NATIONAL LABORATORY OF THE ROCKIES

NATIONAL ACADEMY OF ENGINEERING

Generative AI for Grid Operations

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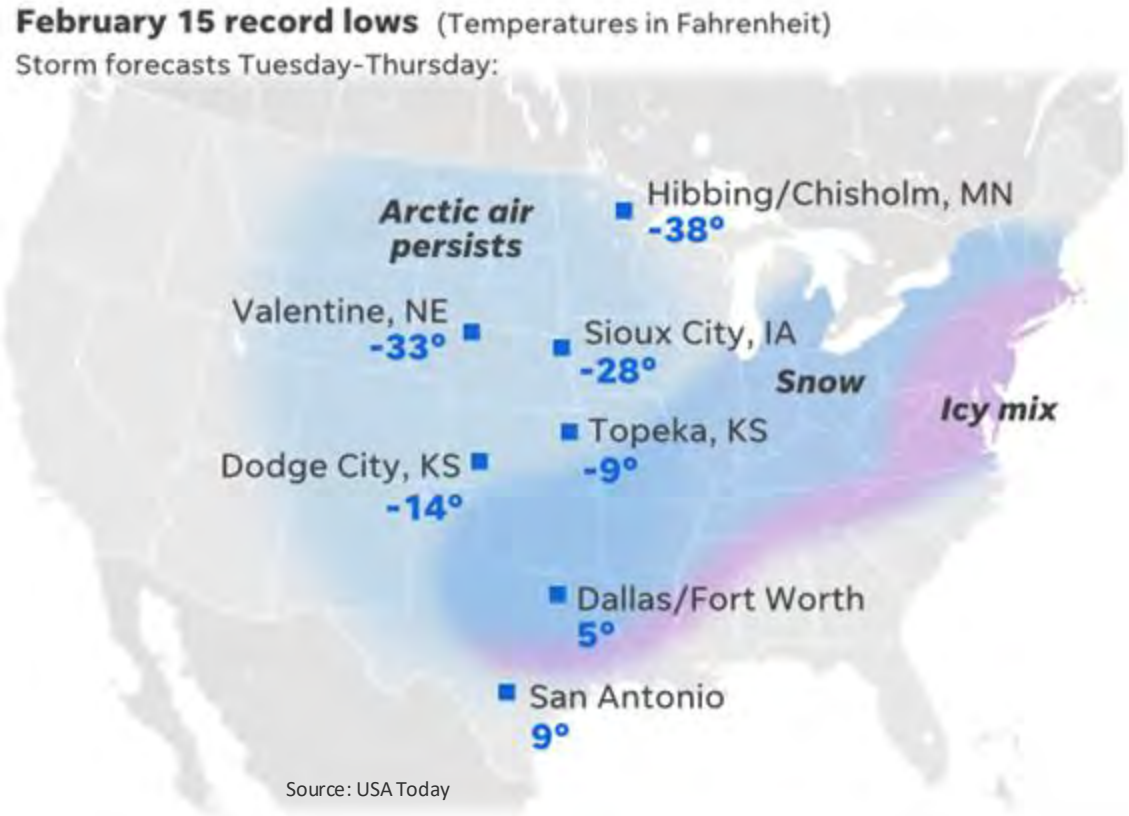
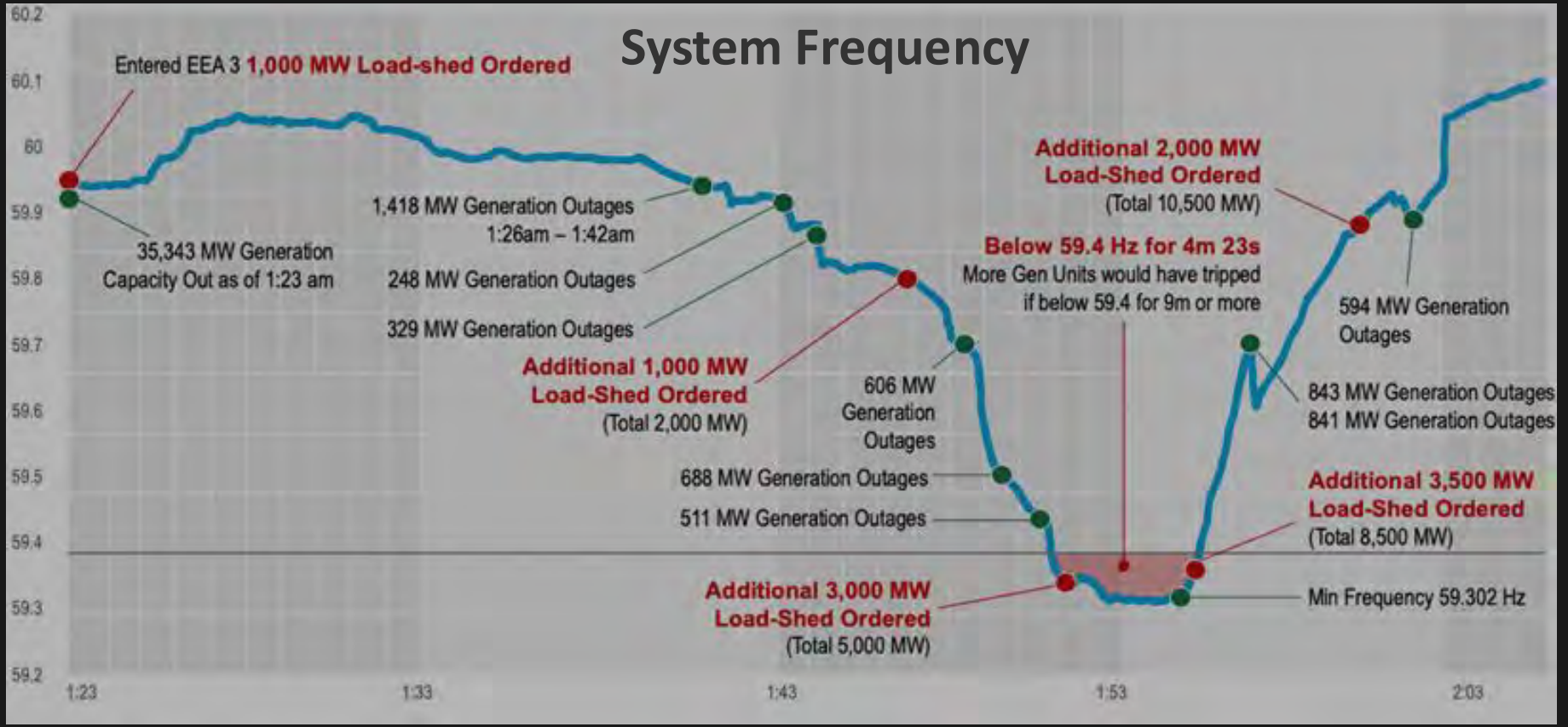
Riding the Storm Out – February 15, 2021



Record cold drove record demand

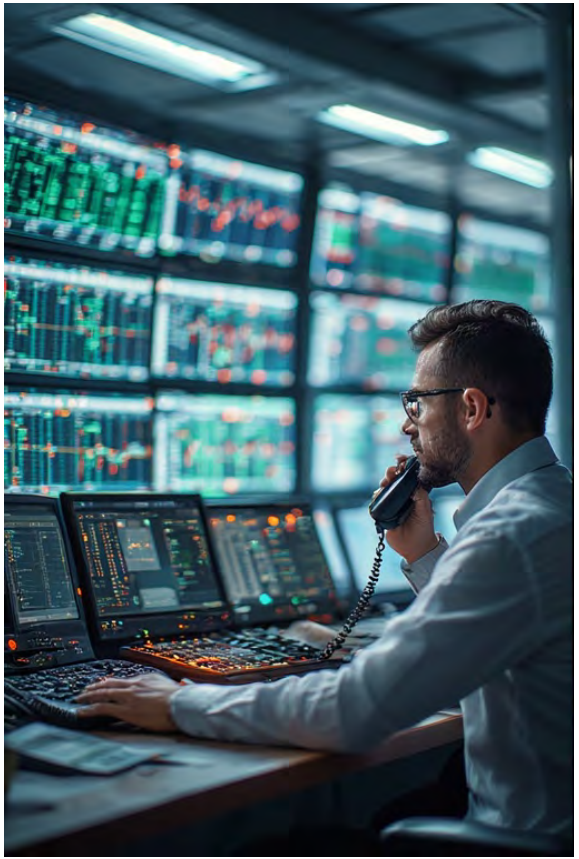
- **Typical Winter Peak = 57 GW**
- **Extreme Winter Peak = 67 GW**
- **Actual Winter Peak = 69 GW**

System Frequency



Source: ERCOT

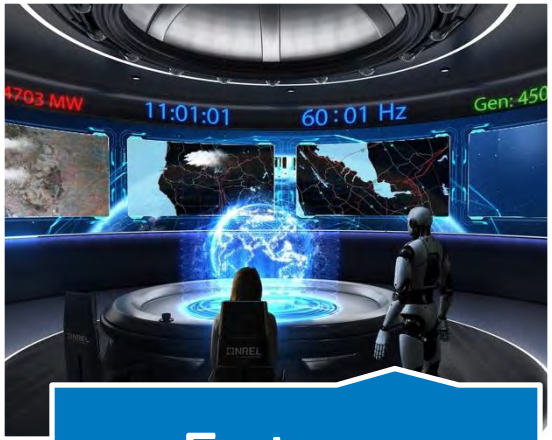
Regular Weather Can Cause Lots of Alarms



Adding Technology into the Control Room

Past
No computer/Analog

Present
Computer/Digital



Future
Digital transformation

Slide Rule

Calculator

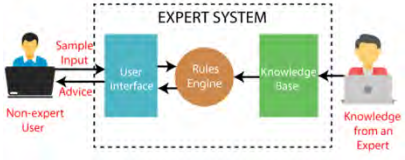
Computer

Internet

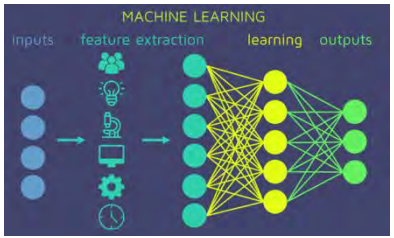
Generative AI

Artificial Intelligence (AI)
Why all the Interest?

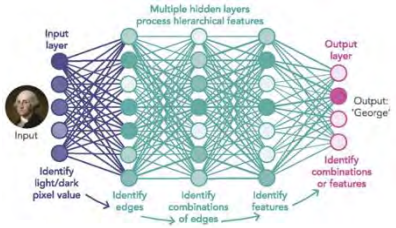
1980s



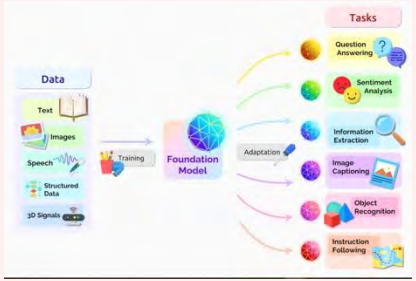
1980s to 2010



2010 to 2017



2017 to Present



Expert Systems
Emulating the decision-making ability of a human expert through if-then rules

Machine Learning
Feature Centric:
Task-specific hand-crafted feature representation

Deep Learning
Model Centric:
Task specific learned feature representation

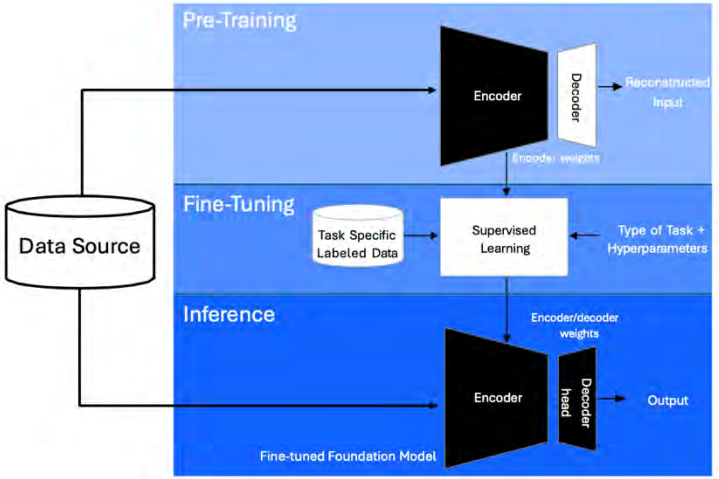
Foundational Models
Data Centric:
Generalizable and adaptable learned representations
Self-supervision at Scale
Natural Language Processing

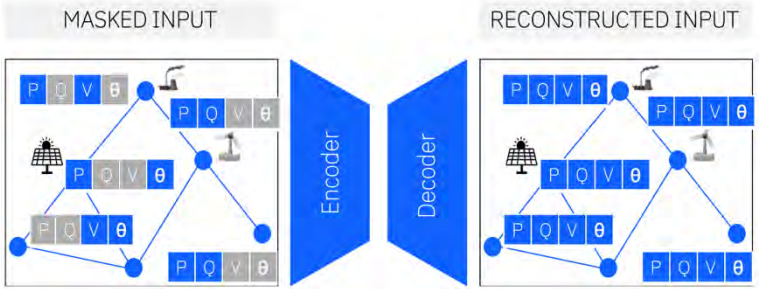
- AI is not new - have been using AI in energy systems for decades
- New techniques such as large language models (LLM) and Generative AI that can provide advanced capabilities

Adapted from: Foundation Models for the Power Grid – Hendrik Hamann et al.

The “new” AI - Generative AI

- Based on Foundational Models
- Foundational model can perform various functions (Q&A, Music, Video, Design, Coding, Translation)
- Foundational Models are pre-trained on massive amounts of data and create weighted inferences
- Learn, judge, and solve problems on its own like a human
- Large Language Models (LLMs) allow you use natural language to communicate, no computer translation is required.





Source: Foundation Models for the Electric Power Grid

AI Use Cases by Functions in Power Systems

Grid Operation

- Load/Gen/Price Forecasting
- Outage Prediction
- Workforce Training
- Distributed Resources Visibility
- Anomaly/Patterns Recognition

Grid Planning

- Capacity Expansion Planning
- Resource Planning
- Asset Inventory
- Wildfire mitigation
- Storm Restoration

Grid Modeling

- Optimal PowerFlow
- Transient & Dynamic Stability
- System Security/Fault Detection

Business Operations

- Rate Case Documentation
- Policy Development
- Company Performance Data

Cybersecurity

- Anomaly Detection
- Vulnerability Assessment
- Incident Response

Customer Service

- Interactions Analysis
- Data Support for Call Center
- Billing Dispute

Have you used ChatGPT?

It's Amazing! –
It can recognize human language

Could we create a Chatbot that would:

1) Be capable of understanding power system information
2) Process large amount of information very quickly
3) Be trustworthy enough to be helpful to control room operators

What Does an Operator Do?

Back to normal

Schedule

- Day-ahead

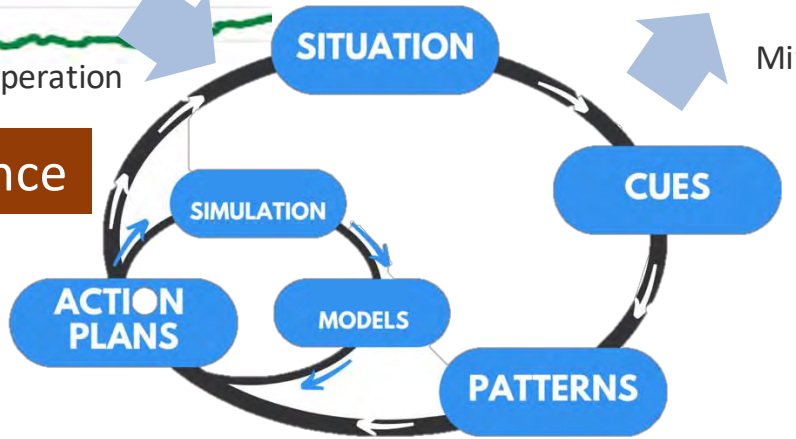
Dispatch

- Intra-day

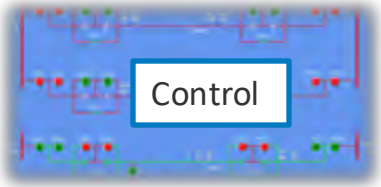
Abnormal operation

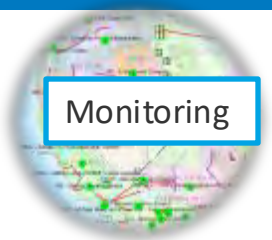
Mitigation

Greatest need for assistance

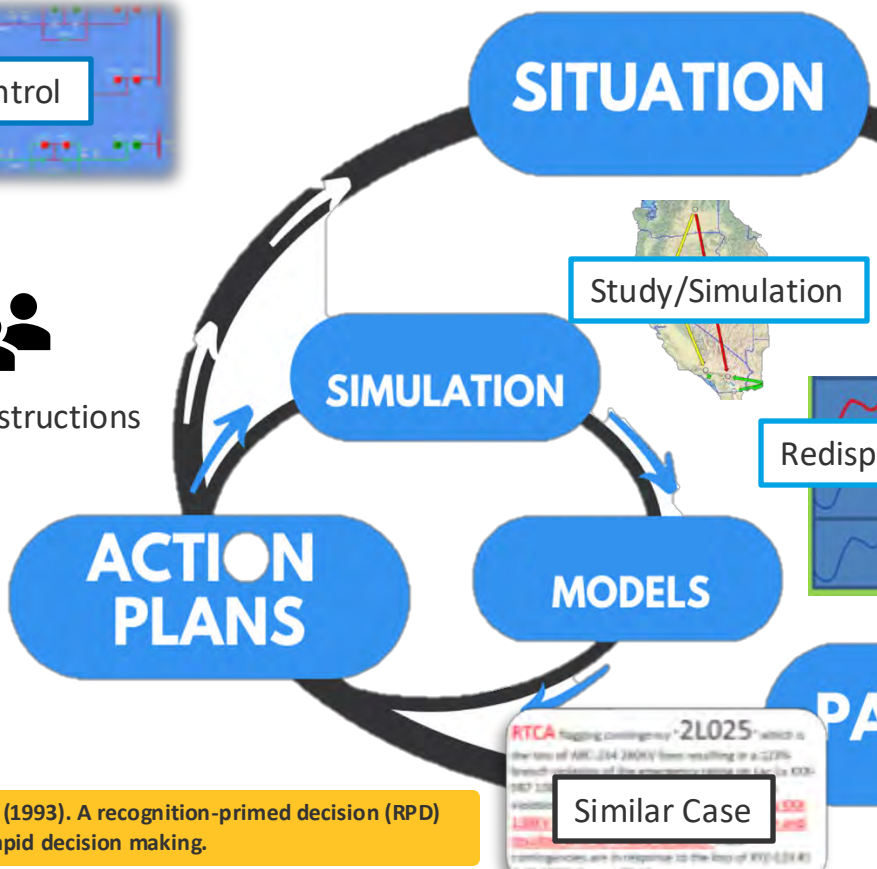


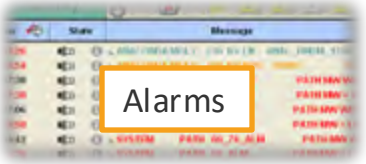
Recognition-Primed Decision (RPD)





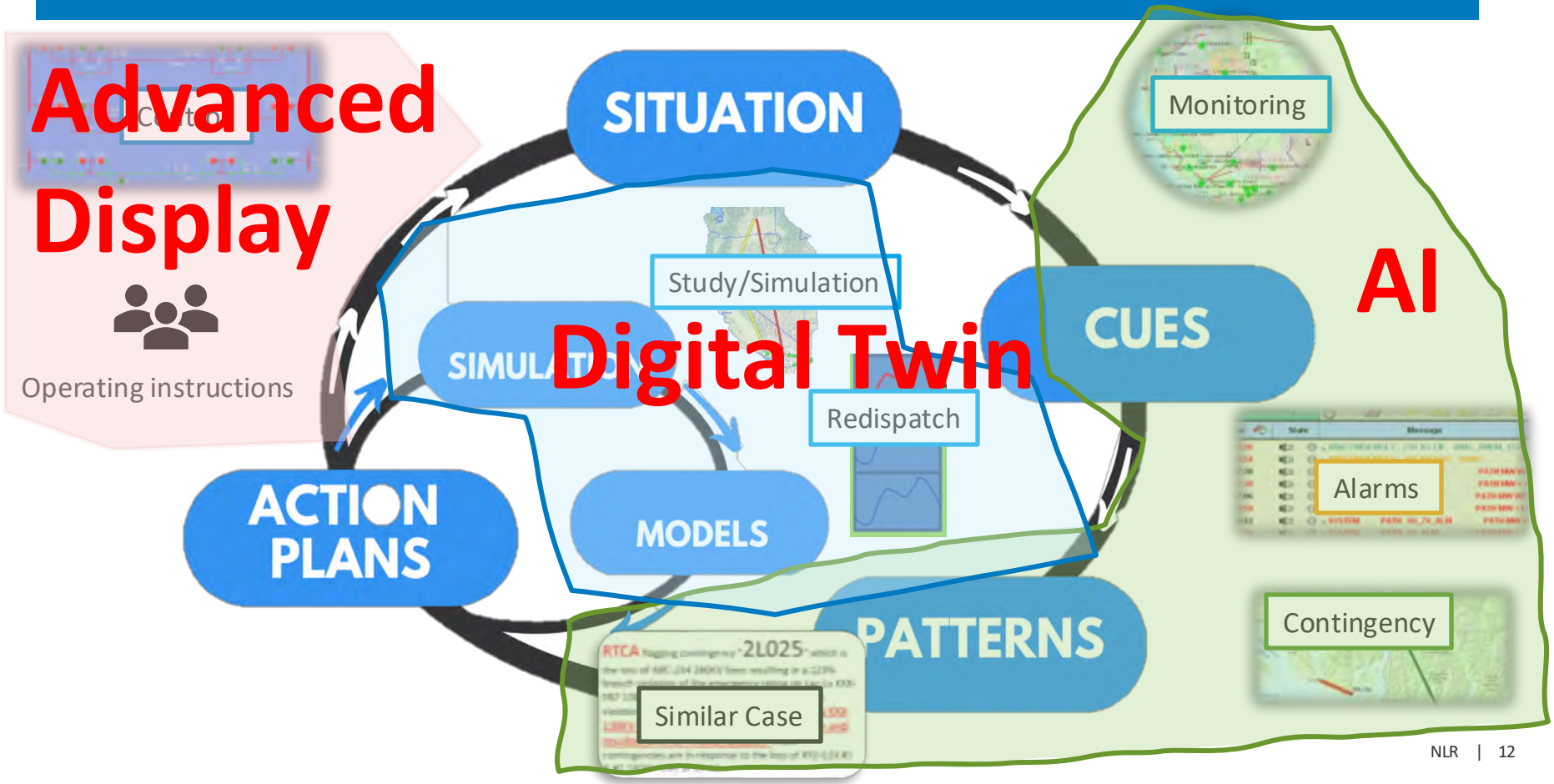
Operating instructions





Klein, G. A. (1993). A recognition-primed decision (RPD) model of rapid decision making.

Technologies to Assist Operators



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eGridGPT

- **Electric Grid Generative Pretrained Transformer (eGridGPT)** is engineered to virtually support power grid control room operators by assisting in decision-making processes and interpreting data and models.

- eGridGPT integrates **large language models**, **digital twin simulations**, and **advanced visualizations** to provide holistic recommendations to grid operators.

eGridGPT Use Cases

Integration	• Different tools talk to each other • Reduce number of displays
Manual to Automation	• Outage study automation • 1,000 scenarios / 30 min
Big Data: Hard to process or never been used	• Flood of alarms • 1,000 alarms / hour

eGridGPT: Control Room of the Future

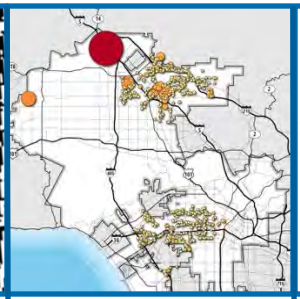
Proof of Concept:
eGridGPT talks to Control room applications

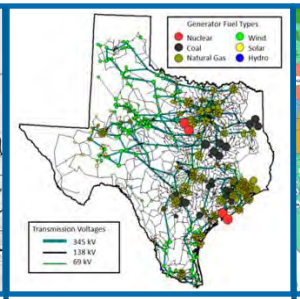
Utility: Highly Reliable Organization

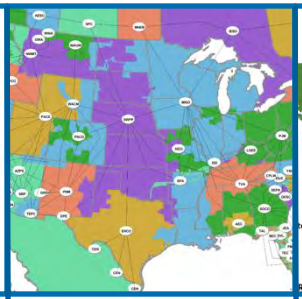
Preoccupation with failure	Operators are constantly on high alert for potential errors, actively seeking out weaknesses to prevent them from escalating into major issues.
Commitment to resilience	Embracing the importance of flexibility, continuous learning, and resilience in the face of disturbances, rather than simply reacting to crises after they occur.
Reluctance to simplify	A reluctance to oversimplify complex situations, acknowledging that nuance and depth are essential to effective decision-making
Deference to Expertise	Valuing and respecting individuals with specialized knowledge, skills, and experience.
Sensitivity to operations	A mindset focused on maintaining a deep understanding of current system performance, with the ability to adapt in real-time to changing circumstances.

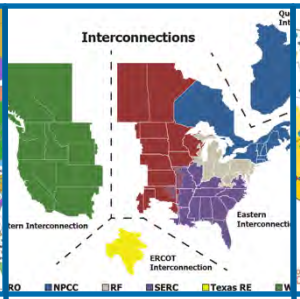
https://www.cascade.app/blog/high-reliability-organizations-overview

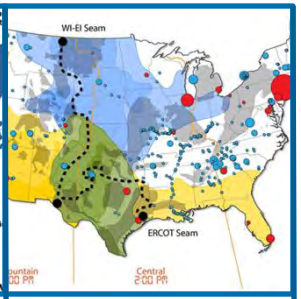
Commitment to resilience: NERC Compliance



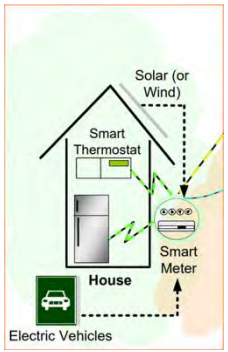




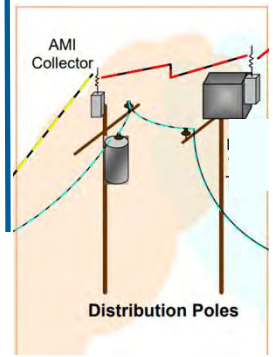




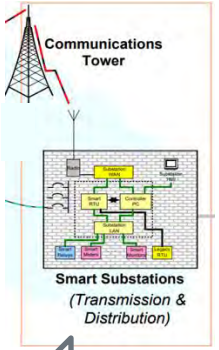
Home



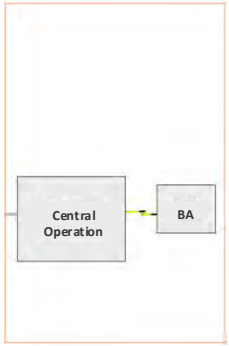
City



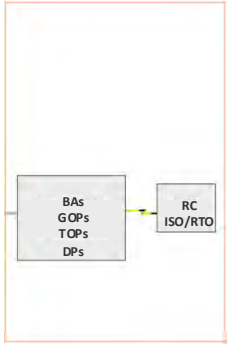
State



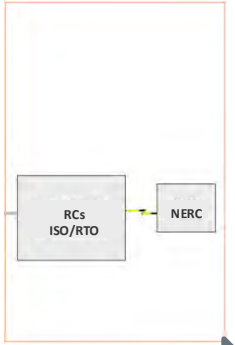
Regional



Interconnection



National

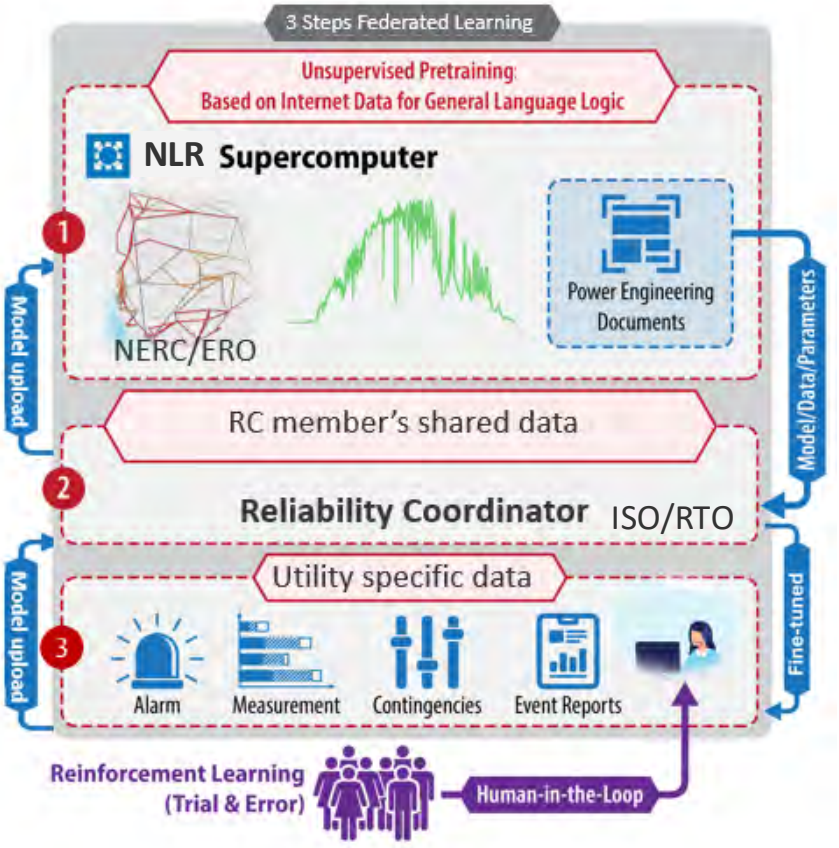


Under NERC Critical Infrastructure Protection

Currently, no cloud service allowed

Image credit: PJM, NERC , Texas A&M & NREL

How to “pre” train your LLM



Secure, Reliable, Affordable & Resilient Operations

Assist at All Scales, T&D + DER

On-premise &

To run on a laptop

Cyber secure & NERC Compliant

Why use a Digital Twin?

Automation + Many Simulations

Dispatcher Training Simulator (DTS)

Training Network Model

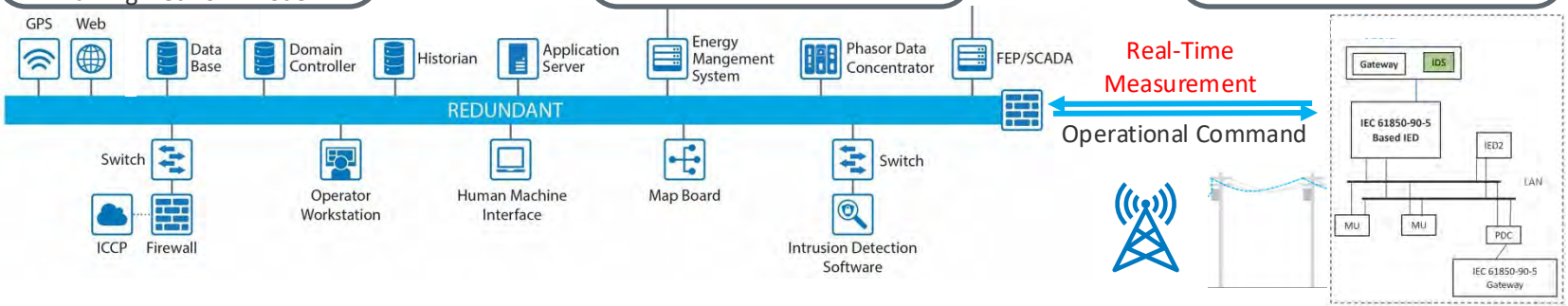
Operation Model

Physical Network Model

Real-Time Measurement

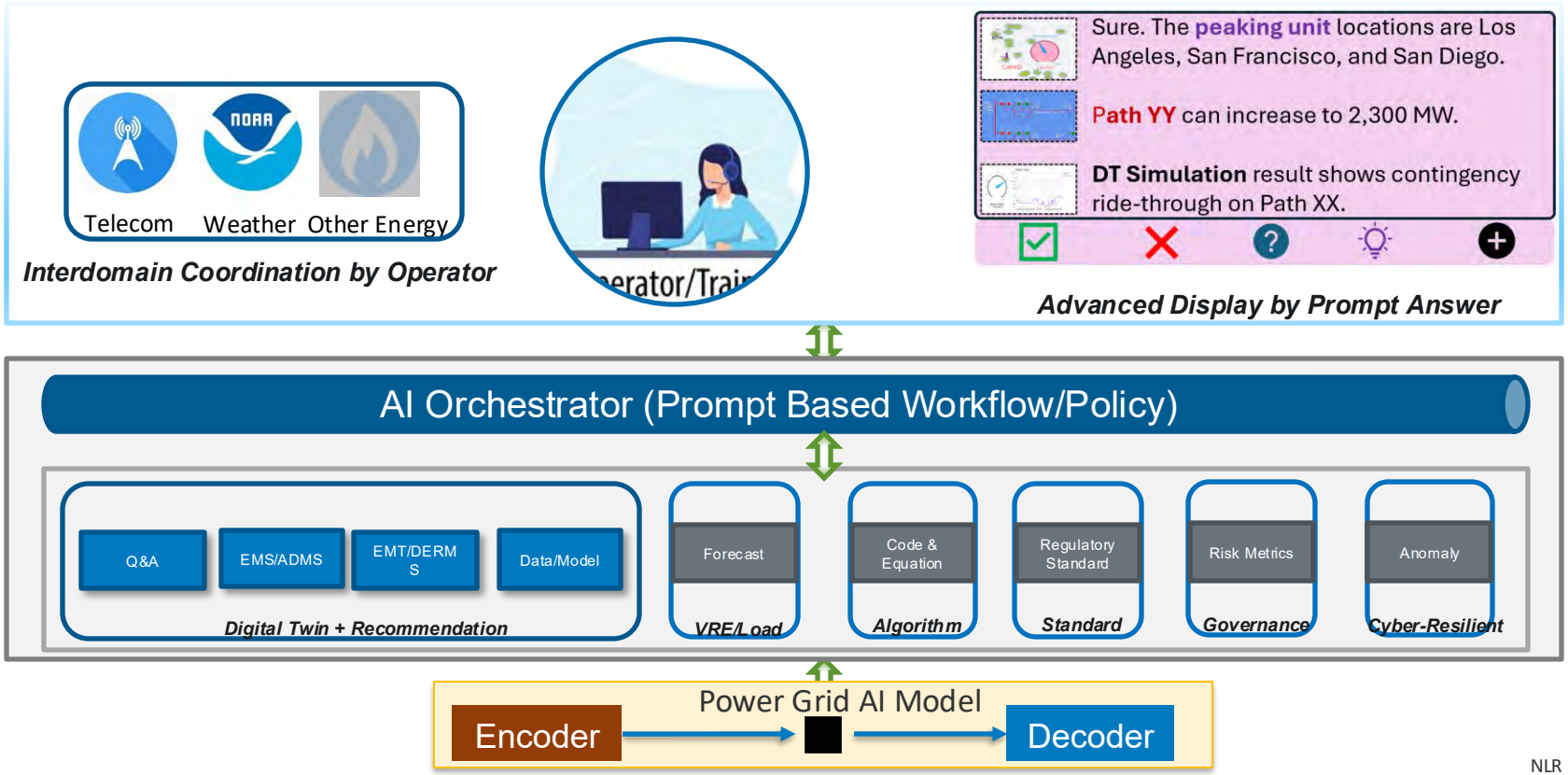
Physical Model

Real-Time Measurement

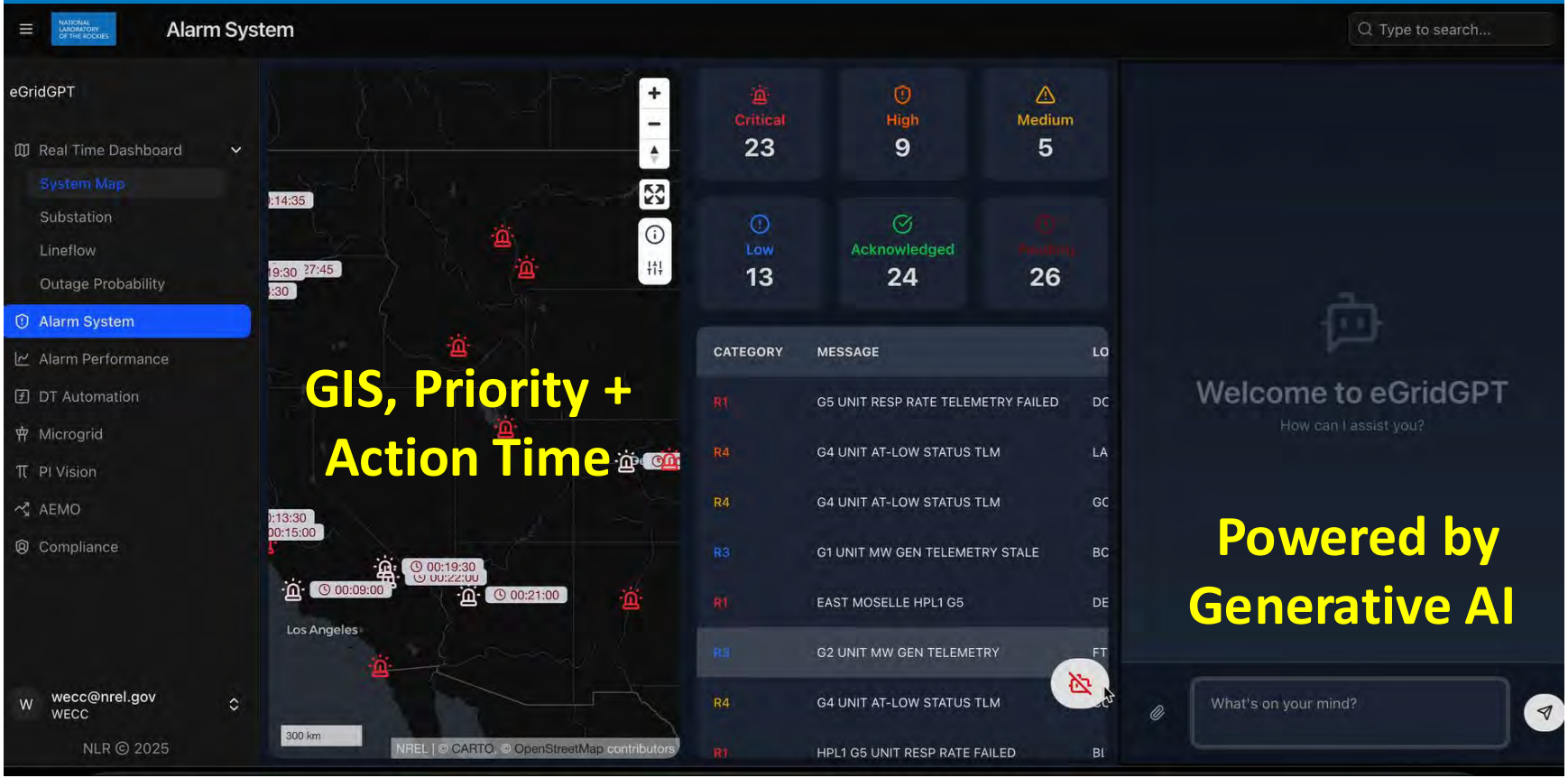


FEP: Front-End Processor, ICCP: Inter-control Center Communications Protocol, IDS: Intrusion Detection System , IED: Intelligent Electronic Device, MU: Merging Unit, PDC: Phasor Data Concentrator

Next Step: Fully Automated Digital Twin + eGridGPT Orchestration



SCADA Enhanced Alarm Intelligence Tool (SEA-IT)



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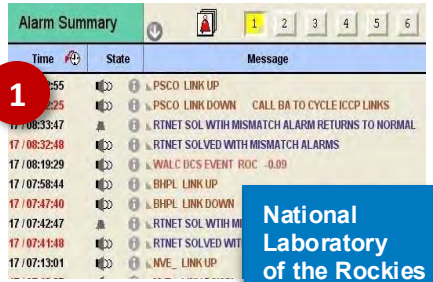

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eGridGPT
Trustworthy AI

5 Agentic AI MCPs

Tools 6

LLMs

2 Hmmm DCS event…Can you check the alarms & run simulations?

3

Alarm DB

Mitigation

Operating instruction

4 Enhanced prompt Relevant answer

It maybe we are heading EEA 1. Here is why 7

Many substations' lines are down. No measurement coming in. (R1) Recycle the link? Y/N

Transmission lines are overloading. (R2) Re-run power flow? Y/N

Frequencies are decreasing. (R3) Redispatch AGC? Y/N

Forecasting shows demand increase in 2 hours. 95% Probability considering weather predicted

EEA 1 is possible. Here is the procedure of NERC EOP-011

Future Control Room Functions

Providing ecosystem and environment for operators to make the right decision at the right time.

Proactive & Automated

- Automation especially in emergency condition
- Empower operators by providing better recommendation
- Integration Digital Twin + Artificial Intelligence

Reliable, Resilient, and Secure

- Backup control center operational within hours
- Tertiary virtual control center in case operators are unable to reach the control room
- Coordination between TSO & DSO
- Collaboration with other sectors like Gas, Water or Telecommunication
- Cybersecurity and physical infrastructure strengthening

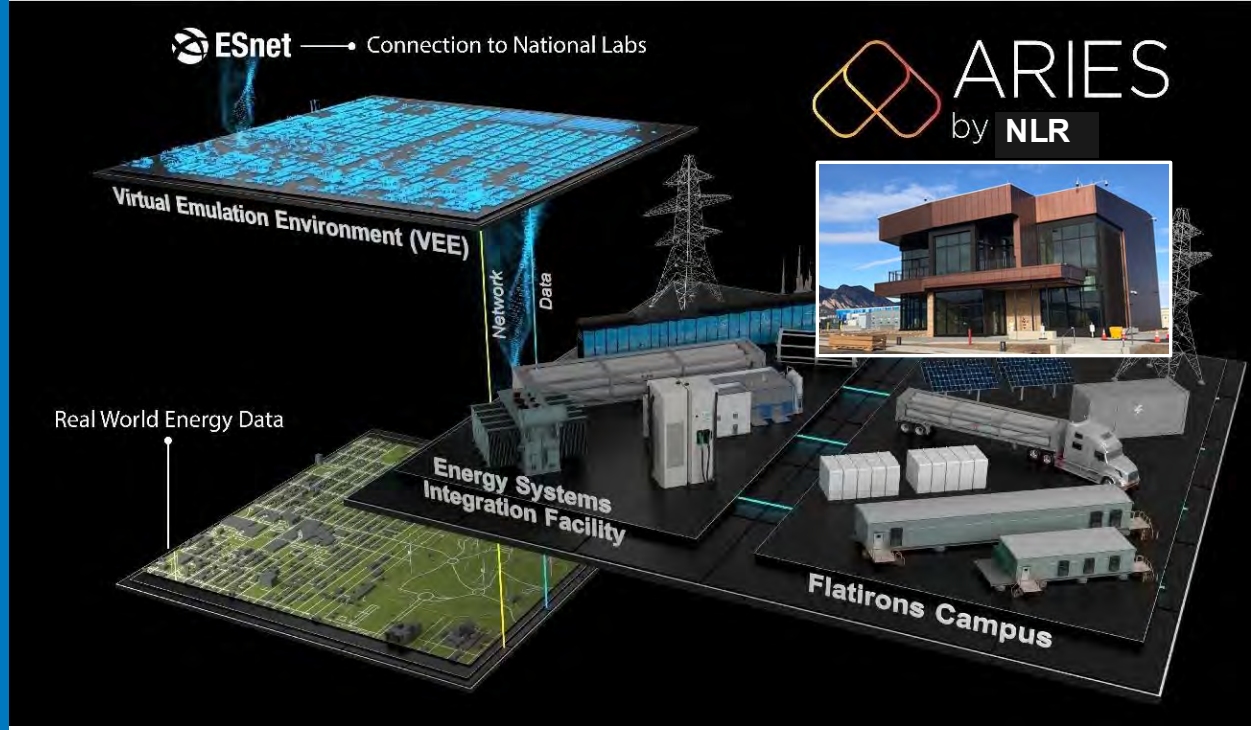
Economical & Affordable

- Integrated applications
- Reduced Hardware and Software cost (Hybrid of on-premise & Cloud)
- Transition from CPU based processes to GPU-based
- Scalable to accommodate more IBR & Electrification
- Improve health-oriented control room settings

AI can help forecast, automate, and optimize operations and decision-making for highly complex energy systems.

How can we validate the AI performance and ensure AI is trustworthy?

ARIES can provide a research platform to connect between AI running in the Virtual Environment and ARIES Hardware Platform and Real World Data.



ARIES validates a broad range of future energy technologies and grid modernization scenarios alongside stakeholders to achieve an **affordable**, **secure**, and **reliable** energy system.


Load: 44875 MW
11:00:09
59.98 Hz
Gen: 45020
It looks like AI can do a lot for Grid Operations!

For More Information

- Veers, P., Kroposki, B., Novacheck, J., Gevorgian, V., Laird, D., Zhang, Y., Corbus, D., Baggu, M., Palmintier, B., & Dhulipala, S. (2021). *Examination of the Extreme Cold Weather Event Affecting the Power System in Texas - February 2021*. https://doi.org/10.2172/1812486

- Choi, S., Jain, R., Emami, P., Wadsack, K., Ding, F., Sun, H., Gruchalla, K., Hong, J., Zhang, H., Zhu, X., & Kroposki, B. (2024). *eGridGPT: Trustworthy AI in the Control Room*. https://doi.org/10.2172/2352232

- Choi, S., Jain, R., Feng, C., Emami, P., Zhang, H., Hong, J., Kim, T., Park, S., Ding, F., Baggu, M., & Kroposki, B. (2024). *Generative AI for Power Grid Operations*. https://doi.org/10.2172/2477920

- Hamann et al., *AI Foundational Model for Power Grid* - https://www.sciencedirect.com/science/article/pii/S2542435124004707

- NLR ARIES Platform - https://www.nrel.gov/aries

- DOE Genesis Mission - https://genesis.energy.gov

Special Thanks

- NLR - Seong Choi – Control Room Operations and eGridGPT Development
- NLR - Joshua Bauer – Control Room Visualizations
- ERCOT – Control Room Videos
- PJM – Control Room Videos