National Laboratory of the Rockies

Integrating Data Centers and Grid Technologies At Scale

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ESIG 2026 Summer Workshops: Large Load Modeling, Testing and Interconnection Requirements Workshop

June 16, 2026, Denver, CO

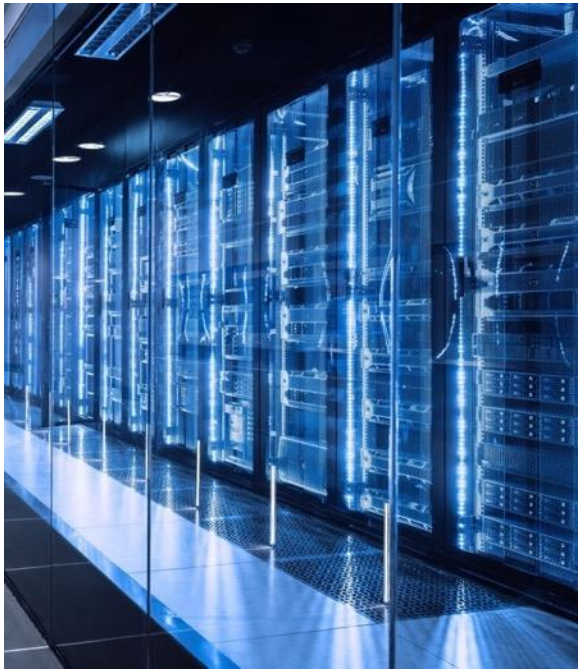
Photo by Josh Bauer, National Laboratory of the Rockies 061725

Powering the AI Era: A Capacity Challenge

Large hyperscale data centers can each require 100–500 MW of power—**comparable to a mid-sized town**.

Unlike many industrial facilities, data centers **typically run 24/7 with high reliability requirements**, creating continuous demand curves.

Data centers tend to cluster near **fiber-optic backbones, cheap power, and available land**.

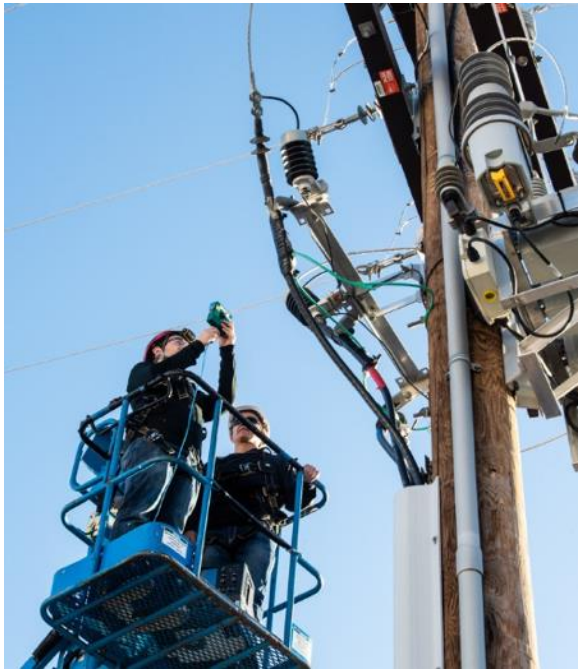


Medium-Voltage DC Technologies

Medium-Voltage Architectures can enable more technology commercialization, field deployment, and reliable data center integration.

Solid-State Transformers that convert different AC voltage levels can replace conventional transformers that have supply chain constraints.

Analytical Tools such as sensors and monitoring devices collect real-time data, helping grid operators make informed decisions for system topology optimization.



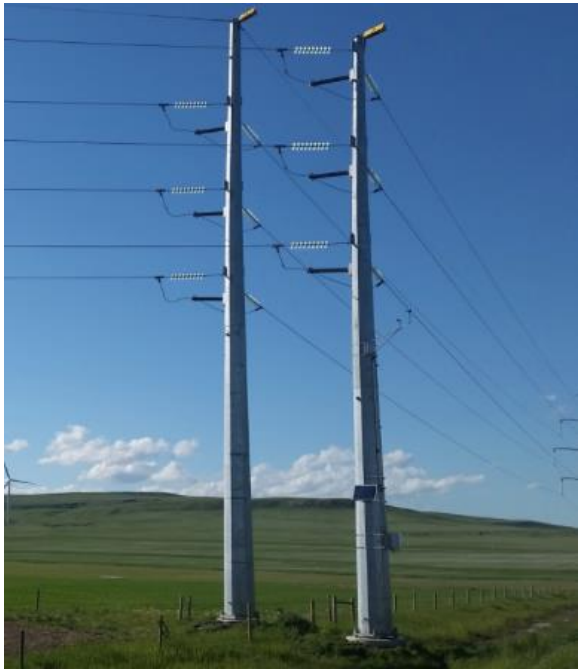
Grid-Enhancing Technologies

Dynamic Line Rating (DLR) hardware and software updates configure capacity limits of existing transmission lines in real time.

Power-Flow Control Devices, often called Flexible AC Transmission Systems (FACTS), allow grid operators to reroute power to lines with available capacity to balance congested lines.

Advanced Conductors and Reconductoring can double the amount of power transmitted through existing lines.

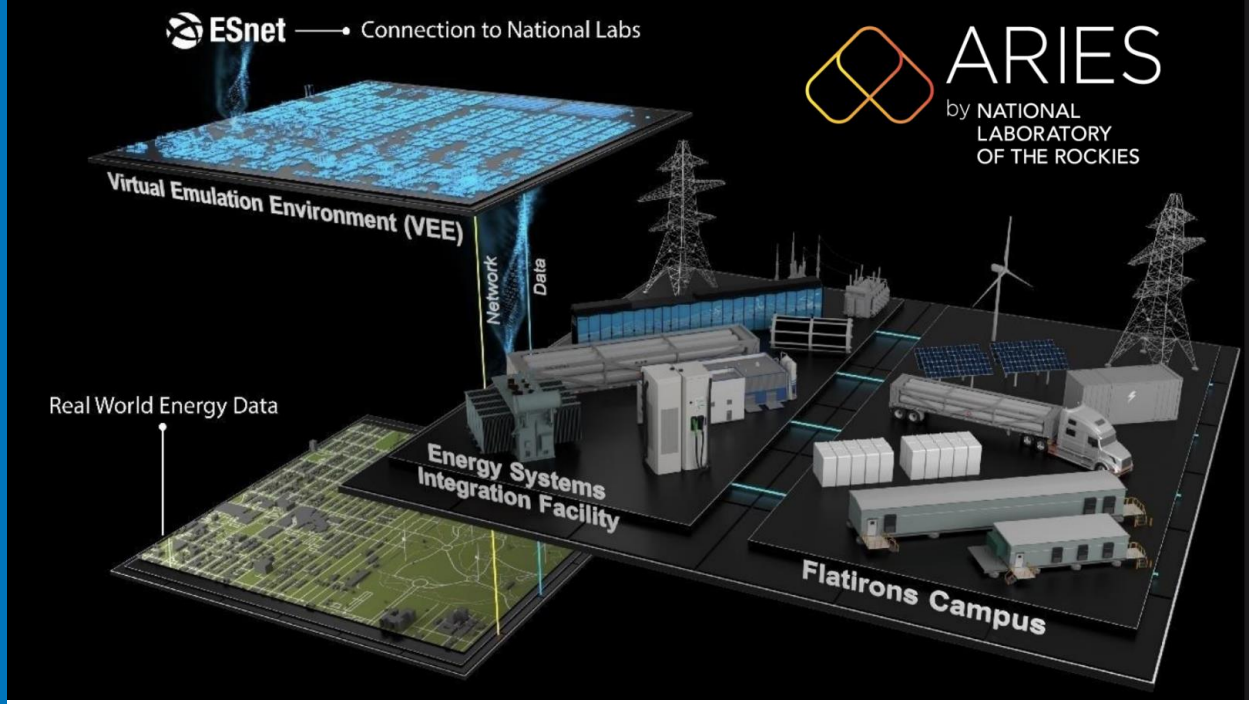
Grid-forming Inverters enable inverter-based resources to improve stability and blackstart the grid.



Research Capabilities

NLR Tools and Test Beds

Advanced Research on Integrated Energy Systems (ARIES)

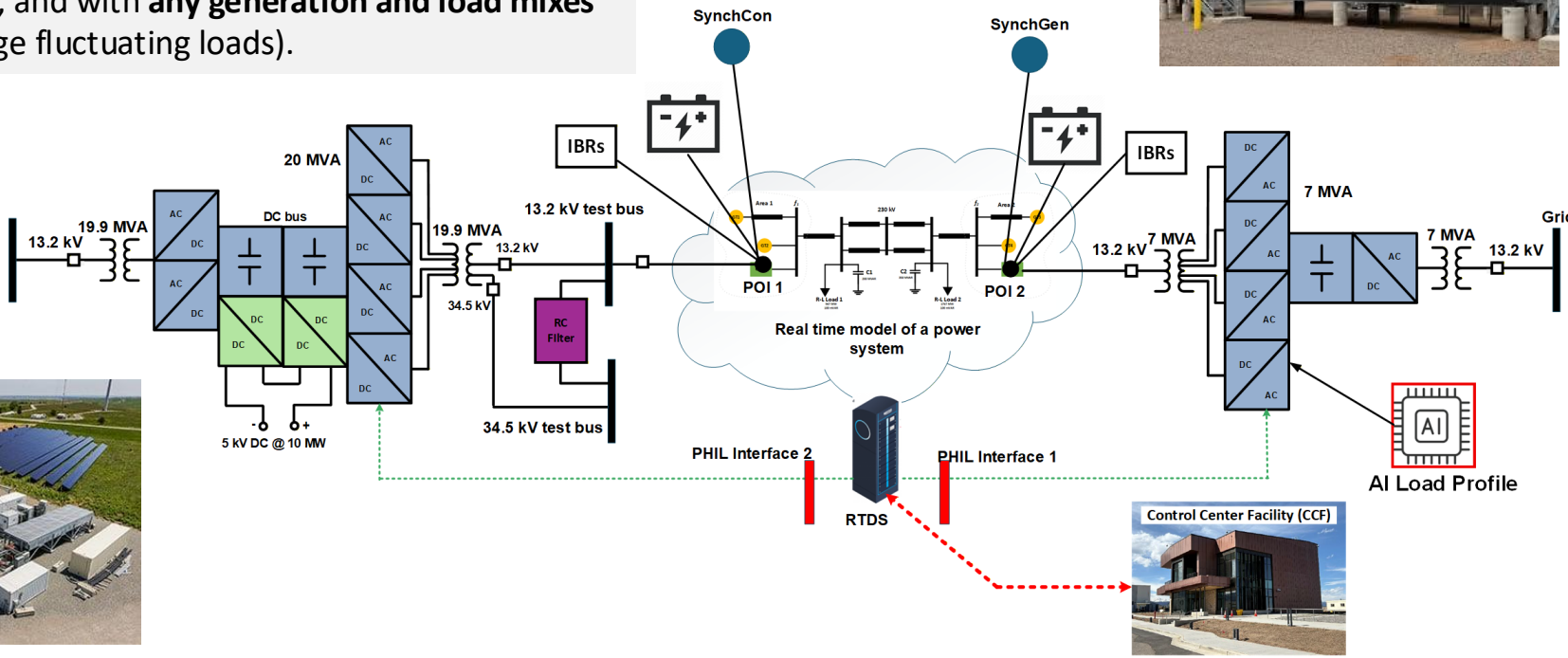


ARIES is DOE's flexible research platform that provides stakeholders with the physical and virtual hardware, testbeds, methodologies, and expertise to address multi-technology energy system integration challenges at a size and scale that matters.

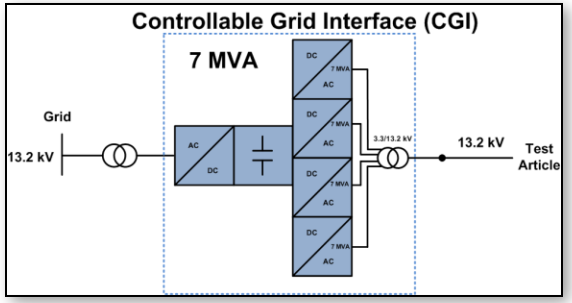
At-Scale Infrastructure at Flatirons Campus

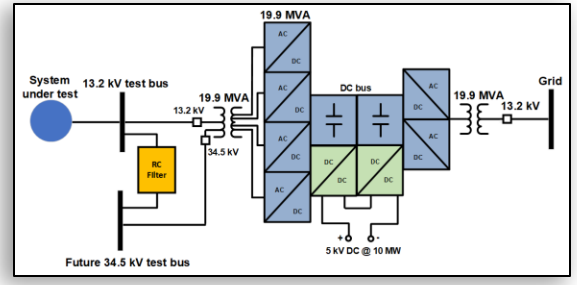
NLR's StableGrid Platform: Multi-Megawatt Test Bed

Designed for testing and validating wide-area and local-mode stability enhancing controls and monitoring methods for power systems of **any type**, **any capacity**, **any topology**, and with **any generation and load mixes** (including large fluctuating loads).

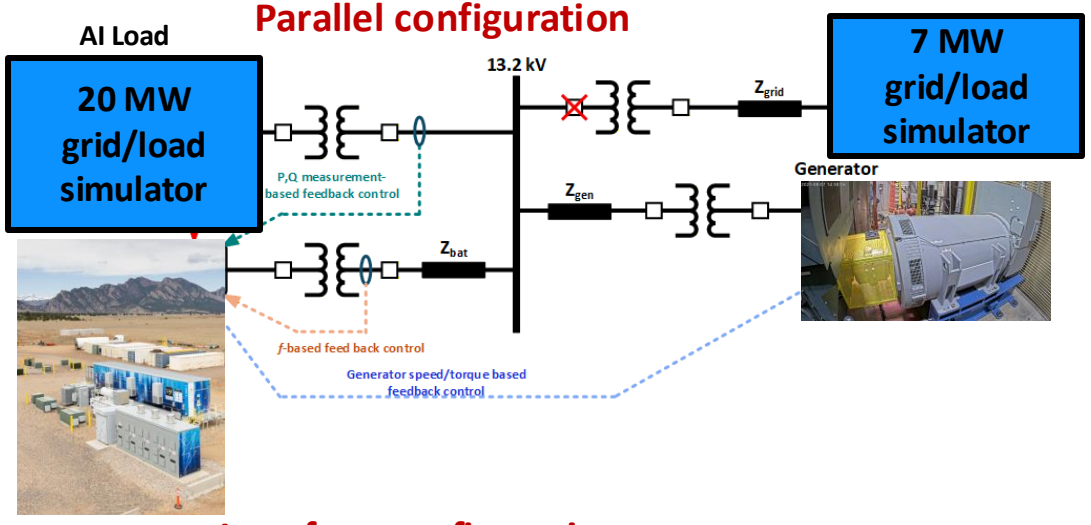


New Types of Microgrids: Data Centers With Co-Located Generation

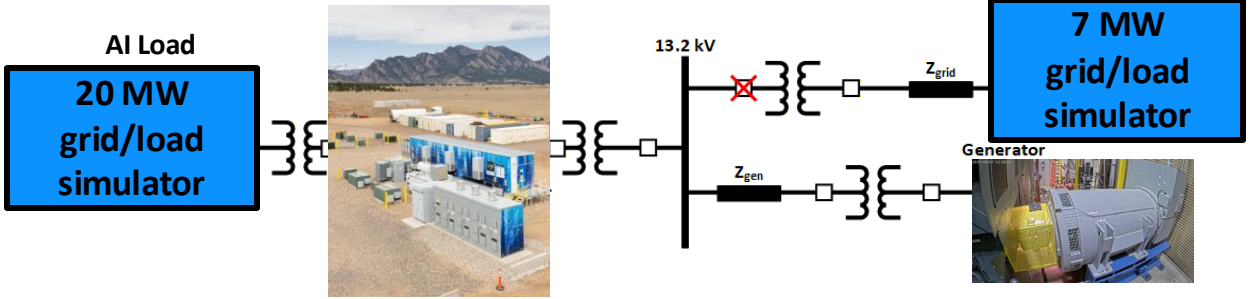




Parallel configuration



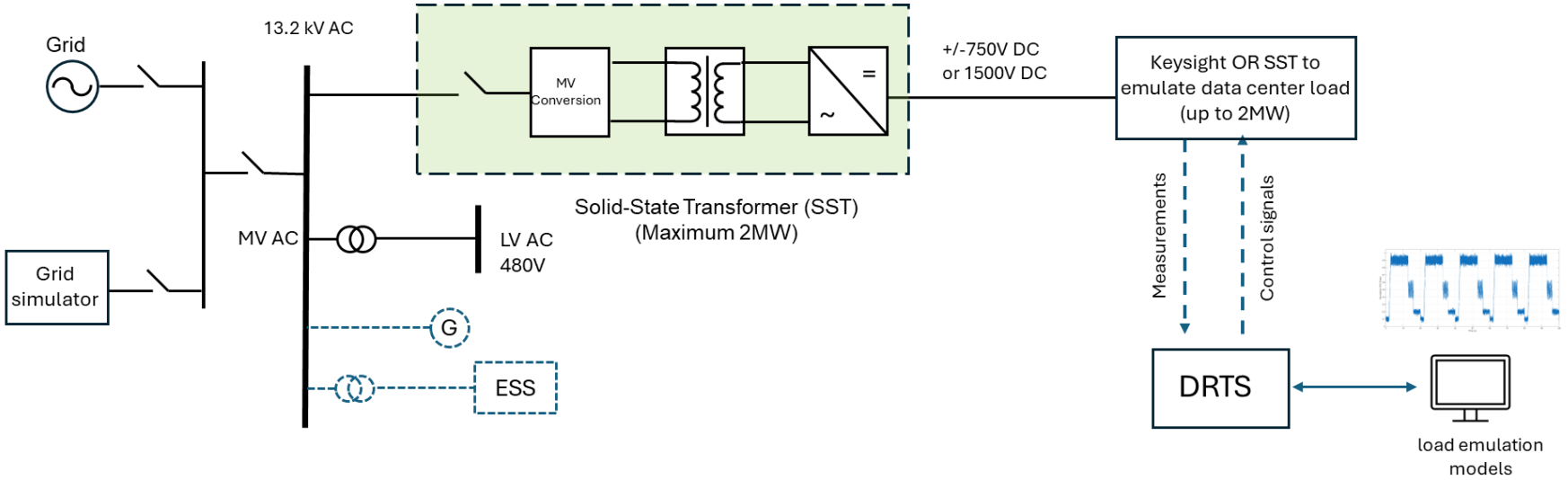
Interface configuration



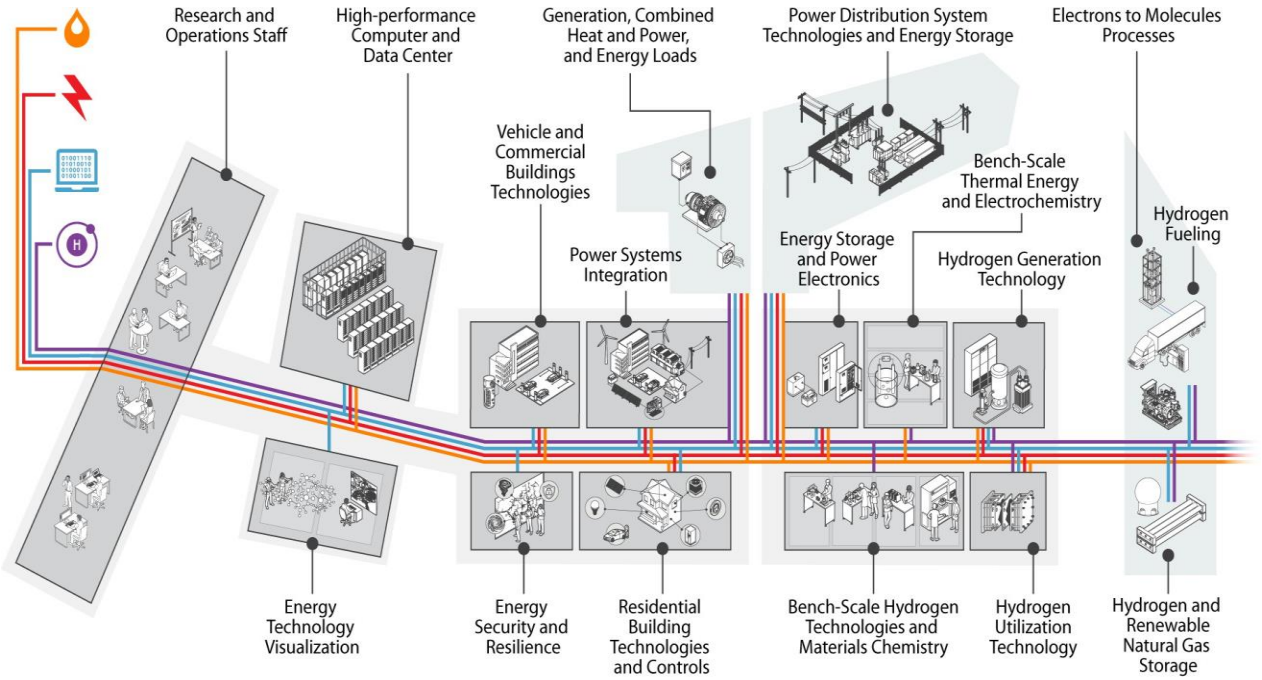
DC Emulation

4 MW capability to emulate DC sources and loads

(Photo from November 2025)

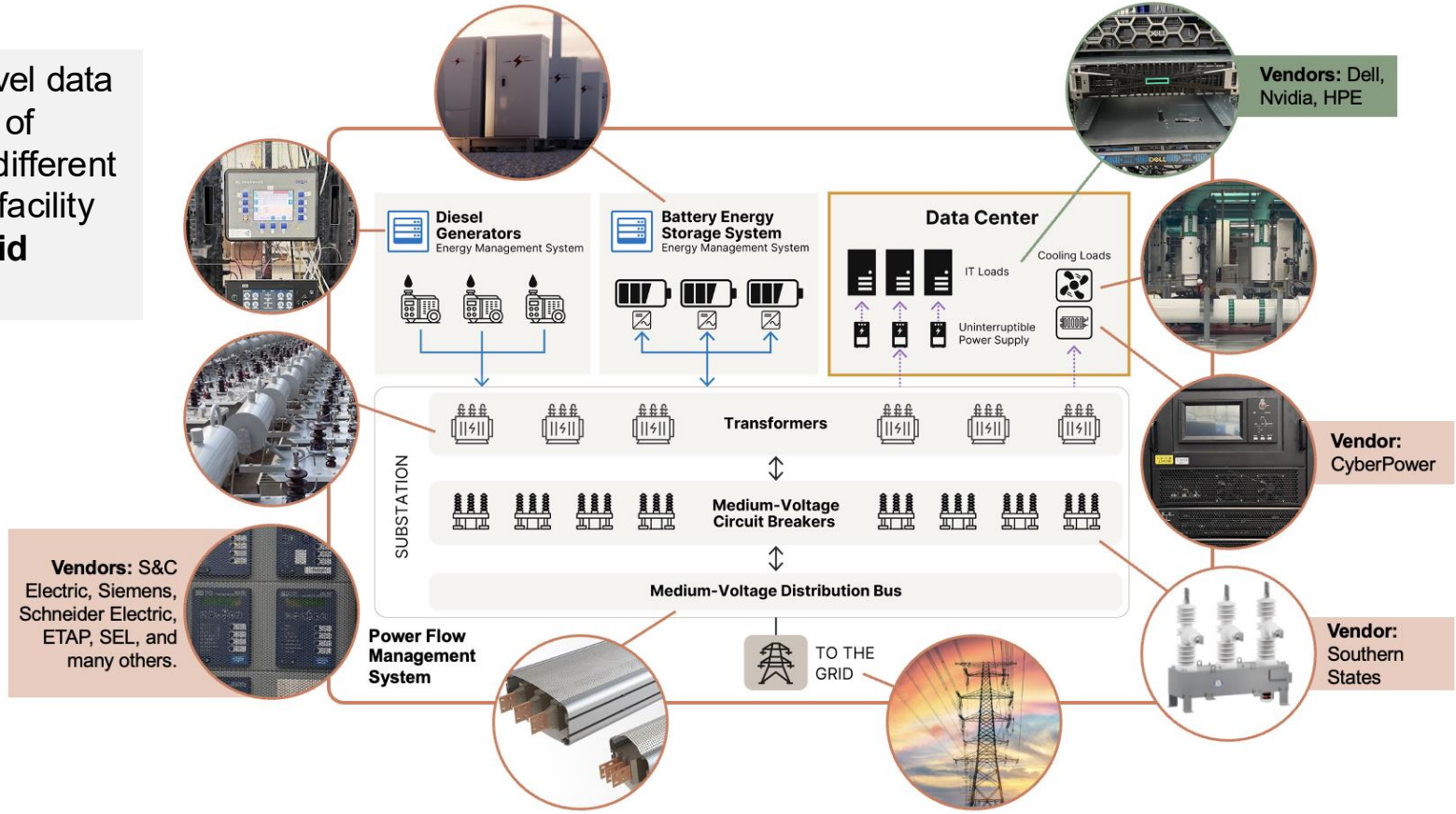


Energy Systems Integration Facility (ESIF)



Agora Large-Load Test Bed

Can evaluate novel data center sequence of operation under different grid conditions—facility hosts a **2-MW grid simulator**.



User-Ready Tools to Support Data Center Deployment and Optimization

These tools have been applied and validated through NLR's private and public collaborations and can be adapted to support data center deployment and optimization across diverse regulatory, infrastructure, and power system contexts.

NLR Tool	Description	Application to Data Centers
REopt	Techno-economic platform that identifies optimal energy system configurations to meet cost, resilience, and performance goals.	Helps data centers reduce reliance on grid energy and minimize costs by optimizing on-site and distributed energy resources.
reV	Geospatial modeling tool that estimates energy generation potential, system performance, and costs based on land use, infrastructure, and climate data.	Identifies high-potential sites for data centers by analyzing siting constraints, grid and fiber access, and regional energy availability.
ReEDS	Long-term capacity planning model that simulates the evolution of generation and transmission systems across regions.	Helps data center stakeholders assess future grid capacity, reliability, and energy cost trajectories for informed siting and investment decisions.
Sienna	Open-source, high-resolution modeling framework for simulating complex, dynamic energy systems with variable generation, storage, and stability requirements.	Enables data center operators to evaluate grid reliability, stability, and energy scheduling impacts under high-demand, variable power conditions.

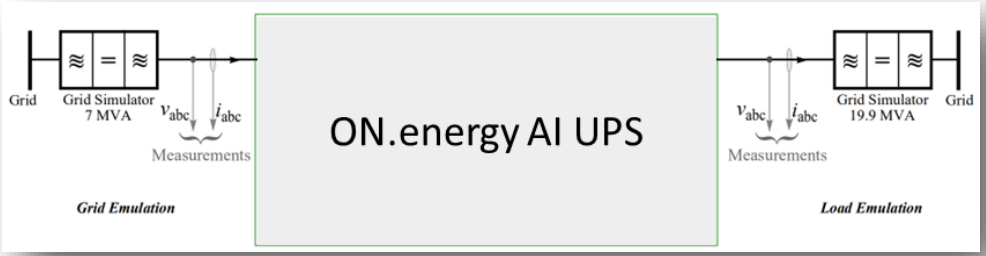
Example Projects

ON.energy AI Uninterruptible Power Supply Validation: First-of-Its-Kind Grid-Safe AI UPS for Data Centers at Scale

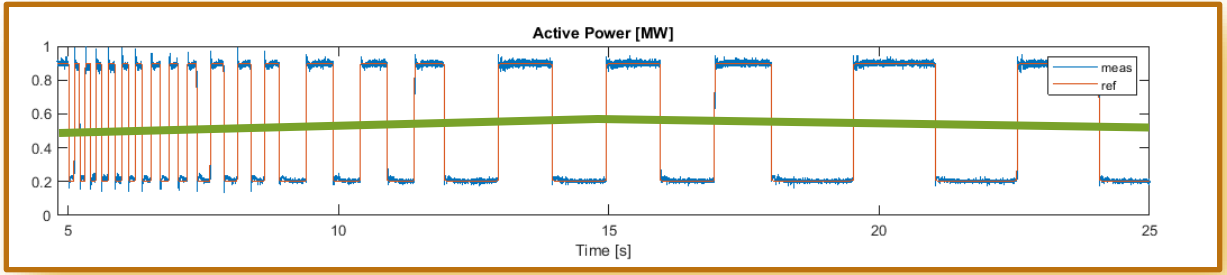
Key ARIES assets used for testing:

- Two grid simulators (7 MVA and 20 MVA) for AI load and grid disturbance emulation, respectively.
- Medium-Voltage Impedence Network for emulating low system strength conditions or load-side impedance.

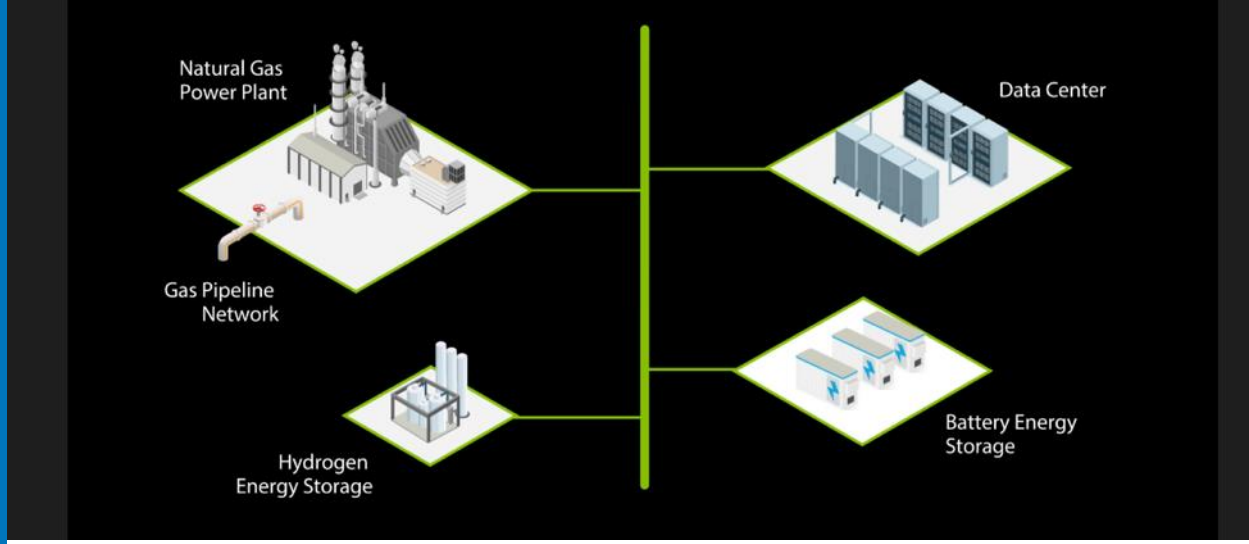
Rapid Timeline. 11/20/2025 12/31/2025



Grid → Load



Hybrid Generation for Pulsating Loads

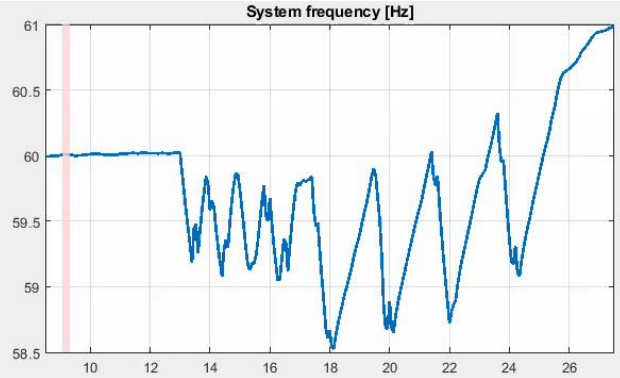


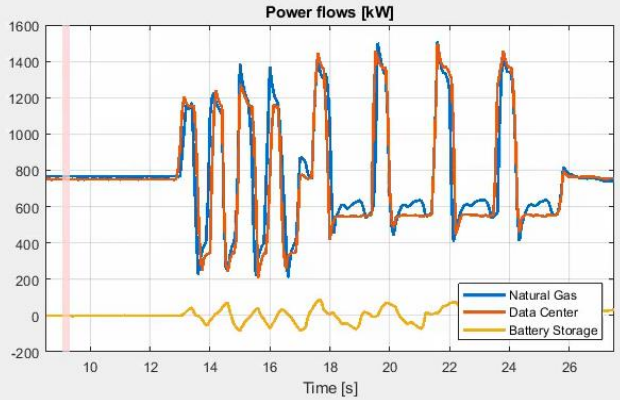
The fast stop-and-start of data centers and other massive manufacturing loads puts mechanical strain on turbines, leading to shorter lifetimes.

NLR demonstrated how **a combination of baseload power and fast-response resources could reliably power data centers** without those ill-effects.

- The demo used ARIES emulations and real hardware

Data Center Load Profile / BESS GFL





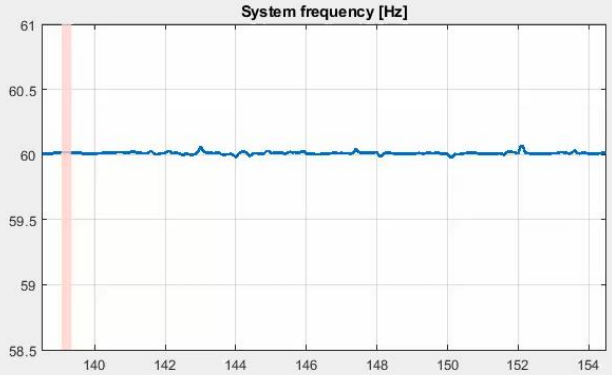
Natural Gas Generator Output
(2.5 MVA Machine)

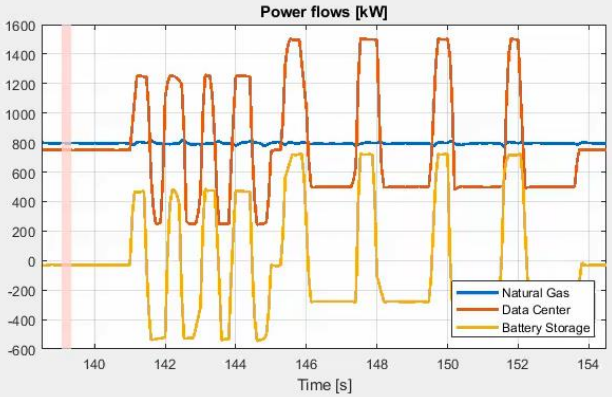
Datacenter Load
(7 MW CGI)

Battery Energy Storage
(1MW/1MWh)

Shaft video at 30fps
With nominal 1800
RPM due to aliasing
the video is still

Impact of Load Fluctuations on Conventional Generation:
With Hybridization – GFM BESS Absorbs Load Fluctuations





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With nominal 1800
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Demonstrating Data Centers as Flexible Grid Assets

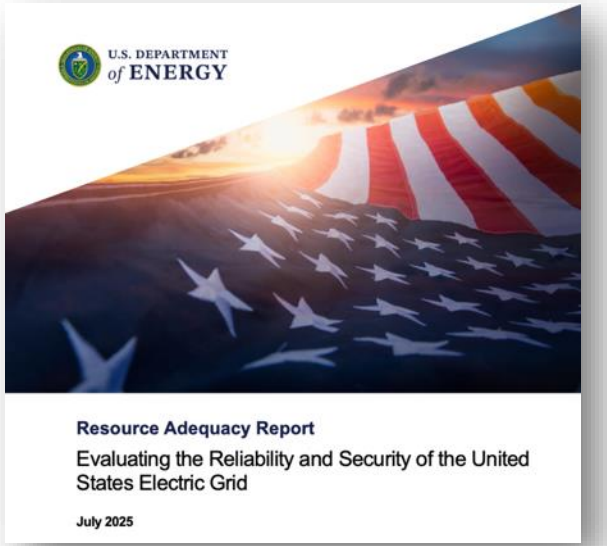
Verrus collaborated with NLR to explore how **data centers can actively support grid stability** without compromising uptime or requiring costly new utility infrastructure.

Researchers modeled a 70-MW data center using ARIES digital real-time simulation and controller hardware-in-the-loop validate **Verrus' power flow solution** combined with battery systems, a power flow management system, and medium-voltage distribution.

Rapid National-Scale Assessment for Grid Security and Reliability Executive Order

In April 2025, Executive Order 14262 directed agencies to ensure the nation can affordably and reliably meet soaring electricity demand from data centers and domestic manufacturing.

- NLR provided DOE's Office of Electricity with the **nation-wide data and validated models** needed to simulate every generator and major transmission line.
- This **enabled rapid identification of at-risk regions** and the plants essential to maintaining reliability.

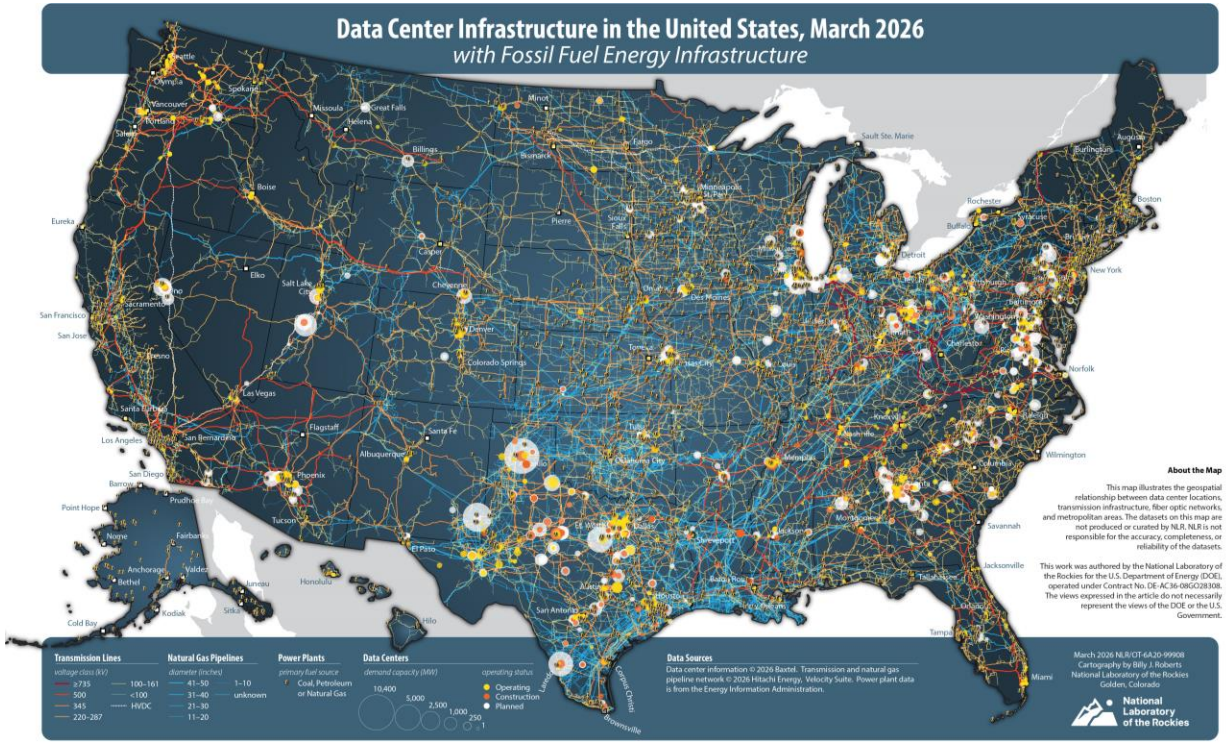


https://www.energy.gov/topics/reliability

Understanding Data Center Siting Factors

Key Siting Considerations:

- Transmission Lines
- Natural Gas Pipelines
- Power Plants
- Data Center Demand Capacity

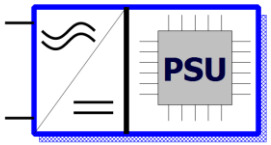


https://docs.nlr.gov/docs/gen/fy26/99908.jpg

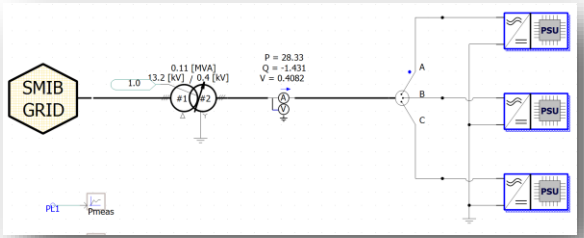
Data Center Modeling and Stability

- **EMT Model of an IT Rack**

Input 1ϕ
Voltage: **LVAC**

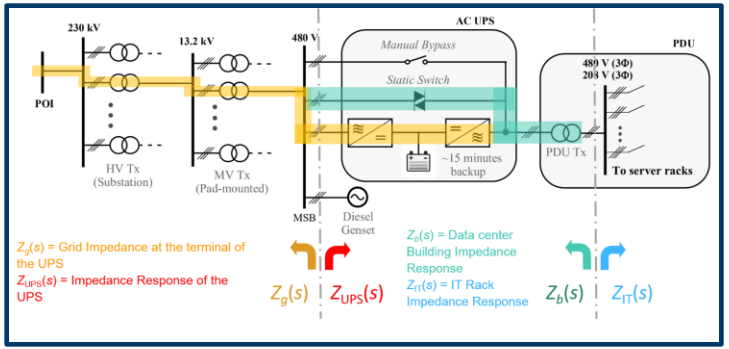


Output Voltage:
400 Vdc

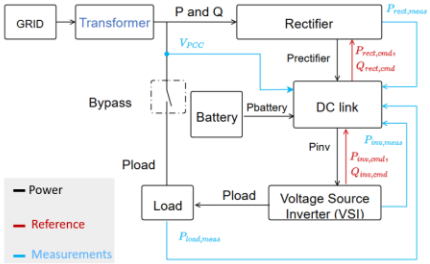


- **Features of the Model**
  - Can represent PSUs of different ratings
  - Advanced averaging techniques
  - GPU load profile can be supplied directly to the EMT model

- **Converter-driven Stability Problems**



- **Phasor Model of Data Centers**



Thank You

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