

A New Report on Dynamic Modeling and Grid Impact Analysis of Data Center Loads

Highlights

- NRECA recently collaborated with the University of North Carolina at Charlotte on a study of the impact of data centers on the power grid, and the resulting report is now available.
- The report introduces a dynamic modeling framework for integrated data center power systems that goes beyond traditional static load modeling approaches.
- It captures interactions among grid infrastructure, co-located generation resources, power electronic interfaces, backup systems, and server-level loads.
- Detailed component-level models are developed for key data center equipment, including power supply units (PSUs), uninterruptible power supplies (UPS), IT loads, and AI-driven load profiles.
- The framework supports evaluation of both steady-state and transient grid behavior, including voltage response, frequency dynamics, oscillations, and harmonic distortion.
- Case studies assess how large data center load variations, source transitions, and disturbance events can affect overall power system performance and stability.
- The results show that data center loads can materially influence system dynamics, including oscillatory modes, damping characteristics, and harmonic content.
- The report can be accessed at [Data Center Modeling and Grid Impact](#). For more details contact Ravindra Singh at Ravindra.Singh@nreca.coop.

Introduction

This advisory introduces a new report published by the University of North Carolina at Charlotte (UNCC), as part of a joint study by UNCC, the National Laboratory of Rockies (NLR), and NRECA, on the impact of data center loads on the power grid. The report provides practical insight into how dynamic modeling and grid impact analysis can support planning, interconnection review, reliability assessment, stability evaluation, and operational preparedness. As co-ops evaluate emerging large-scale loads, such as data centers, AI computing facilities, and other power-electronic-connected infrastructure, understanding their dynamic behavior is increasingly important. The report highlights how advanced load models can help cooperatives assess potential impacts on voltage performance, frequency response, oscillations, harmonics, and overall grid stability as data center development continues to expand across the electric system.

What has changed in the industry?

- Data-center demand growth of 120%+ by 2027 is reaching co-op service territories, often faster than co-ops can plan for.
- Power-electronic loads can swing from full to zero in milliseconds, a behavior most co-ops lack the tools to model.
- One data center can now drop enough load to trigger a major generation outage, straining systems built for smaller, steadier loads.
- Legacy protection settings and interconnection agreements were not designed for this kind of fast, volatile load.

What is the impact on electric cooperatives?

Unlike traditional industrial or commercial loads, computational loads present unique and previously uncharacterized challenges for the bulk power system. They are large in aggregate, power-electronics-based, can ramp up or shed load extremely rapidly, and may respond unpredictably during grid disturbances. These loads can have the following impact on electric co-ops:

- Sudden UPS-driven load drops can strain co-op systems with lower inertia and limited redundancy.
- Large, fast-load shifts increase the need for upfront infrastructure investment and enhanced protection coordination.
- Volatility of large power electronics based loads can cause issues like voltage sags/swells, and harmonics.
- Reliability risks from data-center behavior may translate into higher member rates and stricter interconnection requirements.
- Sudden load swings can ripple through co-ops' wholesale power arrangements, adding cost and stability risk beyond their own lines.

Utilities largely lack accurate dynamic models for these new large, fast data-center loads, so system studies and protection settings are based on outdated assumptions.

How can this report help?

Large, fast load shifts require detailed impact analysis to understand frequency, stability, and protection risks. Accurate planning depends on modeling the true behavior of UPS systems, power electronics, and data center dynamics.

The report provides a systematic modeling and analysis framework for evaluating the dynamic impact of large-scale data centers on power systems. The findings in the report highlight the importance of accurate load representation and coordinated control strategies in maintaining system stability and ensuring reliable operation in future power grids with high data center penetration.

Research Approach

- The comprehensive dynamic modeling framework for integrated data center power systems captured the interactions between grid infrastructure, co-located generation resources, power electronic interfaces, and server-level loads.
- Detailed models were developed for key components, including PSUs, UPS, IT loads, and AI-driven load profiles. Each component was represented using control-oriented dynamic models and validated under various operating conditions to ensure accurate system-level representation.
- An integrated system model was constructed by coupling the data center architecture with a benchmark transmission system, enabling the study of grid data center interactions under realistic operating scenarios. The framework supports analysis of both steady-state and transient behaviors, including voltage and frequency dynamics, oscillatory modes, and harmonic distortion.
- A series of case studies were conducted as part of the research to evaluate the impact of data center operation on power system performance. These include large load variations, source transitions, and disturbance scenarios. The results, which are reviewed in the report, demonstrate that data center loads can significantly influence system dynamics, including shifts in oscillatory modes, reduction in damping characteristics, and increased harmonic content.

What do cooperatives need to do about it?

By utilizing the proposed modeling and analysis framework provided in this report, co-ops can adopt an individualized systematic approach for evaluating the dynamic impact of large-scale data centers on their own power systems.

References

- [1]. M. H. Arifin, S. F. Khan, S. Kamalasadan, M. Smith, Y. P. Agalgaonkar and R. Singh, "Dynamic Modeling of Large Data Centers Integrated Electric Grid With Impact Analysis and Oscillatory Behavior Assessment," *2026 IEEE Rural Electric Power Conference (REPC)*, Tampa, FL, USA, 2026
- [2]. [Integrated Data Center Modeling - Dynamic Modeling Approaches and Case Studies, September 2026.](#)

Contact for Questions

Ravindra Singh

Senior Principal, Distribution Automation
NRECA, Business and Technology Strategies

Ravindra.Singh@nreca.coop