AI Applications for Transmission Operations & Planning

EPRI View from the TOP Webinar Series 2026

Welcome and Agenda

EPRI are recording this webcast and will post the recording, transcription and materials (where possible) for those that could not make it.

Introduction to the EPRI View from the TOP - 2026 Webinar Series
(Adrian Kelly - EPRI)

Alarm Management and Operational Data - the **EPRI aLLarMa** application
(Adrian Kelly - EPRI)

Grid Weather AI Visualization Application - the **EPRI Watt the Forecast** application
(Adrian Kelly, Saumil Shah - EPRI)

Planning Study Automation - the **EPRI Raphson** application
(Sean McGuinness – EPRI)

Electromagnetic Transient (**EMT**) **AI Assistant**
(Bob Arritt - EPRI)

Unit Commitment and Scheduling: - the **EPRI - AI-ccelerating Unit Commitment Challenge**
(Alvaro Porras - EPRI)

EPRI's Open Power AI (**OPAI**) Initiative
(Adrian Kelly - EPRI)

Questions and Open Discussion
(5 Mins All Moderated by EPRI)

Transmission Operations & Planning

- EPRI's Transmission Operations & Planning (TOP) program conducts collaborative research to support reliable, resilient, and economic planning and operation of the bulk electric power system for transmission owners and system operators

- **Focus Areas**
  - Transmission Operations
  - Transmission Planning
  - Bulk System Integration of Renewables and Distributed Energy Resources
  - Electricity Market Design and Operation

- **Value to Industry**
  - Deliver leading-edge research, software tools, and technical guidance
  - Leverage global collaboration across utilities, ISOs, and subject-matter experts
  - Help the industry manage rapid system change, including renewables, large loads, and climate-driven risks

Learn more about TOP: https://top.epri.com/

Transmission Operations and Planning

Innovating Grid Operations, Shaping Strategic Planning

View from The TOP

Transmission Operations & Planning R&D Public Webinar Series

New for 2026: A public webinar series

- R&D highlights from EPRI and our global collaborators
- 8-12 webinars delivered throughout 2026
- Topics spanning operations, planning and markets issues
- Coordinated with existing EPRI forums
- Open to all participants

Not a Member? Sign up Here!

Save the Date

April 8 11am ET

Resource Adequacy and Large Loads

Recordings & materials posted at: top.epri.com/view-from-the-top

EPRI

Slido Survey on Today's Webinar

Please take a moment to complete the Slido survey on AI application interests. Open through March 18th.

https://app.sli.do/event/na5ogLpugNbQ6eBjEWqzJr

Slide.com Code: **3941399**

Transmission & ICCS Advisory Meetings – Winter 2026

Transmission Ops & Planning Area and Program Advisory Meetings:

Monday, March 30th – Wednesday, April 1st, 2026

The upcoming advisory meetings review the progress of ongoing research within the collaborative R&D programs, identify new issues requiring resolution, and prioritize future research to meet the needs of the industry, decision-makers, and the public. The Transmission Operations and Planning area meets in parallel with EPRI's Transmission and Substations and ICCS groups.

These meetings are also excellent opportunities to exchange information and experiences with your industry peers and to identify information and technology that contribute to the success of your company.

Advisors are invited to participate in the meetings, which are held twice each year. Attendance is strongly encouraged as a benefit of your EPRI membership. To be eligible to attend, companies must be engaged in EPRI's ED&CS Sector activities.

Interested to participate?: atuohy@epri.com

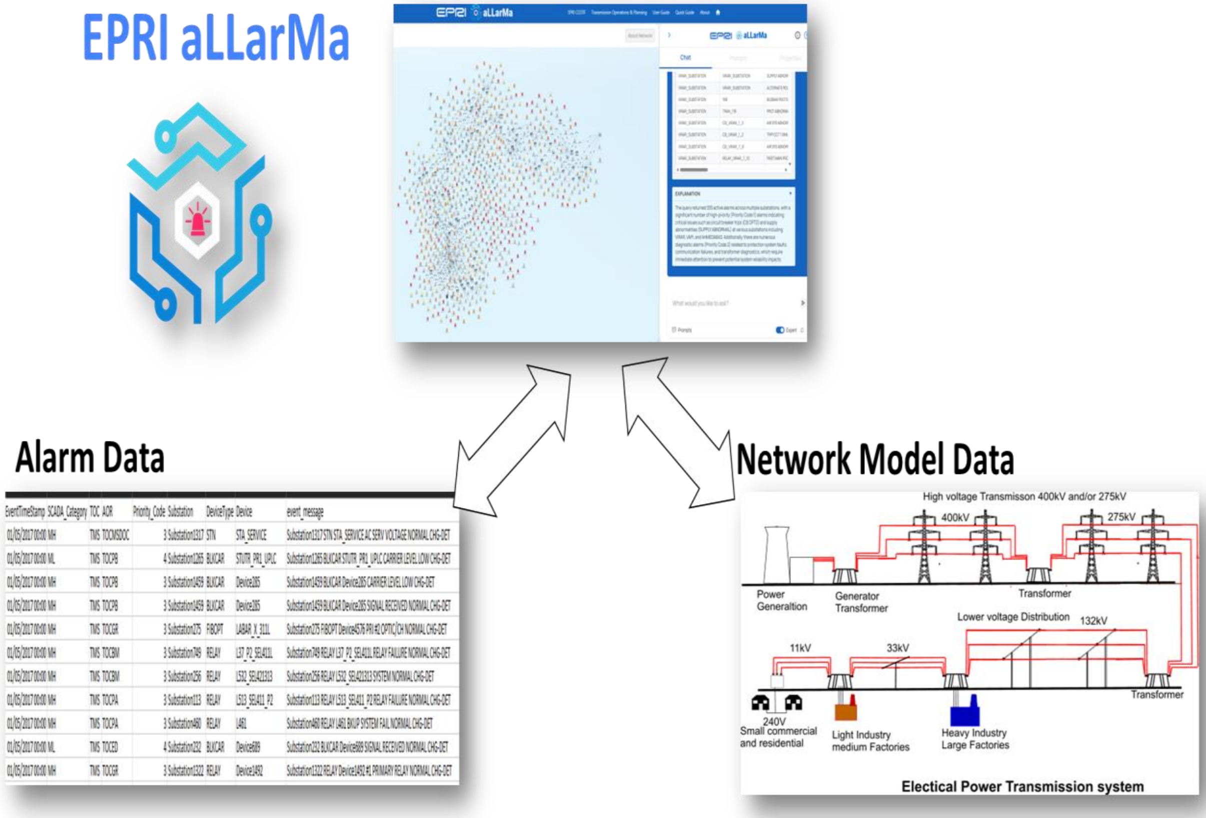
EPRI's aLLarMa Application

Concept – Can AI be Safely Used with Grid Alarm and Network Operational Data?

[Freely Available to Test at: https://allarma.epri.com/](https://allarma.epri.com/)

EPRI aLLarMa:

- An application to interact with real-time and offline operational data and alarms
- Leverages AI-LLM for natural language prompt questions and explanations of the results.
- Operational data is securely segregated from the LLM, by-design guardrails eliminate hallucinations.
- Easily extendible to other assets and domains: grid, generation, demand, assets using graph-based interconnected data
- Securely deployable on prem server or laptop with open weight LLMs (no external internet connection required) or in private cloud with API access to frontier LLMs.



What is the Value of EPRI aLLarMa?

Faster Decision-Making – Ask plain-English questions to quickly access and interpret alarm and network data.

Efficient Alarm Triage – Rapidly identify and prioritize critical alarms and operational states to reduce response time.

Trends & Topology Insights – Analyze historical patterns, understand relationships between alarms and network elements to enhance situational awareness, support proactive planning, and enable informed operational decisions.

Clear, Actionable Outputs – Receive structured summaries and visualizations tailored for control-room use.

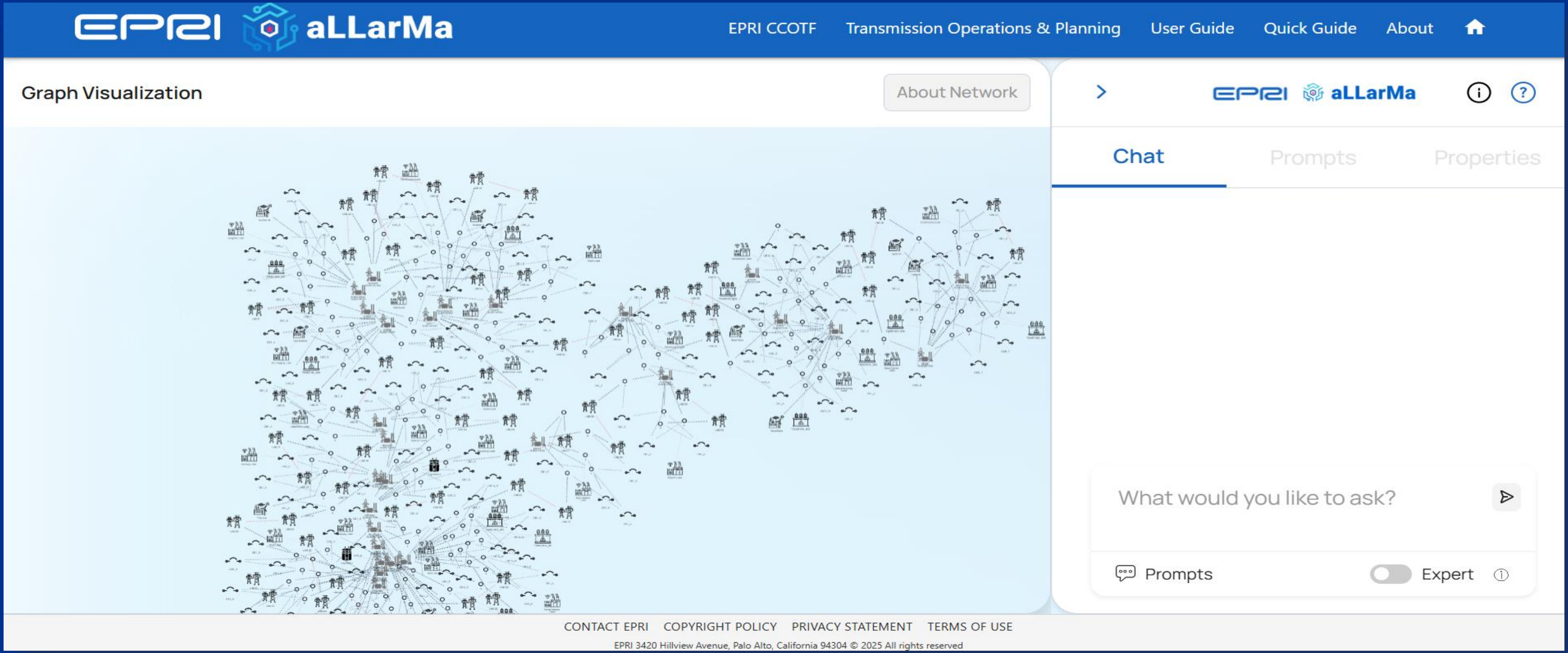
Scalable Architecture – Graph-based design integrated with LLM ensures adaptability for future data growth and complexity.

aLLarMa Demonstration

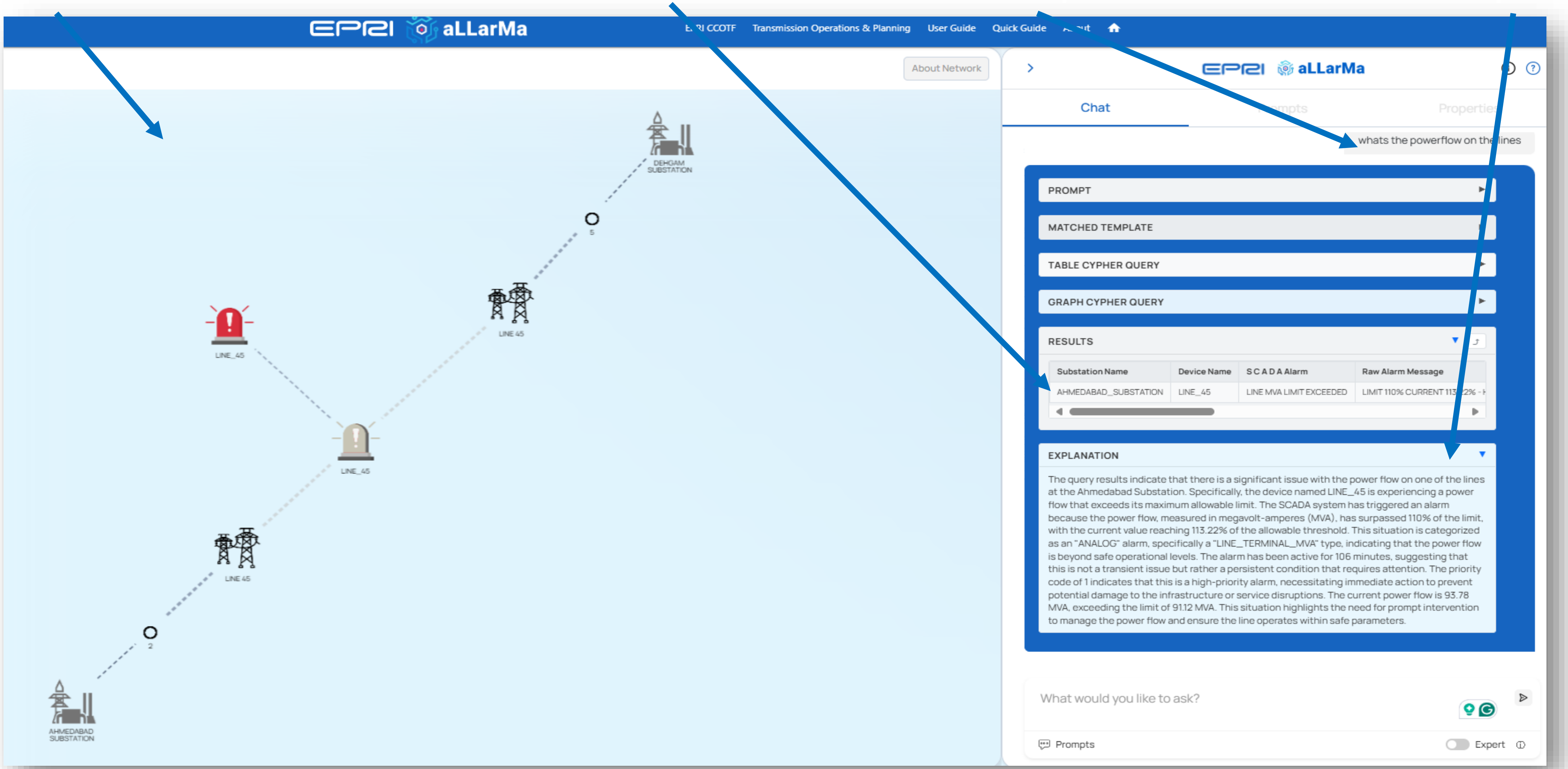
Freely Accessible at https://allarma.epri.com/

The EPRI aLLarMa demo site

Accessible at https://allarma.epri.com/

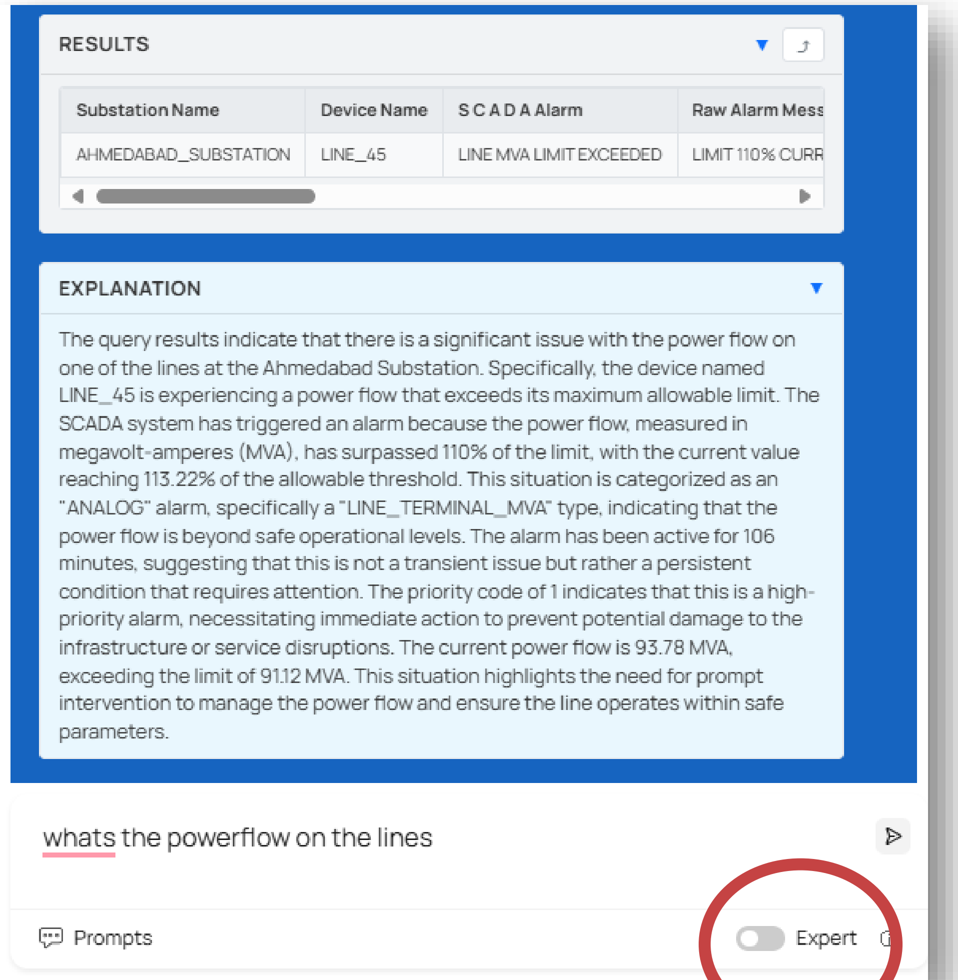


Early Stage aLLarMa Online – A Single Substation

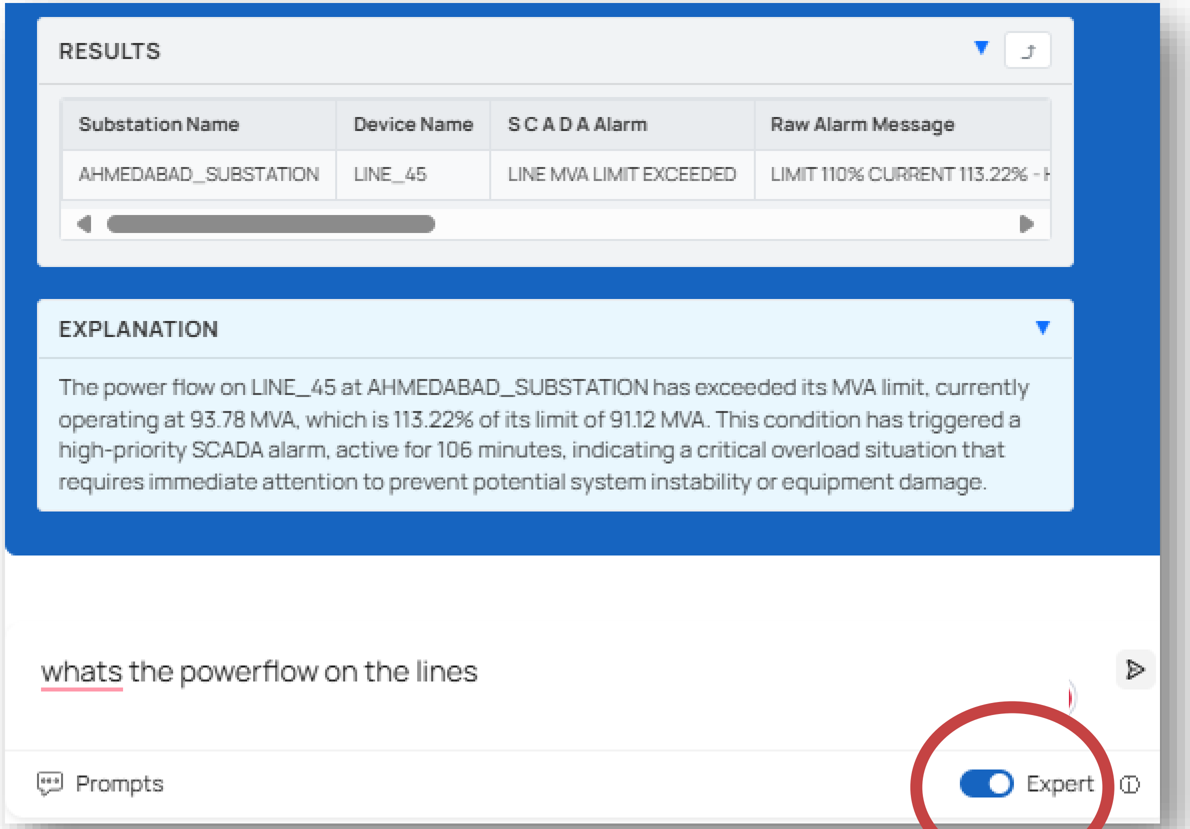


EPRI aLLarMa as a Tool to Train and Educate Operators

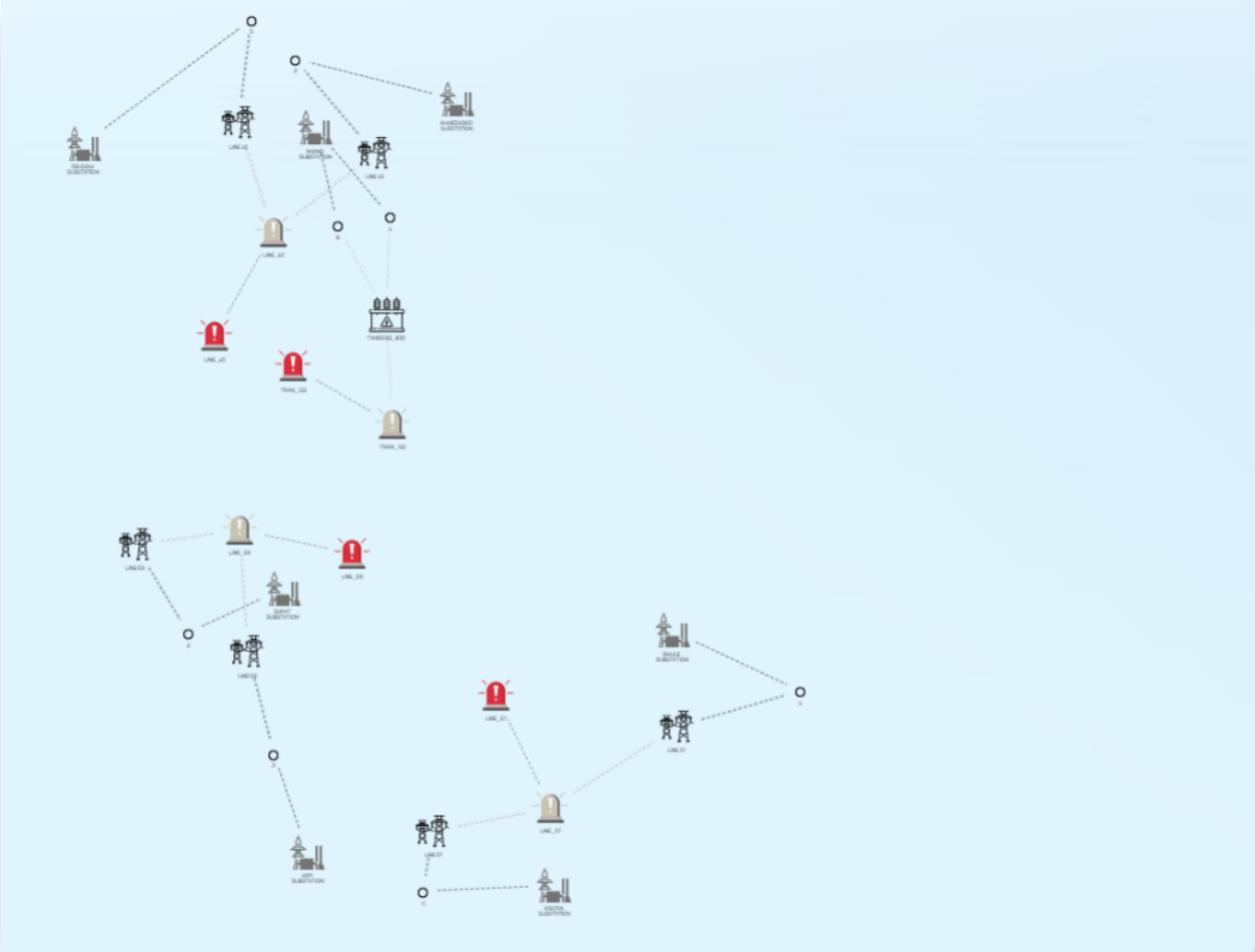
Expert Mode Disabled – For Novice Operators.
More information and context



Expert Mode Enabled – For Expert Operators.
Shorter Explanation, no need for context



EPRI aLLarMa Online – Specific Behavior Alarms – Find Voltage Alarms



Chat | Prompts | Properties

RESULTS

Substation Name	Device Name	S C A D A Alarm	F
SURAT_SUBSTATION	LINE_69	LINE TERMINAL VOLTAGE LIMIT EXCEEDED	L
KALYAN_SUBSTATION	LINE_57	LINE TERMINAL VOLTAGE LIMIT EXCEEDED	L
ANAND_SUBSTATION	TRAN_122	TRANSFORMER VOLTAGE LIMIT EXCEEDED	L
AHMEDABAD_SUBSTATION	LINE_45	LINE TERMINAL VOLTAGE LIMIT EXCEEDED	L

EXPLANATION

The query results indicate that there are voltage issues at multiple substations, with alarms triggered due to voltage levels exceeding specified limits. At the SURAT_SUBSTATION and AHMEDABAD_SUBSTATION, the voltage is below the lower limit, with current values at 82.45% and 84.81% respectively, against a limit of 90%. This suggests that the voltage is lower than expected, which could potentially affect the performance of electrical equipment connected to these lines. Conversely, at the KALYAN_SUBSTATION and ANAND_SUBSTATION, the voltage levels are above the upper limit. The KALYAN_SUBSTATION has a current voltage of 119.52% against a limit of 110%, and the ANAND_SUBSTATION shows a current voltage of 112.85% against the same limit. These high voltage levels can lead to overheating and damage to electrical components if not addressed promptly. All alarms are categorized as high priority, indicating that these voltage discrepancies are significant and require immediate attention to prevent potential disruptions or damage to the electrical infrastructure.

What would you like to ask?

Prompts

Expert

Latest Updates to aLLarMa 2026 – *Basic Suggested Actions*

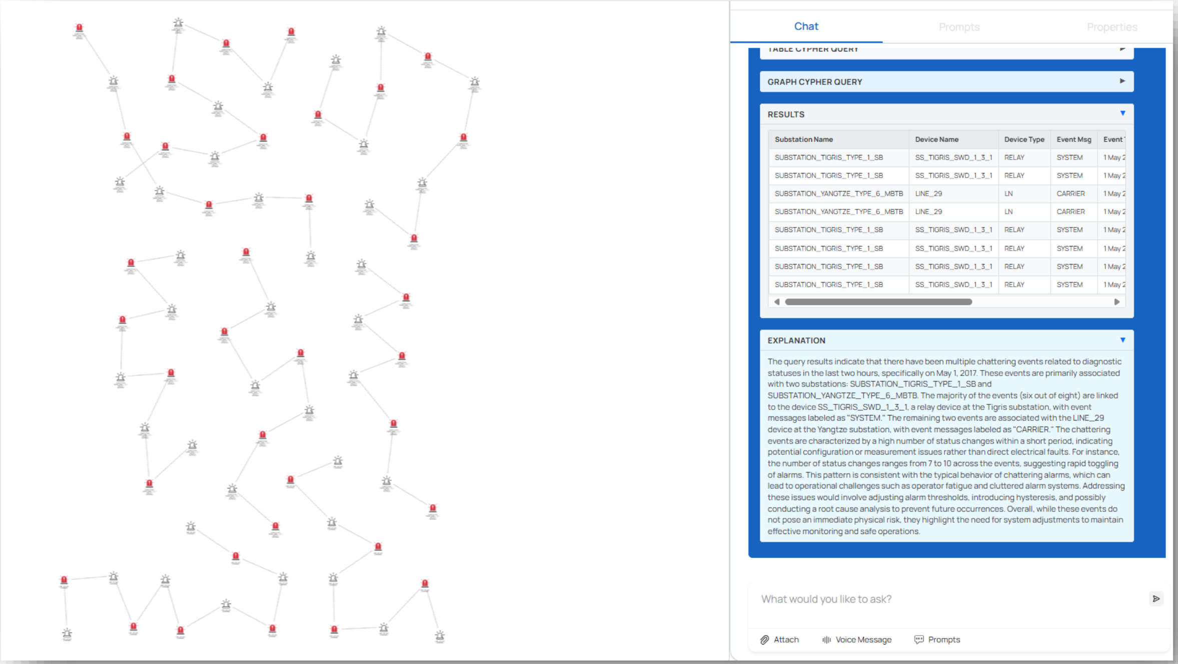
EXPLANATION

The voltage profile shows multiple limit violations across key substations. Surat and Ahmedabad lines are experiencing undervoltage conditions at approximately 82-85% of nominal with alarms active for over 4 hours. Conversely, Kalyan line and Anand transformer are overvoltage, exceeding 110%, with the highest at 119.5% and 112.8% respectively, alarms active for around 1 hour. These voltage deviations present risks for equipment damage and system instability due to prolonged under and overvoltage stress.

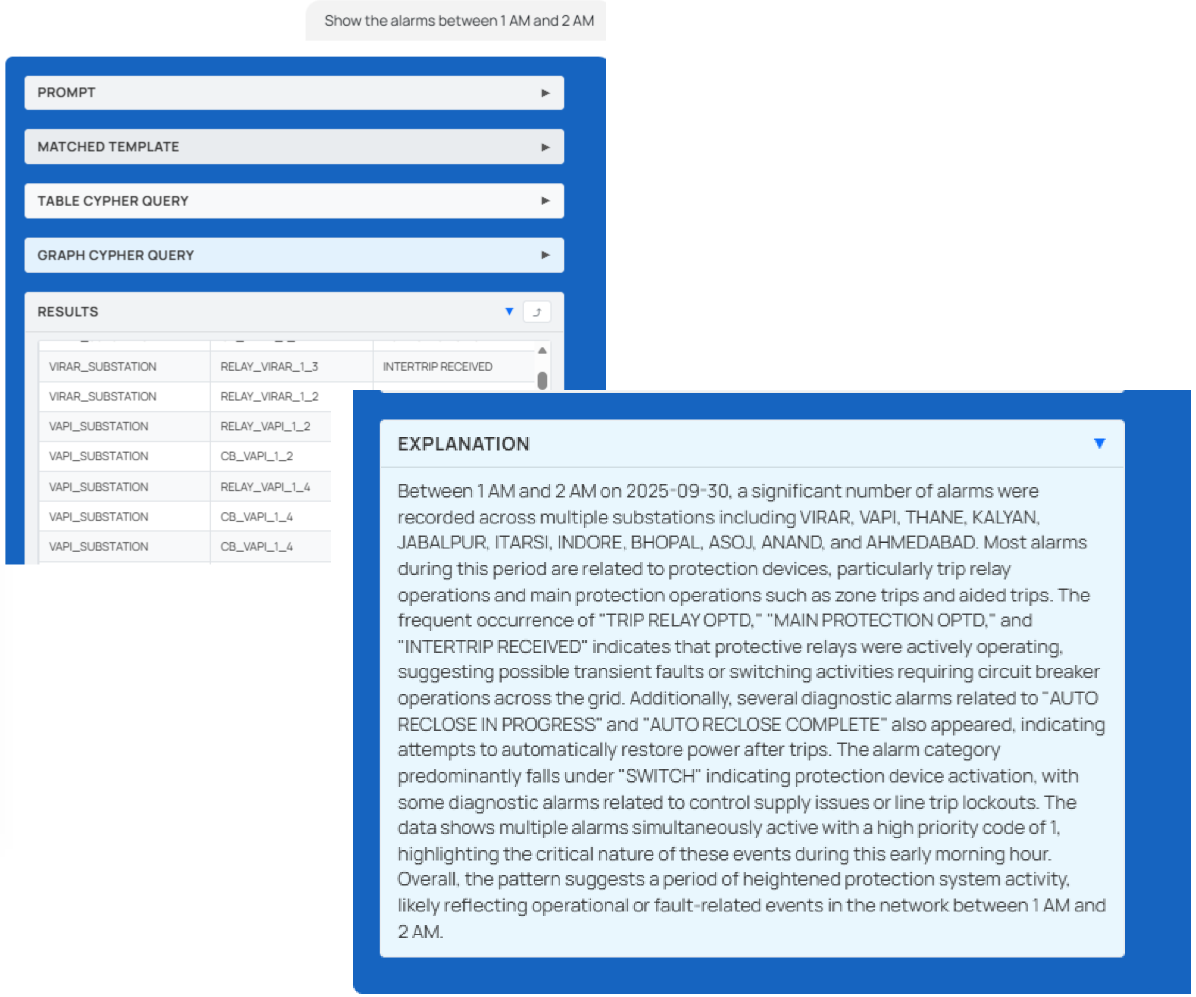
-- Suggested Actions: --
1. Consider redistributing load or adjusting voltage regulator settings at Kalyan and Anand to reduce high voltage stress.
2. It may be beneficial to investigate and alleviate low voltage causes at Surat and Ahmedabad, such as checking feeder loading, transformer tap positions, or potential equipment issues.

EPRI aLLarMa Online – Alarm and Data Queries

Find Chattering Alarms



Find Alarms By Hour



EPRI aLLarMa Tabular Results Format – Can be Copy/Pasted

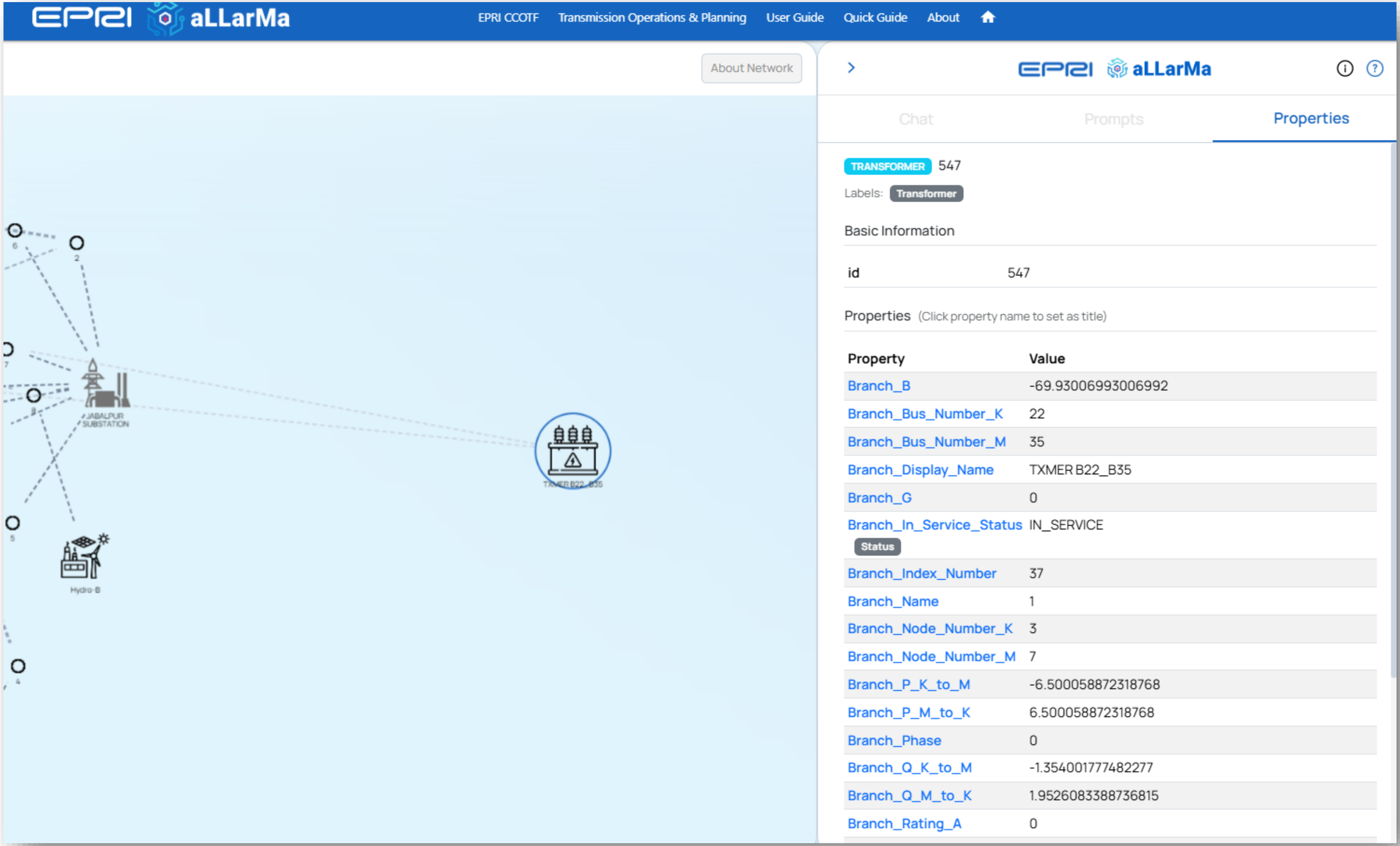
EPRI CCOTF | Transmission Operations & Planning | User Guide | Quick Guide | About

sualization Selected Node: TXMER B22_B35 | About Network

Show the alarms between 1 AM and 2 AM

Substation Name	Device Name	S C A D A Alarm	Raw Alarm Message	Condition	Alarm Category	Alarm Type	Last Update Time	Current Time	Time Act
VIRAR_SUBSTATION	RELAY_VIRAR_1_2	TRIP RELAY OPTD	BSSEC1 BUSBAR PROT M1Z TRIP RELAY 2	OPERATE	SWITCH	BUSBAR_SWITCH	30 Sept 2025, 01:28:07.971	30 Sept 2025, 23:59:36.920	1351
VIRAR_SUBSTATION	CB_VIRAR_1_2	CB OPTD	CB TRIPPED	TRIP	SWITCH	BUSBAR_SWITCH	30 Sept 2025, 01:28:08.071	30 Sept 2025, 23:59:36.920	1351
VIRAR_SUBSTATION	RELAY_VIRAR_7_10	TRIP RELAY OPTD	1 Feb 2001, 00:00:00.000	OPERATE	SWITCH	CB_RELAY_SWITCH	30 Sept 2025, 01:42:15.000	30 Sept 2025, 23:59:36.920	1337
VIRAR_SUBSTATION	CB_VIRAR_7_10	MAIN PROTECTION OPTD	FIRST MAIN PROTECTION AIDED TRIP	OPERATE	SWITCH	CB_RELAY_SWITCH	30 Sept 2025, 01:42:15.100	30 Sept 2025, 23:59:36.920	1337
VIRAR_SUBSTATION	RELAY_VIRAR_1_2	TRIP RELAY OPTD	1 Feb 2001, 00:00:00.000	OPERATE	SWITCH	CB_RELAY_SWITCH	30 Sept 2025, 01:44:42.000	30 Sept 2025, 23:59:36.920	1334
VIRAR_SUBSTATION	CB_VIRAR_1_2	MAIN PROTECTION OPTD	1 Jan 2001, 00:00:00.000	OPERATE	SWITCH	CB_RELAY_SWITCH	30 Sept 2025, 01:44:42.100	30 Sept 2025, 23:59:36.920	1334
VIRAR_SUBSTATION	RELAY_VIRAR_1_3	TRIP RELAY OPTD	INTERTRIP RECEIVED TRIP RELAY	OPERATE	SWITCH	LINE_RELAY_SWITCH	30 Sept 2025, 01:14:00.000	30 Sept 2025, 23:59:36.920	1365
VIRAR_SUBSTATION	CB_VIRAR_1_3	BU PROTECTION OPTD	1 Mar 2001, 00:00:00.000	OPERATE	SWITCH	LINE_RELAY_SWITCH	30 Sept 2025, 01:14:00.150	30 Sept 2025, 23:59:36.920	1365
VIRAR_SUBSTATION	RELAY_VIRAR_1_2	TRIP RELAY OPTD	INTERTRIP RECEIVED TRIP RELAY	OPERATE	SWITCH	LINE_RELAY_SWITCH	30 Sept 2025, 01:48:00.000	30 Sept 2025, 23:59:36.920	1331
VIRAR_SUBSTATION	CB_VIRAR_1_2	BU PROTECTION OPTD	1 Feb 2001, 00:00:00.000	OPERATE	SWITCH	LINE_RELAY_SWITCH	30 Sept 2025, 01:48:00.150	30 Sept 2025, 23:59:36.920	1331
VIRAR_SUBSTATION	RELAY_VIRAR_1_3	INTERTRIP RECEIVED	INTERTRIP RECEIVED	OPERATE	DIAGNOSTIC	LINE_RELAY_SWITCH	30 Sept 2025, 01:14:00.050	30 Sept 2025, 23:59:36.920	1365
VIRAR_SUBSTATION	RELAY_VIRAR_1_2	INTERTRIP RECEIVED	INTERTRIP RECEIVED	OPERATE	DIAGNOSTIC	LINE_RELAY_SWITCH	30 Sept 2025, 01:48:00.050	30 Sept 2025, 23:59:36.920	1331
VAPI_SUBSTATION	RELAY_VAPI_1_2	TRIP RELAY OPTD	1 Feb 2001, 00:00:00.000	OPERATE	SWITCH	LINE_RELAY_SWITCH	30 Sept 2025, 01:12:00.000	30 Sept 2025, 23:59:36.920	1367
VAPI_SUBSTATION	CB_VAPI_1_2	MAIN PROTECTION OPTD	FIRST MAIN PROTECTION AIDED TRIP	OPERATE	SWITCH	LINE_RELAY_SWITCH	30 Sept 2025, 01:12:00.100	30 Sept 2025, 23:59:36.920	1367
VAPI_SUBSTATION	RELAY_VAPI_1_4	MAIN PROTECTION OPTD	1 Jan 2001, 00:00:00.000	OPERATE	SWITCH	LINE_RELAY_SWITCH	30 Sept 2025, 01:02:00.000	30 Sept 2025, 23:59:36.920	1377

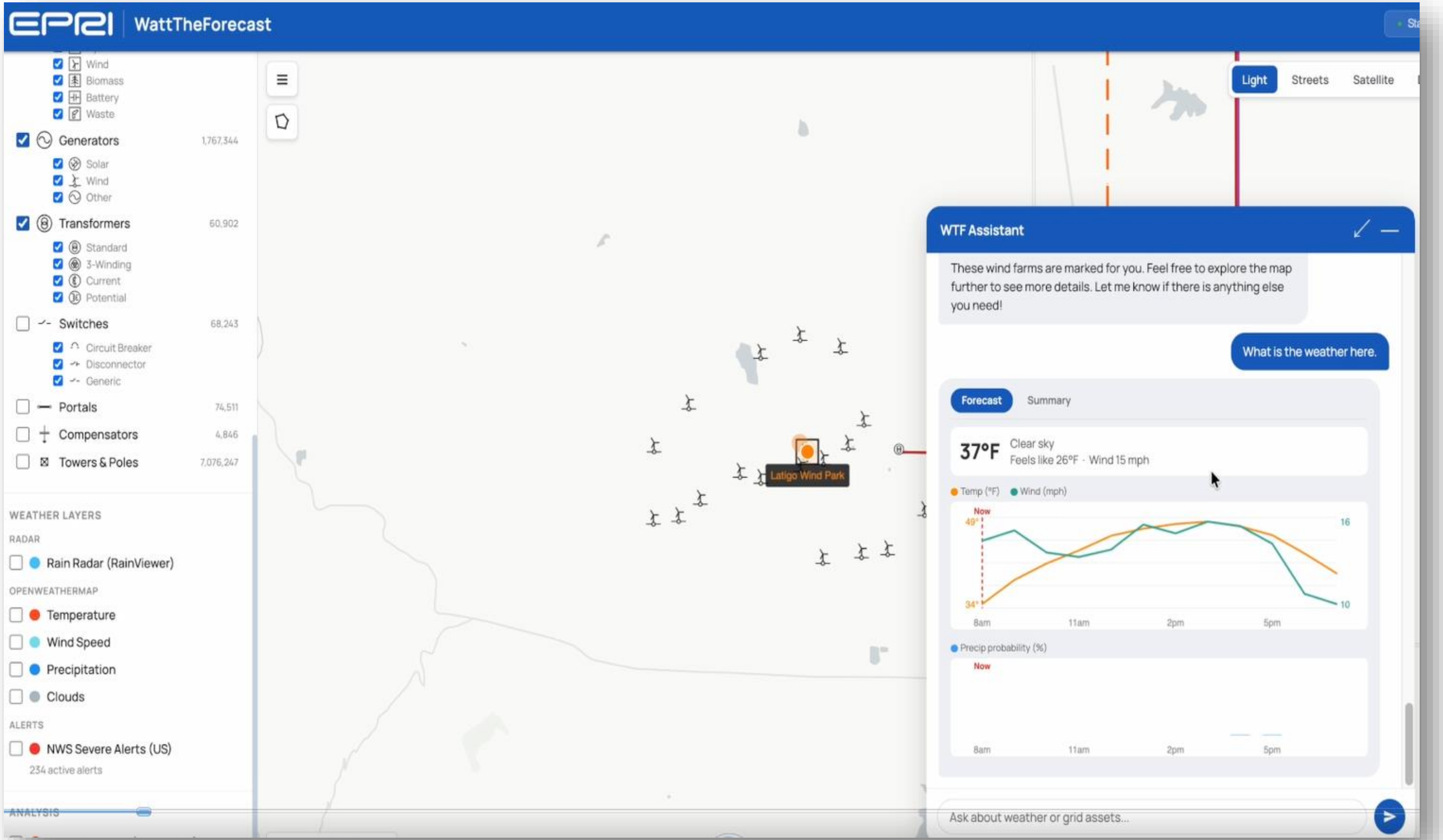
Early Stage aLLarMa Online – Node Data Properties



Property	Value
Branch_B	-69.93006993006992
Branch_Bus_Number_K	22
Branch_Bus_Number_M	35
Branch_Display_Name	TXMER B22_B35
Branch_G	0
Branch_In_Service_Status	IN_SERVICE
Branch_Index_Number	37
Branch_Name	1
Branch_Node_Number_K	3
Branch_Node_Number_M	7
Branch_P_K_to_M	-6.500058872318768
Branch_P_M_to_K	6.500058872318768
Branch_Phase	0
Branch_Q_K_to_M	-1.354001777482277
Branch_Q_M_to_K	1.9526083388736815
Branch_Rating_A	0

EPRI’s Watt the Forecast application

EPRI Watt the Forecast



EPRI's Raphson Application

Raphson

The AI Power Grid Analysis Assistant,

EPRI Raphson: AI Grid Studies Assistant

View from the TOP Webcast

4th March, 2026

Sean McGuinness,
smcguinness@epri.com
Senior Technical Executive,
Transmission Ops & Planning

Key Objectives
Grid Studies AI Assistant

Raphson

The AI Power Grid Analysis Assistant,

- Be **cyber secure** and **data secure**
- Build **decision-auditing** and **data governance** into the core

- Fully self-contained code: <u>**zero**</u> **third-party libraries** required

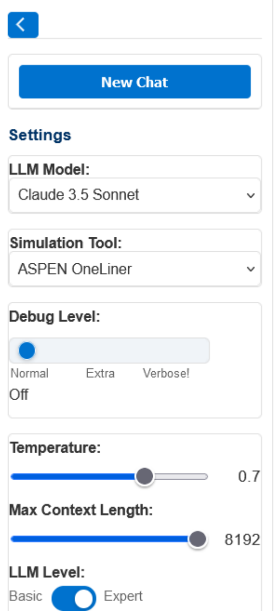
- Just require an LLM and simulation tool
- Use routers instead of direct interfaces for tool-mobility

- Use open standards for data storage (CIM etc)
- Focus on performance for large-scale tasks e.g. **150,000 bus models**

EPRI Raphson: AI Grid Planning Assistant

Ask it to perform studies, data analysis, and other tasks…

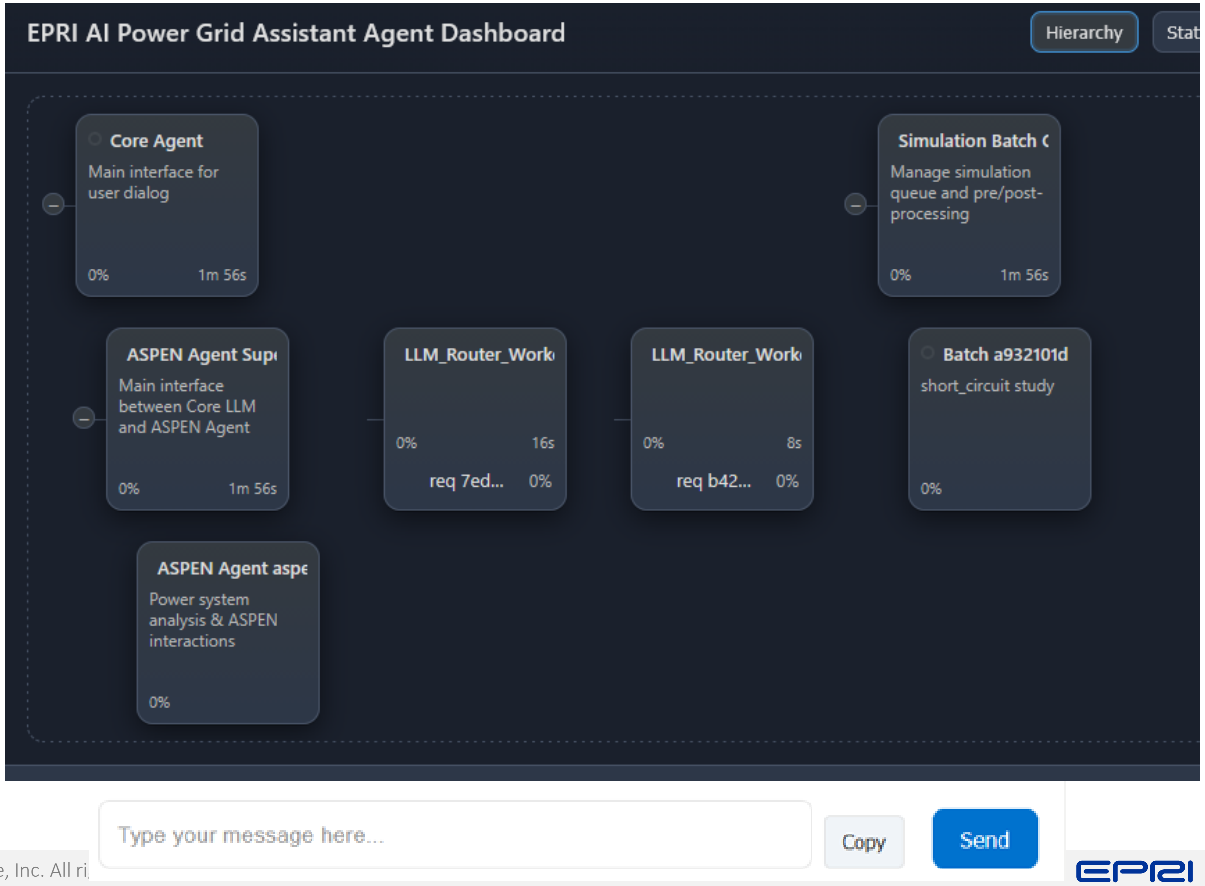
load newzealand.olr model and run SLG faults on the first ten 220 kV busbars. Then sort the results by fault current magnitude and show them in a table. Perform all simulations



Now I'll present the results in a sorted table by fault current magnitude:

Rank	Bus Number	Bus Name	Fault Current (A)	Fault Current Angle (deg)	Voltage Level (kV)
1	10	ARA22/ARA220	15,724.6	-81.4	220
2	28	BHL/BHL220B	14,016.4	-68.8	220
3	27	BHL/BHL220A	14,002.1	-68.9	220
4	18	ATI2/ATI220A	14,203.7	-79.1	220
5	4	ALB/ALB220A1	13,280.8	-65.7	220
6	103	DRY2/DRY220A	10,780.7	-71.5	220
7	34	BPE220A1a	9,167.4	-78.7	220
8	38	BRK2/BRK220B	5,961.8	-81.2	220
9	23	BFT22/BFT220	5,678.8	-78.8	220
10	36	BRB2/BRB220A	5,399.1	-73.4	220

…Raphson creates a swarm of AI Agents to execute the task



What does it look like?

Open the chat interface in your web browser

Raphson

The AI Power Grid Analysis Assistant,

load newzealand.olr model and run SLG faults on the first ten 220 kV busbars. Then sort the results by fault current magnitude and show them in a table. Perform all simulations

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2	28	BHL/BHL220B	14,016.4	-68.8	220
3	27	BHL/BHL220A	14,002.1	-68.9	220
4	18	ATI2/ATI220A	14,203.7	-79.1	220
5	4	ALB/ALB220A1	13,280.8	-65.7	220
6	103	DRY2/DRY220A	10,780.7	-71.5	220
7	34	BPE220A1a	9,167.4	-78.7	220
8	38	BRK2/BRK220B	5,961.8	-81.2	220
9	23	BFT22/BFT220	5,678.8	-78.8	220
10	36	BRB2/BRB220A	5,399.1	-73.4	220

Type your message here...

Copy

Send

- Engineer:
  - Define objective(s) or ask questions
  - Review results, provide feedback, ask questions
- AI Assistant:
  - Creates a scope of work for approval
  - Pulls relevant information from local files, memory, skills
  - Configures batches of simulations
  - Solves basic model and simulation issues using guides, memory, and skills
  - Creates charts, spreadsheets, and reports

EPRI Protection Tool Integration Trials

Current R&D Experiments

Raphson

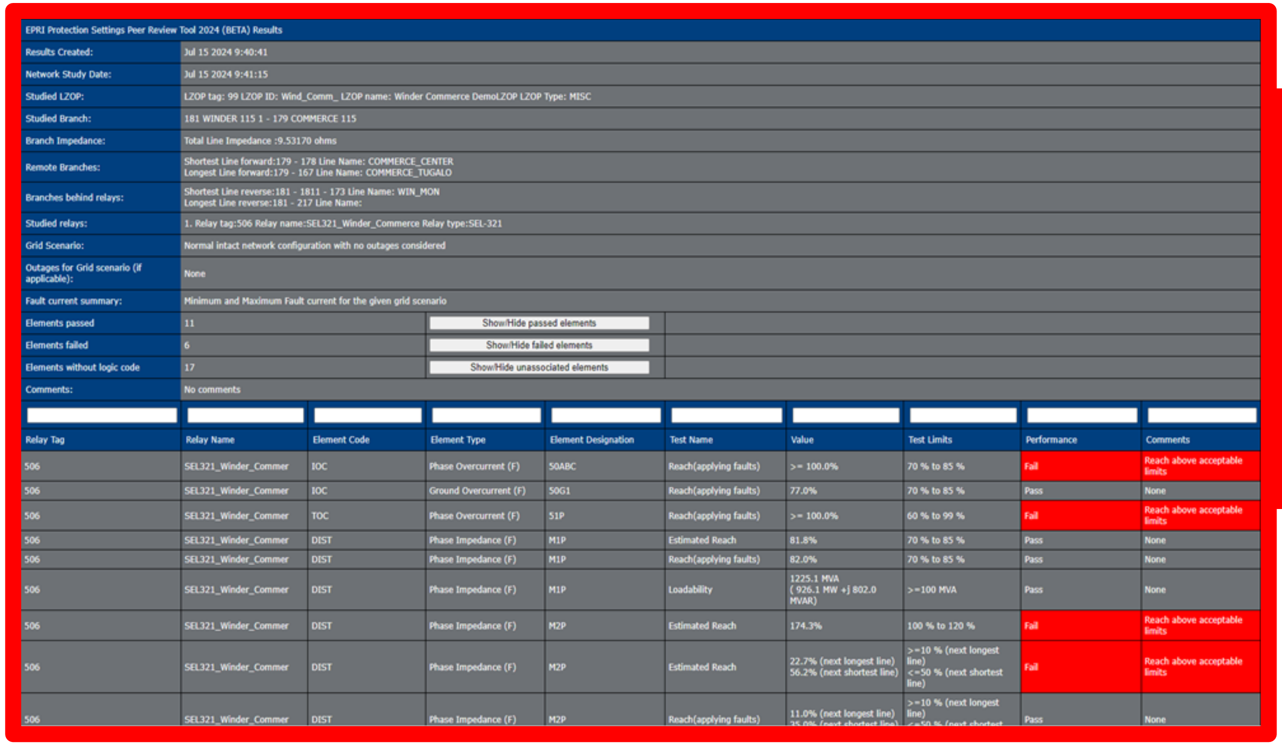
The AI Power Grid Analysis Assistant,

Wide-Area Protection Study

(Screen grid for issues)

Individual Relay Assessment

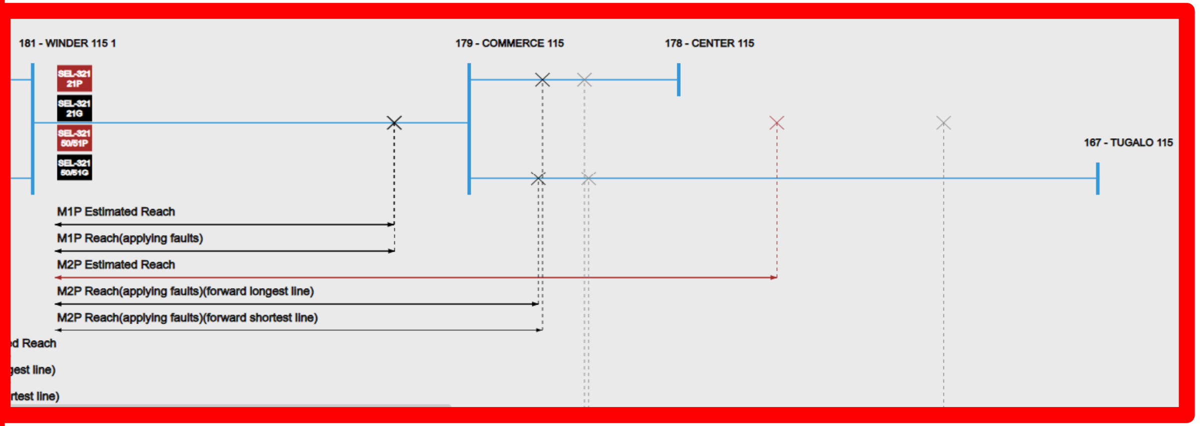
(Deep testing of relay)



EPRI Protection Settings Peer Review Tool 2024 (BETA) Results

Results Created:	Jul 15 2024 9:40:41
Network Study Date:	Jul 15 2024 9:41:15
Studied LZOP:	LZOP tag: 99 LZOP ID: Wind_Comm_ LZOP name: Winder Commerce DemoLZOP LZOP Type: MISC
Studied Branch:	181 WINDER 115 1 - 179 COMMERCE 115
Branch Impedance:	Total Line Impedance :9.53170 ohms
Remote Branches:	Shortest Line forward:179 - 178 Line Name: COMMERCE_CENTER Longest Line forward:179 - 167 Line Name: COMMERCE_TUGALO
Branches behind relays:	Shortest Line reverse:181 - 1811 - 173 Line Name: WIN_MON Longest Line reverse:181 - 217 Line Name:
Studied relays:	1. Relay tag:506 Relay name:SEL321_Winder_Commerce Relay type:SEL-321
Grid Scenario:	Normal intact network configuration with no outages considered
Outages for Grid scenario (if applicable):	None
Fault current summary:	Minimum and Maximum Fault current for the given grid scenario
Elements passed	11 Show/Hide passed elements
Elements failed	6 Show/Hide failed elements
Elements without logic code	17 Show/Hide unassociated elements
Comments:	No comments

Relay Tag	Relay Name	Element Code	Element Type	Element Designation	Test Name	Value	Test Limits	Performance	Comments
506	SEL321_Winder_Commer	IOC	Phase Overcurrent (F)	50ABC	Reach(applying faults)	>= 100.0%	70 % to 85 %	Fail	Reach above acceptable limits
506	SEL321_Winder_Commer	IOC	Ground Overcurrent (F)	50G1	Reach(applying faults)	77.0%	70 % to 85 %	Pass	None
506	SEL321_Winder_Commer	TOC	Phase Overcurrent (F)	51P	Reach(applying faults)	>= 100.0%	60 % to 99 %	Fail	Reach above acceptable limits
506	SEL321_Winder_Commer	DIST	Phase Impedance (F)	M1P	Estimated Reach	81.8%	70 % to 85 %	Pass	None
506	SEL321_Winder_Commer	DIST	Phase Impedance (F)	M1P	Reach(applying faults)	82.0%	70 % to 85 %	Pass	None
506	SEL321_Winder_Commer	DIST	Phase Impedance (F)	M1P	Loadability	1225.1 MVA (926.1 MW +j 802.0 MVAR)	>=100 MVA	Pass	None
506	SEL321_Winder_Commer	DIST	Phase Impedance (F)	M2P	Estimated Reach	174.3%	100 % to 120 %	Fail	Reach above acceptable limits
506	SEL321_Winder_Commer	DIST	Phase Impedance (F)	M2P	Estimated Reach	22.7% (next longest line) 56.2% (next shortest line)	>=10 % (next longest line) <=50 % (next shortest line)	Fail	Reach above acceptable limits
506	SEL321_Winder_Commer	DIST	Phase Impedance (F)	M2P	Reach(applying faults)	11.0% (next longest line)	>=10 % (next longest line)	Pass	None

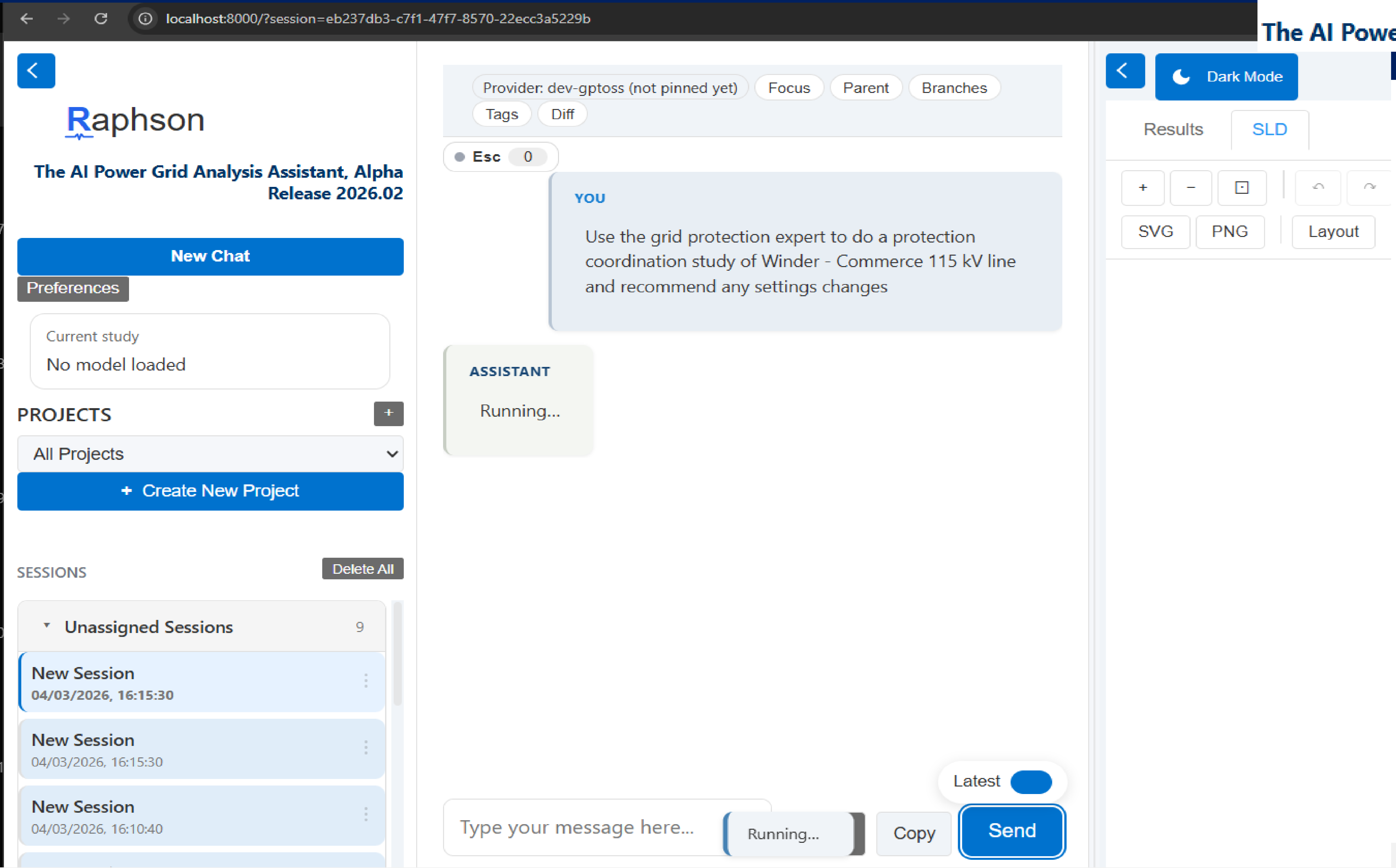


Evaluates every element in every relay which misoperates
Automatically visualize zone reaches in an SLD
Tabulate pass/fail test results for every element

Web Interface

Raphson

The AI Power Grid Analysis Assistant,



EPRI Protection Tool Integration Trials
Current R&D Experiments

Raphson

The AI Power Grid Analysis Assistant,

Transmission Line Protection Coordination Report

Line: 181 WINDER 115–179 COMMERCE 115 (Zline = **9.5317 Ω**)
Relay: SEL-321 "SEL321_Winder_Commerce" (Tag 506)
Scenario: Normal system (no outages)
Results timestamp: Feb 4, 2025

Introduction

Protection coordination on transmission lines is a balancing act: trip fast and decisively for in-zone faults, stay quiet for out-of-zone events, and ride through heavy load and power swings. Distance (impedance) elements provide primary, selective protection by measuring apparent impedance to a fault, while instantaneous and time-overcurrent elements add backup and security for high-current faults and abnormal conditions. Good coordination requires that forward Zone 1 reach ~80% of the protected line, Zone 2 just overreach into the next line to cover remote-end faults with time delay, and Zone 3 (or reverse zones) be set deliberately for backup without endangering neighboring lines. Overcurrent pickups and load encroachment must also be set so the relay won't see load or mutual coupling as faults. This study injected close-in, remote-end, and adjacent-line faults (three-phase and SLG), plus loadability checks, to verify reach, timing, and security. What follows is a straight reading of how the relay actually behaved on this specific Winder–Commerce 115 kV circuit, where it passed most core functions but has several reach and coordination problems that must be corrected before commissioning.

Summary of results

- **Element checks evaluated: 32**
  - **Pass: 12**
  - **Fail: 6**
  - **No trip logic associated (N/A): 14**
- **Fault current envelope (study case):**
  - Phase faults on studied line: **4.64–16.96 kA**
  - Ground faults on studied line: **2.06–16.51 kA**
- **High-level takeaways**
  - **Distance Z1P/Z1G**: In the sweet spot (≈77–83% reach) and loadability margins are ample.
  - **Zone 2 (M2P)**: **Overreaching**—both absolute and relative (to adjacent lines).
  - **Zone 3 (M3P)**: **Inconsistent**—too long toward the next-shortest line (risk of overreach) yet **too short** toward the next-longest line (insufficient backup).
  - **50/51 phase overcurrent**: Instantaneous and inverse-time **reach past 100%** of the line—unacceptable; both need higher pickups (and possibly added restraint).
  - Several forward/reverse zones and 51N are **not mapped to trip logic**; they can't provide protection as configured.

Detailed discussion of issues

1) 50ABC – Phase Instantaneous OC (IOC) reach too long

- **Evidence:** "Reach (applying faults)" **Fail**; relay operated for 3ϕ remote-end (I ≈ **4.64 kA**) and labeled "≥ 100% reach," while acceptable is **70–85%**.
- **Expected:** No trip at remote-end; operate decisively ≤ 85% of line.
- **Actual**: Trips at 100% of line.
- **Fix:** Raise 50ABC pickup so that **Ipk > Iremote-end,3ϕ**.
  - **Setting recommendation: 50ABC pickup = 5.5 kA** (≈1.2× 4.64 kA) minimum. If CT ratio and burden allow, **5.5–6.0 kA** gives margin against source variability.
  - **Optional:** Add **forward directional** supervision tied to MTA of distance Z1 to prevent reverse/load misops.

2) 51P – Phase TOC reach too long

- **Evidence:** "Reach (applying faults)" **Fail** with operation at remote-end (≈**4.64 kA**), and long clearing times (≈**12.1 cycles**) still counted as reach violation (limit expects **≤ 99%** of line).
- **Expected:** 51P should **not** assert for remote-end faults on the protected line at its pickup; it is a backup, coordinated element.
- **Actual**: Reaches full line.

EPRI Protection Tool Integration Trials

Current R&D Experiments

Raphson

The AI Power Grid Analysis Assistant,

Transmission Line Protection Coordination Report

Line: 181 WINDER 115–179 COMMERCE 115 (Zline = **9.5317 Ω**)
Relay: SEL-321 "SEL321_Winder_Commerce" (Tag 506)
Scenario: Normal system (no outages)
Results timestamp: Feb 4, 2025

Introduction

Protection coordination on transmission lines is a balancing act: trip fast and decisively for in-zone faults, stay quiet for out-of-zone events, and ride through heavy load and power swings. Distance (impedance) elements provide primary, selective protection by measuring apparent impedance to a fault, while instantaneous and time-overcurrent elements add backup and security for high-current faults and abnormal conditions. Good coordination requires that forward Zone 1 reach ~80% of the protected line, Zone 2 just overreach into the next line to cover remote-end faults with time delay, and Zone 3 (or reverse zones) be set deliberately for backup without endangering neighboring lines. Overcurrent pickups and load encroachment must also be set so the relay won't see load or mutual coupling as faults. This study injected close-in, remote-end, and adjacent-line faults (three-phase and SLG), plus loadability checks, to verify reach, timing, and security. What follows is a straight reading of how the relay actually behaved on this specific Winder–Commerce 115 kV circuit, where it passed most core functions but has several reach and coordination problems that must be corrected before commissioning.

Summary of results

- **Element checks evaluated: 32**
  - **Pass: 12**
  - **Fail: 6**
  - **No trip logic associated (N/A): 14**
- **Fault current envelope (study case):**
  - Phase faults on studied line: **4.64–16.96 kA**
  - Ground faults on studied line: **2.06–16.51 kA**
- **High-level takeaways**

  - **Distance Z1P/Z1G**: In the sweet spot (≈77–83% reach) and loadability margins are ample.
  - **Zone 2 (M2P)**: **Overreaching**—both absolute and relative (to adjacent lines).
  - **Zone 3 (M3P)**: **Inconsistent**—too long toward the next-shortest line (risk of overreach) yet **too s**
  - **50/51 phase overcu** of the line—unacce restraint).
  - Several forward/rev can't provide protec

Detailed discussion of issues

1) 50ABC – Phase Instantaneous

- **Evidence:** "Reach (applyin kA) and labeled "≥ 100% re
- **Expected:** No trip at remot
- **Actual:** Trips at 100% of lin
- **Fix:** Raise 50ABC pickup so
  - **Setting recommen** If CT ratio and burden allow, **5.5–6.0 kA** gives margin against source variability.
  - **Optional:** Add **forward directional** supervision tied to MTA of distance Z1 to prevent reverse/load misops.

Expected: No trip at remote-end; operate decisively ≤ 85% of line.

Actual: Trips at 100% of line.

Fix: Raise 50ABC pickup so that **Ipk > Iremote-end,3ϕ**.

- **Setting recommendation: 50ABC pickup = 5.5 kA** (≈1.2× 4.64 kA) minimum. If CT ratio and burden allow, **5.5–6.0 kA** gives margin against source variability.
- **Optional:** Add **forward directional** supervision tied to MTA of distance Z1 to prevent reverse/load misops.

2) 51P – Phase TOC reach too long

- **Evidence:** "Reach (applying faults)" **Fail** with operation at remote-end (≈**4.64 kA**), and long clearing times (≈**12.1 cycles**) still counted as reach violation (limit expects ≤ **99%** of line).
- **Expected:** 51P should **not** assert for remote-end faults on the protected line at its pickup; it is a backup, coordinated element.
- **Actual:** Reaches full line.

Raphson Memory
Distill the useful learnings

Raphson
The AI Power Grid Analysis Assistant,

- **User memory:** "Sean hates yellow in charts"
- **Episodic memory**: key learnings from each user or agent session
- **Contextual memory**: what have we learned in this project
- **Semantic memory:** useful information learned about an asset
- **Procedural memory:** if we've learned how to do something new

- **Contradiction**: does a new memory contradict a past one?
- **Reinforcement**: does a new memory enforce an old one?

Raphson Agent Loops
“Ralph Wiggum Mode”

Raphson

The AI Power Grid Analysis Assistant,

- Put an agent in a “while” loop
- Give it a new experiment with specific objective and files
  - Let each agent run until their context window reaches X tokens (avoid dumb zone)
  - Don’t expect the work to finish in one loop
  - Start a new iteration – the agent has the same objective, but it starts from the latest files and experiment progress
- Each loop just progresses the solution/report a little further
- Memory builds across iterations

EPRI Raphson

Engineer

User-Facing Agent

Protection Agent

Contingency Analysis Agent

Transient Stability Agent (future)

Vendor-Neutral Interface

Data Storage Interface

- SQLite
- SQL server, Oracle (future if needed)
- Grid model data, simulation results, and other data stored in CIM structure

Simulation/ Tool Interface

- ASPEN, PSSE, CAPE
- PSLF, PowerFactory, PSCAD (future)
- User-written python tools
- EPRI tools
- EPRI/user-written skills

LLM Interface

- ChatGPT, Claude, Gemini
- AWS/Azure
- Copilot (in development)
- Ollama/vLLM (on-premises or on-PC)

Document and RAG Interface

- How-tos and step-by-step guides
- Relay Manuals, Standards, templates
- LLM Memory modules
- Create reports in PDF or HTML format
- Export results in CSV, JSON, XML etc

Role-Specific Agents

- Example: Agent for Protection
  - **Run short circuit simulations**
  - Run wide-area protection studies
  - Check coordination, update settings
  - **Document** settings and performance
  - Create high-level or detailed **reports**
  - **Remember** successful/failed solutions to re-use in future
- Agents have vendor-neutral access to grid data, simulation tools, LLMs, RAG

Electromagnetic Transient (EMT) AI Assistant

PS40D(C) Transmission Transients

Objective

- The aim of the research is to create a set of application guides, investigative reports, and tools to support practical approaches to modeling, statistical switching, simulating and analyzing power system transients

Current Gaps

- Can the EMT assessment process be more streamlined?
- How to model power system components?
- 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?
- Case studies and worked examples.

R&D Focus Areas

Education Support Tools

EMT studies are often considered a relatively specialist area with expertise being difficult to source. Guidelines and tools providing step-by-step guidance on what needs to be modeled and built-in engineering assumptions with supporting documentation.

Transient Guidelines

Application guides will provide members with a solid basis for identifying when EMT studies are warranted, how detailed the models need to be for the task and what error margin to expect from their modeling assumptions. .

Transient Analysis Tools

Increase engineer efficiency by providing step-by-step tools with guidance on what needs to be modeled and built-in engineering assumptions with supporting documentation.

Guidance on the use of AI in EMT Simulations

NEED

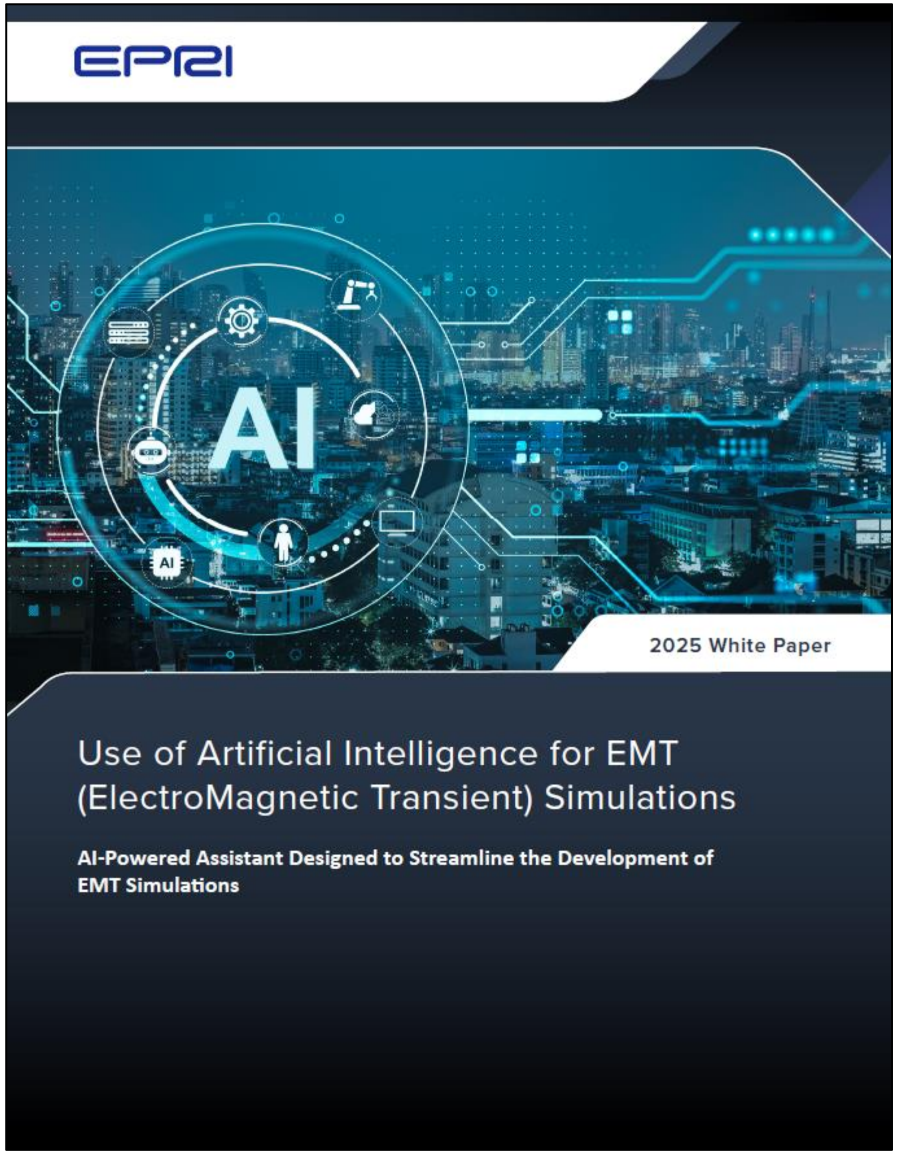
Guidelines and tools to demonstrate the use of AI to improve EMT simulations.

OBJECTIVE/VALUE

EMT studies are often considered a relatively specialist area with expertise being difficult to source. This task will explore the use in AI to improve efficiency. This will include guidelines and tools providing step-by-step guidance on what needs to be modeled and built-in engineering assumptions with supporting documentation.

SCOPE

- Explore the use of AI in EMT simulations
- Prove use cases to illustrate potential uses
- Provide benchmarking in the use of AI for EMT simulations.



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AI Assistant Prototype For EMT Simulations

- **The goal of this prototype:** is to make an assistant that will help developers and users to have a smoother experience writing EMTP scripts.
- **Improved Accuracy and Usability:** The AI ensures syntactical correctness, and the end goal is to offer context-aware support, improving script reliability and user experience.

- **Natural Language Code Generation:** LLMs convert descriptive user input into precise EMTP script snippets with high syntactical accuracy.
- **Documentation Assistance:** LLMs enhance comprehension by summarizing and clarifying EMTP technical documentation for developers. Examples:
  - is there a function that will return ....
  - how can I get/set ....

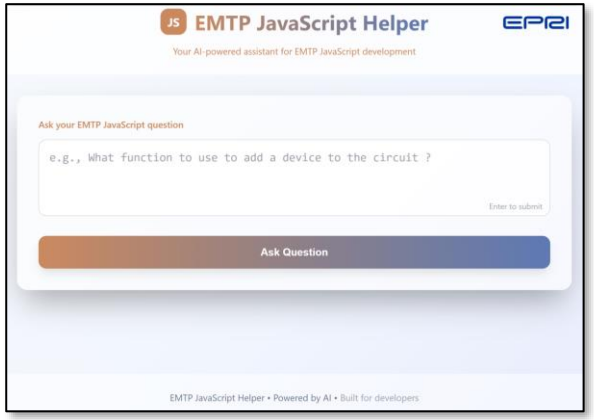
A Prototype for AI Driven Script Generation and Documentation Navigation

ok i have another question now, can you make a script that adds an ideal switch in a existing design in EMTP.

Thought for 1m 27s >

5 searches · 18 sources EMTPWorks JavaScript function that will insert an **Ideal switch** into your currently open schematic. You'll need to adjust the `libName` and `partName` to match exactly how the "Ideal switch" appears in your Parts palette (and which library file it's in), and set the insertion coordinates (`posX` , `posY`) to wherever you'd like it placed:

EMTP Java Script code generated by ChatGPT-4o-mini-high user's prompt and ChatGPT explanation.



Citations

EMTP
Object: DWStatic
A DWType object if successful, or null if unsuccessful. Method: newDesign. Creates a new, empty design...

EMTP
Object: DWCircuit - EMTP
Object: DWCircuit. addDevice - Adds a device to the circuit (i.e. places it on the diagram); addGraphic -...

EMTP
emtp.com

EMTP
[PDF] Ideal switch - EMTP
May 29, 2012 — The library contains two versions of this device: Ideal switch and Ideal closed switch. The...

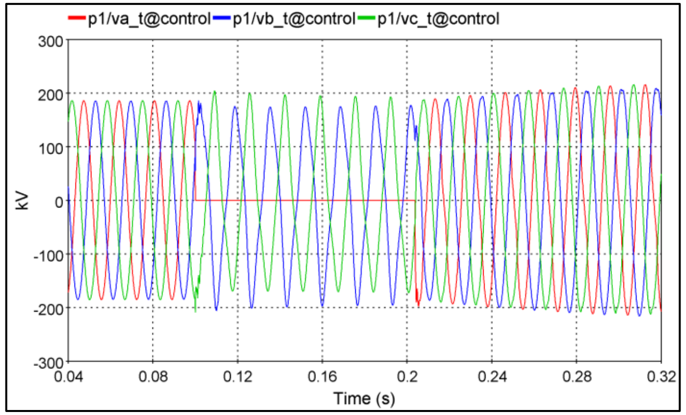
Citations of the links on the internet that GPT-4o-mini-high reached to generate code for the user.

```
/**
 * Adds an Ideal switch to the active circuit.
 *
 * @param {number} posX        - X position on the page (in 1/1000").
 * @param {number} posY        - Y position on the page (in 1/1000").
 * @param {char}   orient      - Orientation: 'E','W','N','S', etc.
 * @param {number} closeTime   - Switch closing time (seconds).
 * @param {number} openTime    - Switch opening time (seconds).
 */
function addIdealSwitch(posX, posY, orient, closeTime, openTime) {
  // 1) Get the active circuit
  var ckt = currentCircuit();                              // DWStatic.current
  if (!ckt) {
    alert("No active circuit found.");
    return;
  }

  // 2) Define your library and part names (adjust these!)
  var libName  = "Switch";                                 // your switch libr
  var partName = "Ideal switch";                           // exactly as it ap

  // 3) Add the device at the specified location
  //    (libName, partName, posX, posY, orient, page#, hitTest)
  var sw = ckt.addDevice(libName, partName, posX, posY, orient, 1, false);
                                                           // DWCircuit.addDev
  if (!sw) {
    alert("Failed to add Ideal switch.  Check libName/partName.");
    return;
  }

  // 4) Set the switch timing parameters
  //    (attribute names from the Ideal switch spec)
  sw.setAttribute("close t", String(closeTime));           // DWDevice.setAttr
  sw.setAttribute("open t",  String(openTime));            // DWDevice.setAttr

  // 5) (Optional) isolate this instance's type so future library changes don
  sw.makeUnique();                                         // DWDevice.makeUni

  // 6) Refresh the schematic display
  ckt.redraw();                                            // DWCircuit.redraw

  alert("Ideal switch added at (" + posX + ", " + posY + ").");
}

// --- example usage: ---
addIdealSwitch(700, 1400, 'E', 0.0, 0.0);
```

EMTP Java Script code generated by ChatGPT-4o-mini-high generated code.

A Prototype for LLMs For Analyzing Waveforms

- EMTP AI assistant integrated with ScopeView



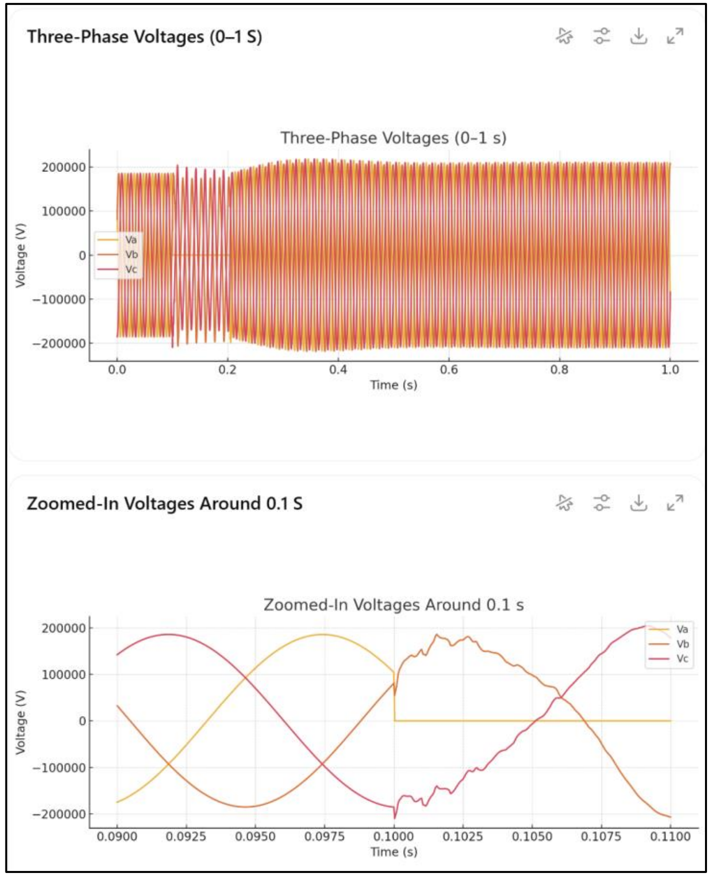
hi, I have this voltages, any idea what is happening at t=0.1?

Thought for 12 seconds

Around **t = 0.1 s** you see **phase A (red) suddenly drop to zero** and stay there, while phases B and C immediately go through a transient before settling back into a sinusoid of shifted amplitude and phase. That flat-line on Va means that leg has either been **clamped** (or opened) by your control/fault logic (i.e. Va is being forced to 0 V). With one phase effectively "lost," the neutral point floats and you get those overshoots and dips on Vb and Vc.

In other words, you've inserted a **single-phase fault or control-leg disable** at t = 0.1 s. If that wasn't intentional, check whatever part of your code or protection scheme kicks in at 0.1 s and forces Va to zero.

ChatGPT diagnosing a single-phase fault from a waveform screenshot.(a) Screenshot of a single-phase fault given to ChatGPT;(b) Analysis of the screenshot.



Here's what the plots reveal:

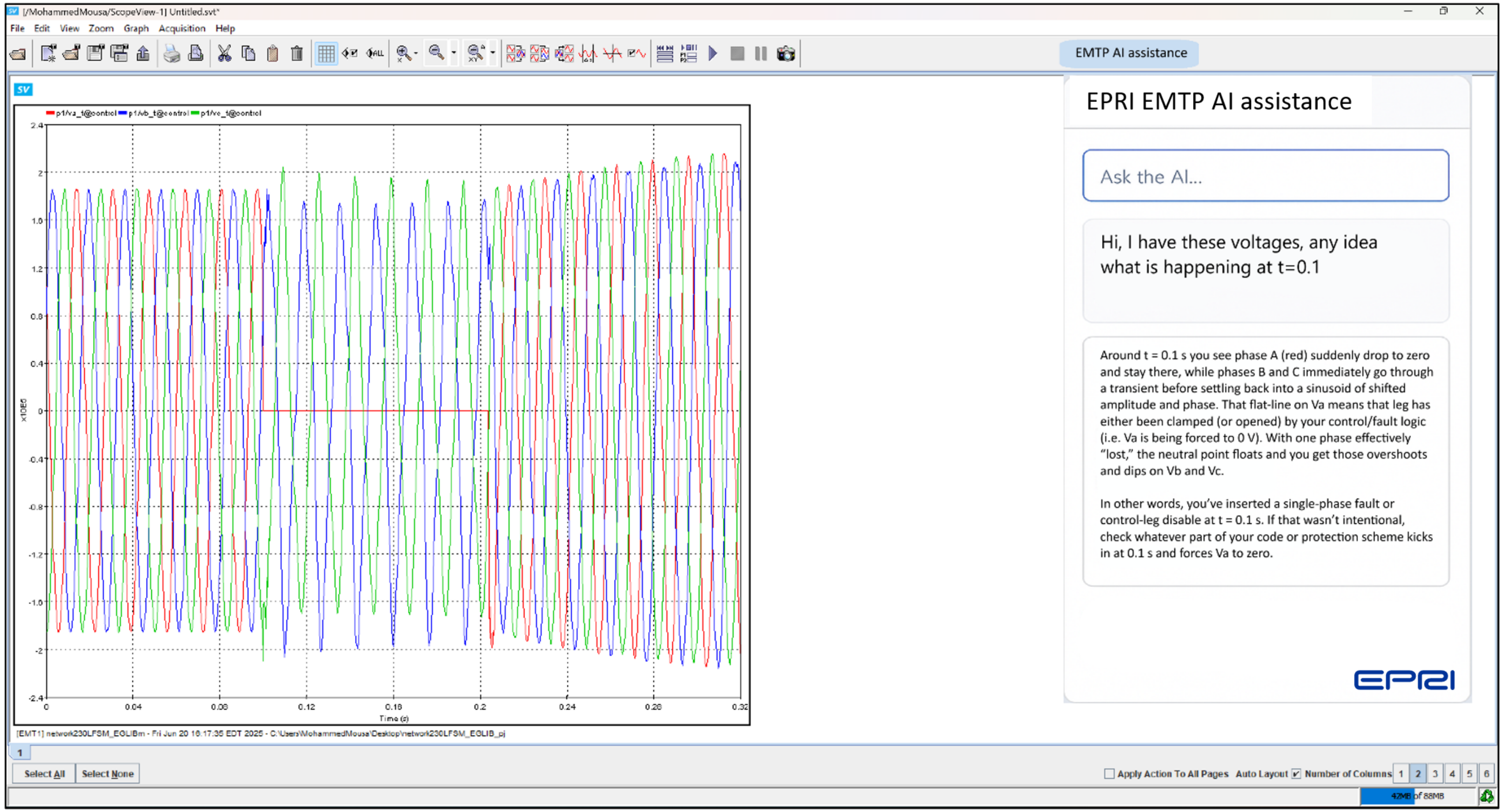
- **Balanced pre-fault** (0 – 0.1 s): Va, Vb, and Vc are equal-amplitude, 120°-phase-shifted sinusoids—indicating a healthy three-phase source.
- **Fault initiation at 0.100 s**: Va (orange) abruptly clamps to 0 V. This is a clear single-phase fault or leg disconnection.
- **Transient ringing (0.100 – 0.200 s)**: With Phase A held at zero, Phases B (blue) and C (red) show overshoots and high-frequency oscillations as the network's capacitances and inductances rebalance the unbalanced load.
- **Fault clearance (~ 0.200 s)**: All three phases resume balanced sinusoidal operation, with only lightly damped ripples remaining.

This sequence—clamp, ringing, and recovery—confirms a temporary single-phase fault was applied at exactly 0.1 s and cleared around 0.2 s, producing the characteristic fault and post-fault response in a three-phase system.

ChatGPT reproducing three-phase voltage plots from raw CSV data. Plots reproduced after ChatGPT was fed the raw CSV data; The explanation of the wave behavior..

A Prototype for LLMs For Analyzing Waveforms

- EMTP AI assistant integrated with ScopeView



EPRI EMTP AI assistant integrated with ScopeView

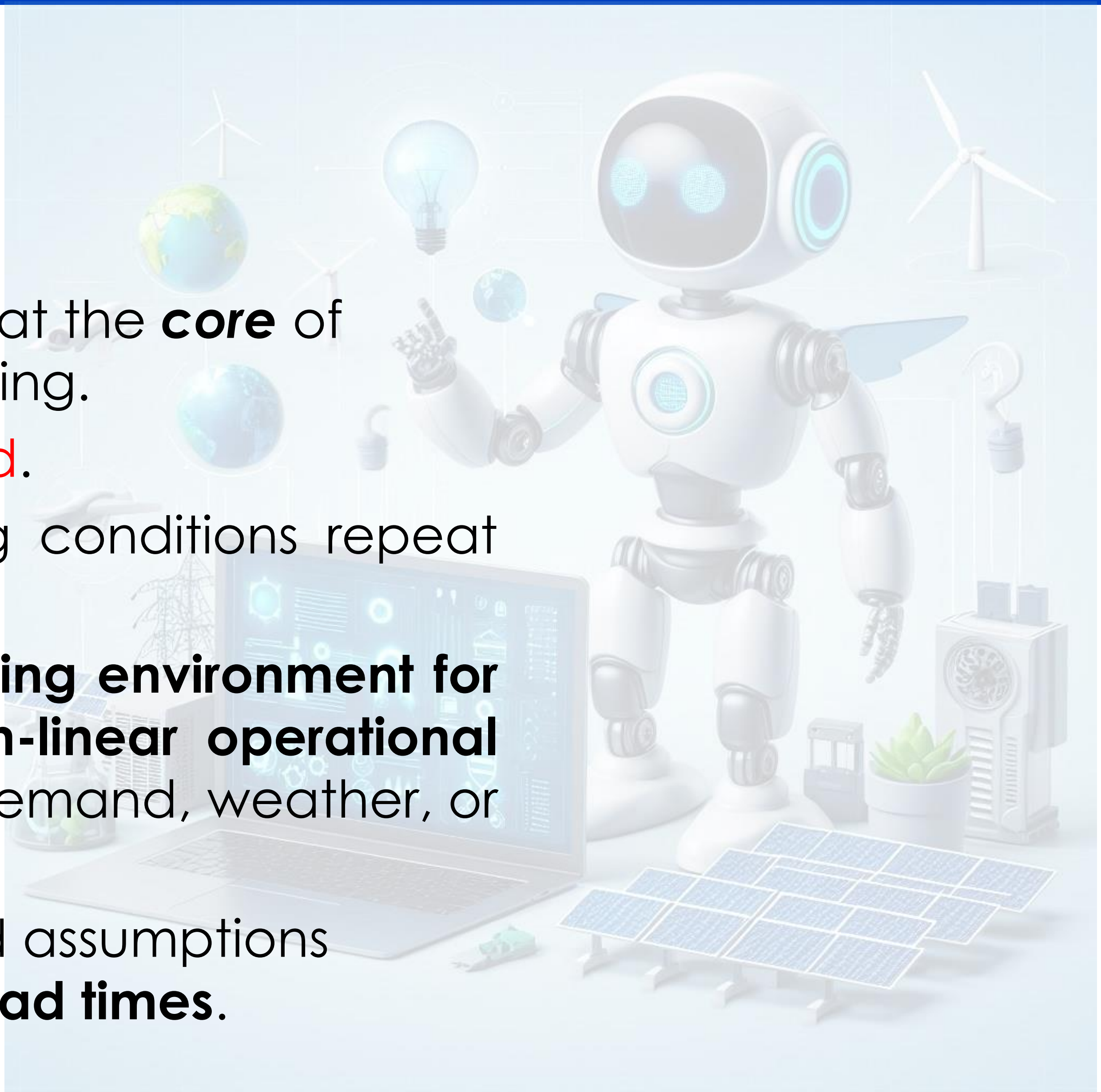
Next Steps

- Further advance capabilities with the EPRI EMTP AI assistant:
  - Provide guidance to the user according to analysis needs by selecting appropriate components based on voltage levels and the studied transients.
  - Provide guidance and automatic completion in component data input based on the studied system parameters.
  - Study the completed design for detecting anomalies and inappropriate engineering practices.
  - Provide support and verification with references to available standards related to insulation coordination, integration of data centers and other simulation needs.
  - Deliver data from existing simulation cases and expected results for given events. Existing simulation results could be based on a large collection of simulation samples and practices in the industry.
  - Validate simulation results based on existing knowledge from similar studies and typical data.

EPRI - AI-ccelerating Unit Commitment Challenge

Production Cost Models

- **Context**
  - <u>*Production cost models (PCMs)*</u> are at the **core** of power systems operation and planning.
  - **Drawback:** High computational load.
  - In **power systems**, many operating conditions repeat and recur as the grid **runs 24/7**.
  - This makes it an ideal **data-generating environment for AI**, which can **learn complex, non-linear operational patterns driven by** factors such as demand, weather, or time of year.
  - **Current solutions**: Simplifications and assumptions leading to **inaccuracies and long lead times**.

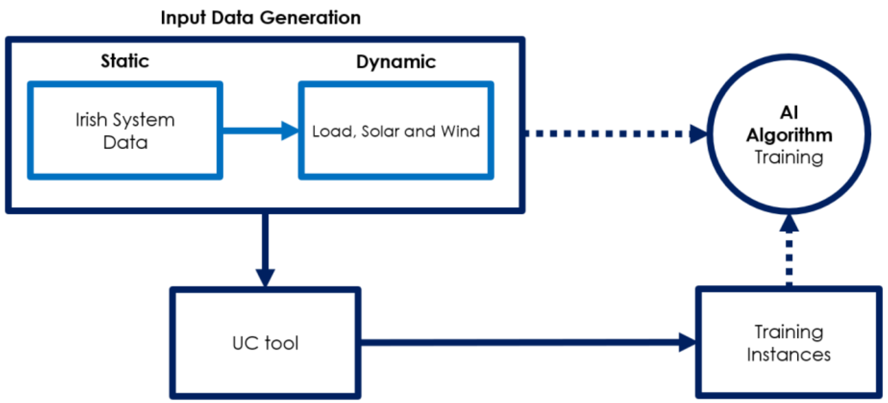


– Research Question: Could AI solutions improve <u>*PCM*</u> ***efficiency*** with accurate results?

AI-ccelerating Production Cost Models

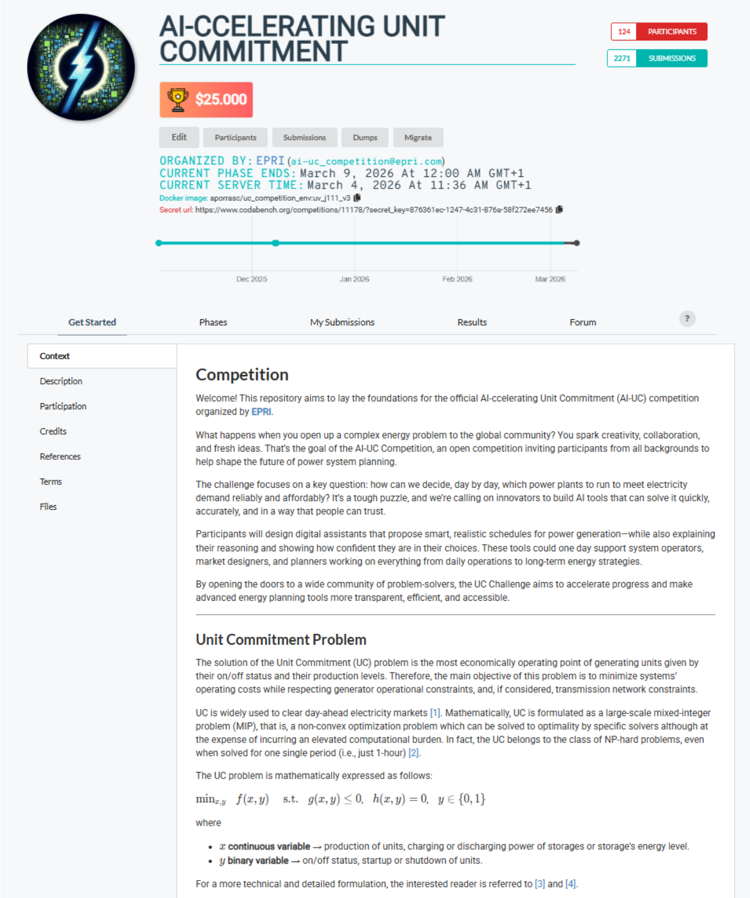
Competition for benchmarking AI models in PCM → Realistic scenarios using data from the Irish Power System → Platform for participants to submit their AI agents and receive evaluations. → Phase 1 Nov 3 – Mar 9

- **Value**
  - Discover which **AI** techniques works adequately for **PCM**
  - **Test if AI** can enable and **enrich long-term studies** by allowing a multitude of scenarios to be run and more operational details.
  - Engage broader community of researchers and SMEs in AI with compelling use case



AI Competitions foster innovation and engage beyond the world of power systems

AI-ccelerating PCM Competition



AI-CCELERATING UNIT COMMITMENT

124 PARTICIPANTS

2271 SUBMISSIONS

$25.000

Edit | Participants | Submissions | Dumps | Migrate

ORGANIZED BY: EPRI (ai-uc_competition@epri.com)
CURRENT PHASE ENDS: March 9, 2026 At 12:00 AM GMT+1
CURRENT SERVER TIME: March 4, 2026 At 11:36 AM GMT+1
Docker image: aporrasc/uc_competition_env:uv_j111_v3
Secret url: https://www.codabench.org/competitions/11178/?secret_key=876361ec-1247-4c31-876a-58f272ee7456

Dec 2025 | Jan 2026 | Feb 2026 | Mar 2026

Get Started | Phases | My Submissions | Results | Forum

Context
Description
Participation
Credits
References
Terms
Files

Competition

Welcome! This repository aims to lay the foundations for the official AI-ccelerating Unit Commitment (AI-UC) competition organized by EPRI.

What happens when you open up a complex energy problem to the global community? You spark creativity, collaboration, and fresh ideas. That's the goal of the AI-UC Competition, an open competition inviting participants from all backgrounds to help shape the future of power system planning.

The challenge focuses on a key question: how can we decide, day by day, which power plants to run to meet electricity demand reliably and affordably? It's a tough puzzle, and we're calling on innovators to build AI tools that can solve it quickly, accurately, and in a way that people can trust.

Participants will design digital assistants that propose smart, realistic schedules for power generation—while also explaining their reasoning and showing how confident they are in their choices. These tools could one day support system operators, market designers, and planners working on everything from daily operations to long-term energy strategies.

By opening the doors to a wide community of problem-solvers, the UC Challenge aims to accelerate progress and make advanced energy planning tools more transparent, efficient, and accessible.

Unit Commitment Problem

The solution of the Unit Commitment (UC) problem is the most economically operating point of generating units given by their on/off status and their production levels. Therefore, the main objective of this problem is to minimize systems' operating costs while respecting generator operational constraints, and, if considered, transmission network constraints.

UC is widely used to clear day-ahead electricity markets [1]. Mathematically, UC is formulated as a large-scale mixed-integer problem (MIP), that is, a non-convex optimization problem which can be solved to optimality by specific solvers although at the expense of incurring an elevated computational burden. In fact, the UC belongs to the class of NP-hard problems, even when solved for one single period (i.e., just 1-hour) [2].

The UC problem is mathematically expressed as follows:

$$\min_{x,y} \quad f(x,y) \quad \text{s.t.} \quad g(x,y) \leq 0, \quad h(x,y) = 0, \quad y \in \{0,1\}$$

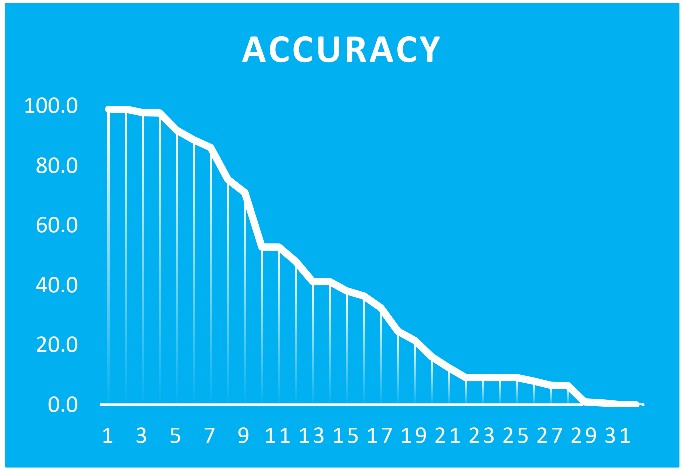
where

- x **continuous variable** → production of units, charging or discharging power of storages or storage's energy level.
- y **binary variable** → on/off status, startup or shutdown of units.

For a more technical and detailed formulation, the interested reader is referred to [3] and [4].

Note: Unit Commitment is a particular case of PCM

Scan this QR to access to the competition



Participant Ranking

[AI-ccelerating Unit Commitment - Codabench](https://www.codabench.org/competitions/11178/)

Link to the competition

Competition closes on March 9

Phase 1 Results

- Challenge of scheduling **51** number of **assets**.
- Test with **504** demand **scenarios** of 3-day horizon.
- **Top 1**:
  - 99% traditional tools accuracy
  - 449 perfect predictions (504)

Name	Organization	Accuracy	Duration 1 Scenario Avg.
Imperial College	Academia	99%	6.5s
Vertrage	SME	99%	5.8s
University of Colorado	Academia	98%	8.4s
MIT	Academia	97%	9.7s
CAU	Academia	92%	11.3s

Traditional optimization resources ran the set of scenarios with **90s** on average **per scenario**.

Top 4 participants get **97%** the same level of **accuracy** as using commercial tools but in **6s-10s per scenario**.

AI can deliver fast and qualitative optimization results

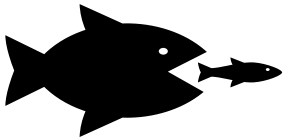
Next Steps

These results clearly show that AI can tackle this challenge effectively, with multiple teams reaching strong solutions through different approaches

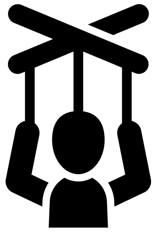
EPRI are excited to keep building on this momentum and to see how these methods get matured as we introduce more complexity

Next Steps

2nd Challenge adding more complexity to the problem



Collaborations for applications of lessons learned in a case study with real data



AI enhances Power System Operation and Planning

EPRI

EPRI's Open Power AI (OPAI) Initiative

Open Power AI Consortium

Creating an ecosystem for stakeholders to identify, develop, validate, and deploy AI solutions to transform the electric sector

- Develop AI Models, Data & Roadmaps
- Create an AI Sandbox
- Implementation and Lessons Learned

OPEN POWER
AI CONSORTIUM

>200 Confirmed Members

>+ MOU/Requests In-Process

>250 Use cases identified

https://openpowerai.org/

OPAI Use Case Survey Links – Remains Open Indefinitely

Technology Provider Survey

Click or Scan

https://www.surveymonkey.com/r/OPAI-USe-Cases-Tech-Providers

Transforming Survey Data to OPAI Member Value

Use Case Assessment Criteria Prioritization

- Top 5-10 Reliability and Resilience
- Easiest to implement
- Least risky…etc
- Company confidential benchmarks relative to indu

Published soon on https://openpowerai.org/

Utility and Industry Demo Spotlights

- Reference and spotlight utility or technology use case implementations

Use Case Functional Prioritisation

- Top 5 10 Asset Management
- Top 5-10 Operations
- Top 5-10 Markets, Nuclear….etc

Use Case to Technology Matching

- Map high priority use cases to medium to high techno

Use Case Co-Development

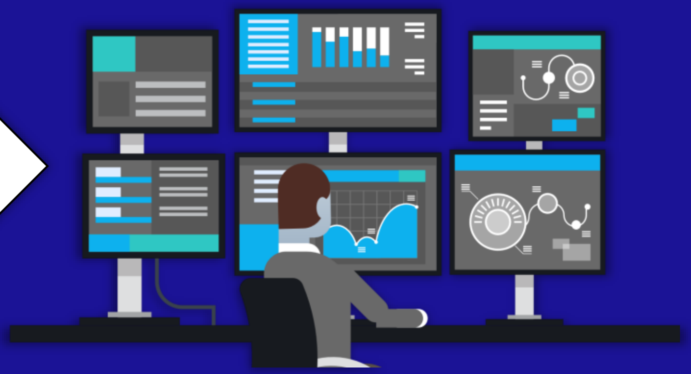
Use Case Co-Development

- OPAI will bring forward the highest priority use cases for co-d opment
- Potential data availability identified in survey, utilities with highest need may provide

What Does This Look Like for a Typical Use Case?

Use Case Priority #2 *Grid and Asset High-Speed Recording Data Insights*

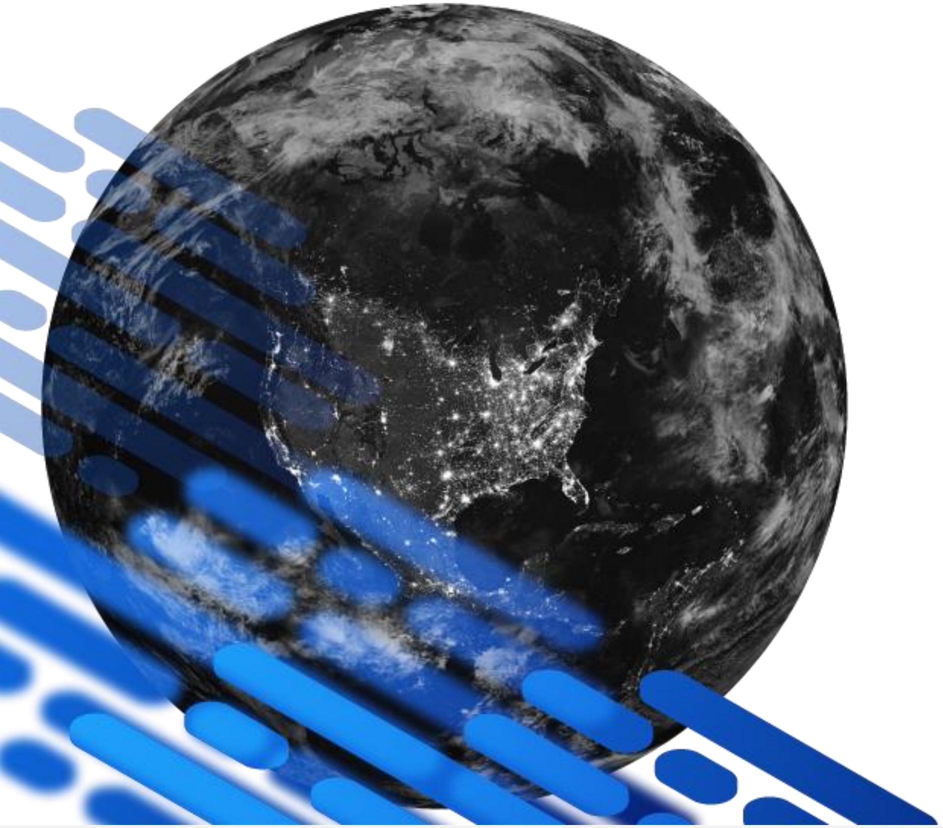
High-frequency data from Digital Fault Recorders (DFRs) and transient recorders is analyzed using deep learning to detect sub-cycle events and transient disturbances as well as power quality. AI models can automatically classify fault types, identify affected components, and reconstruct event timelines. Pattern recognition and clustering models identify recurring issues and affected network areas. Insights support root cause analysis and corrective actions. This helps utilities maintain compliance with power quality standards and improve customer satisfaction. These insights support root cause analysis and post-event reporting. Integration with asset condition monitoring enhances predictive maintenance strategies.



Development Phase	Energy Utility Contributions	Technology Provider Contribution
Requirements Discovery & Prototyping	Define the problem, scope, personas, define data, define end state.	Defining architecture, app requirements, building blocks available.
Environment Setup & Data Engineering	Data provision, synthesization, quality checking	Compute resource design and allocation
Core Development & Model Integration	Oversight on product direction, features	App and AI model development, CI/CD pipelines
QA, Security, and UAT	User testing and feedback, integration oversight and design (IT/OT teams)	Test harness development, cyber security, AI model validation
Deployment & Operational Monitoring	Demo of application, sandboxing, feedback on prototype	Deploy and troubleshoot protype application

Any Question?

Thank You for Your Participation and Engagement. Look out for the *Next ‘Views from the TOP’ invite for April 8th, 2026.*



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Slide.com Code: **3941399**

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