
- Transformer symbol (two windings)

Transmission lines (by kV):

- 765 kV
- 500 kV
- 345 kV
- 230 kV
- 161 kV
- 138 kV
- 115 kV
- <69 kV

Line Loading:

- Normal (<80%)
- High (80-100%)
- Overload (>100%)

Overload Severity:

- Moderate (100-110%)
- High (110-120%)
- Severe (>120%)

Show Flow Arrows

Show Bus Labels

EMT Output Statistics

EMT database:

IEEE 39-bus EMT output v2

EMT table:

Output 507-532 ABC network voltages

Number of Channels: 117

Number of Data Points: 250,000

EMT plots

Clear plots

EMT plot prompts add charts here (x-axis: Time, rows ordered by iStepNo).

Plot: EMT: Plot LOAD4_VA · Analytics: agent: get_bus_voltage_rms_summary for LOAD4

- LLM-based EMT data visualization tool is developed based on PNNL's ChatGrid+.
- Pre-loaded SQL database is utilized for quick and efficient data query.
- *User request: "In the selected EMT table, list all of the columns for me."*



Demo 2 — Locate: find a component and show it on the grid

ChatGrid+
Grid map · EMT plots & analytics (RMS, overvoltage, overcurrent)

You:
Show me the generator with the largest active power.

ChatGrid:
The generator with the largest active power is **GBUS38**.

- **Generator name:** GBUS38
- **Bus number:** 38
- **Generation type:** thermal
- **Active power generated:** 830.0 MW
- **Power capacity:** 1531.0 MW
- **Coordinates:** POINT(824.0 155.0)

You:
Highlight it on the map.

ChatGrid:
Highlight this generator on the map:

Sample questions +

EMT: Plot GEN30_VA · agent: RMS summary for BUS19
Grid: highlight line 15-16

Send

Clear chat

Clear Map Highlights

Power Grid Statistics -

Select Grid:
IEEE 39-bus v2

Generation Units:	10
Buses:	39
Transmission Lines:	34
Transformers:	12
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Show Flow Arrows

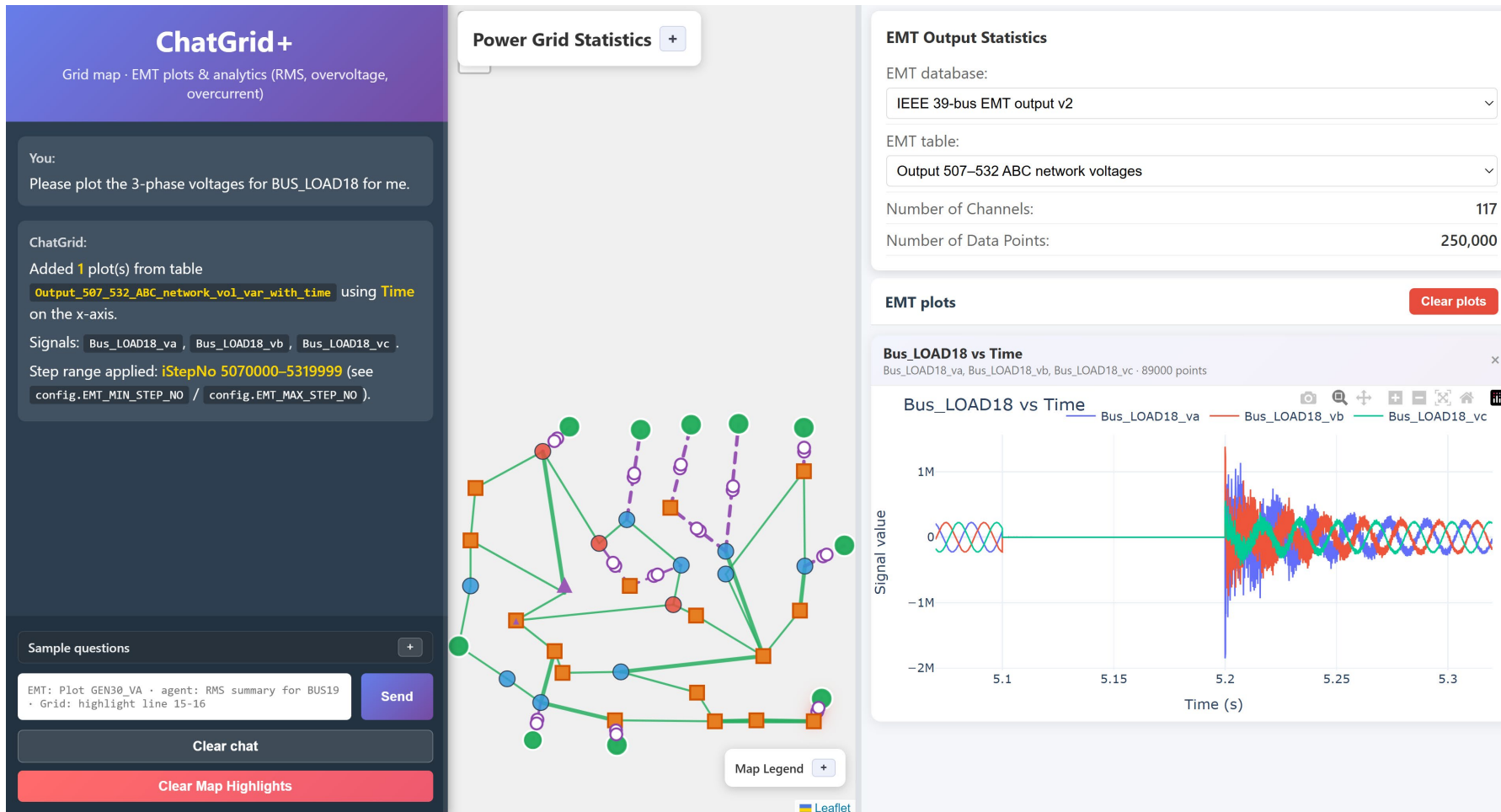
Show Bus Labels

Leaflet

- Data query to explore the power flow data.
- Highlight key components on the system topology and save time in locating them.
- *User requests: “Show me the generator with the largest active power.” & “Highlight it on the map.”*



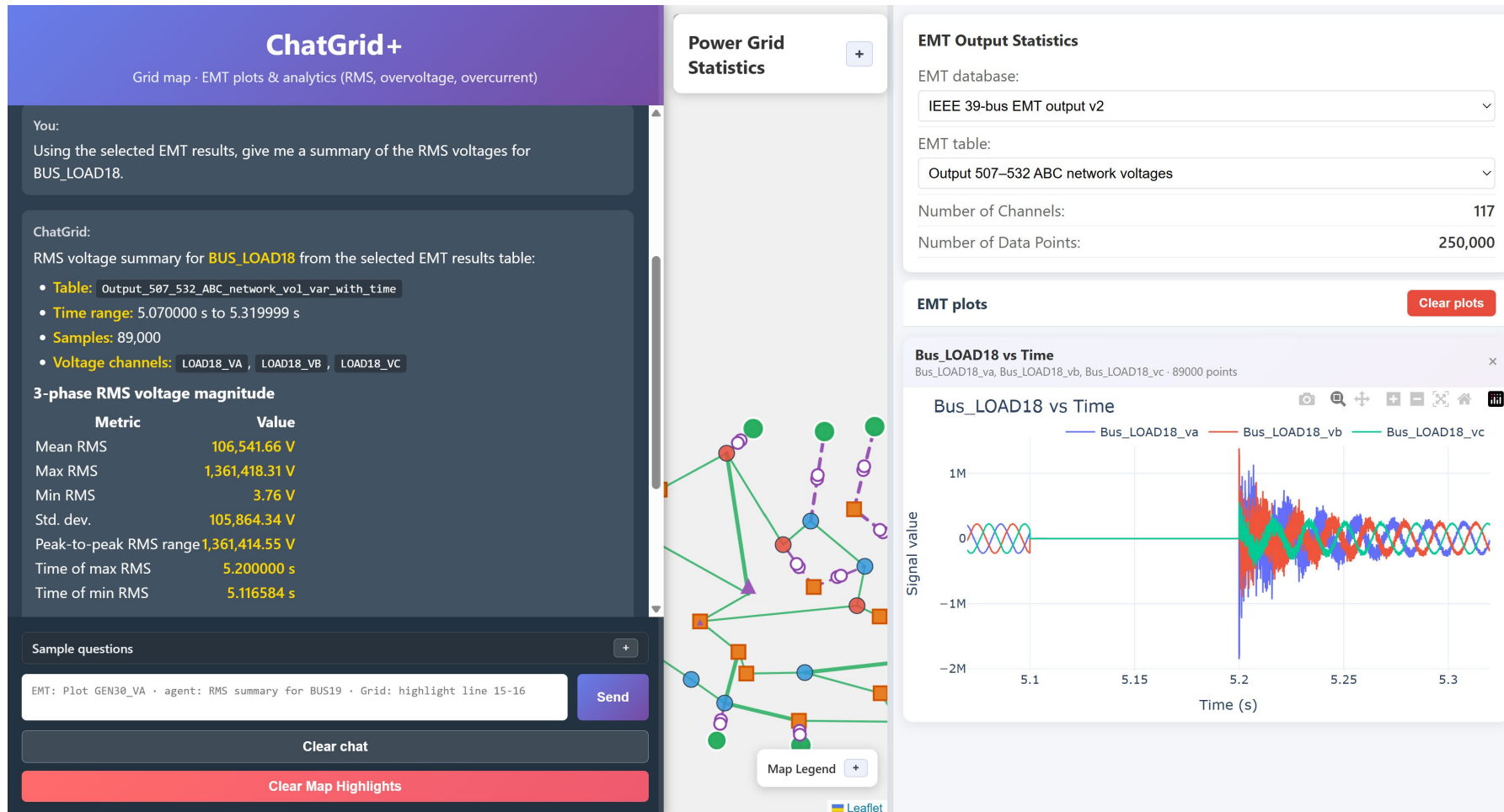
Demo 3 — Visualize: plot signals by prompt, not by script



- Plot channels of interest by entering user prompts.
- *User request: "Please plot the 3-phase voltages for BUS_LOAD18 for me."*



Demo 4 — Analyze: statistics computed on demand



- Capability to summarize RMS voltages/currents through agent's autonomous tool calling.
- *User request: “Using the selected EMT results, give me a summary of the RMS voltages for BUS_LOAD18.”*



Observations and Conclusions

- ❖ Users can quickly access and review the initial power flow condition of an EMT simulation through the power grid data query.
- ❖ EMT simulation results, including the channel information and point-on-wave time series data, can be promptly extracted and displayed on the user interface without explicit coding skills and efforts.
- ❖ Existing data analytics functions implemented in ChatGrid+ can assist engineers perform basic screening of data statistics and generate reports to summarize key findings without human intervention.
- ❖ **Value:** ChatGrid+ lowers the barrier to EMT result exploration from *scripting-level* to *conversation-level*, shortening the path from simulation output to engineering insight.



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Next Steps

- ❖ Implement functions to extract and query dynamic model data used in RE-INTEGRATE and interconnect tool.
- ❖ Initiate the work to deploy ChatGrid+ within integration tool at ORNL.
- ❖ Request configuration files from ORNL to systematically integrate power flow data, dynamic model data, EMT output definition, and EMT data post-processing into ChatGrid+.
- ❖ Enrich the EMT data analytics features (e.g. Fast Fourier Transform (FFT)) by implementing more agent tools.
- ❖ Test and improve the enhanced ChatGrid+ with more commonly-used prompts and more EMT data to spot and mitigate LLM hallucination.



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Thank You

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